TIBIAL TORSION CALCULATED BY COMPUTERISED TOMOGRAPHY AND COMPARED TO OTHER METHODS OF MEASUREMENT

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A new method for the measurement of tibial torsion using computerised transverse tomography is presented. Its accuracy is equal to that of cadaveric skeletal measurement. This method may be used in patients with unilateral post-traumatic torsional deformities, especially when these are combined with genu varum or valgum. The study of torsional aberrations in connection with congenital abnormalities of the foot is of further interest.

The successful treatment of rotational deformities of the lower limb must be based on accurate diagnosis. Various clinical, anthropometric and radiological methods have been used to determine tibial torsion.

A simple clinical method is to have the patient sit with the legs hanging over the edge of the examination table. The angle formed by the second metatarsal ray and the tibial tuberosity gives the tibial rotation. A similar method is to measure the angle formed by the transmalleolar axis and the edge of the table. In children another method is to turn the plantigrade foot into maximal medial and lateral rotation. The tibial torsion is approximately equal to the mean of the two angles.

On necropsy specimens tibial torsion may be measured using anthropometry. The angle between a pin passed through the transcondylar axis of the head of the tibia and another through the axis of the distal articular surface of the tibia is measured. This is the most accurate technique but the disadvantage is that this method cannot be used clinically. In 1909 Le Damany reported the mean lateral tibial torsion measured by anthropometry using Broca's instrument as 23.7 degrees. Other studies (Dupuis 1951; Wynne-Davies 1964; Khermosh, Lior and Weissmann 1971) have reported clinical values employing instruments similar to the anthropometer. They used the patella or the tibial tuberosity and the malleoli as reference points. Difficulty in centring the instrument on the mobile patella or the tibial tubercle decreases the accuracy of this method.

Rosen and Sandick (1955) have described a rather elaborate radiological technique for measuring tibial torsion. They introduced the concept of measuring tibiofibular torsion as opposed to isolated tibial torsion, the implication being that the alignment of the ankle joint is determined by the relationship of the talus to the complete ankle mortise.

There is a general agreement that all clinical and radiological methods for measuring tibial torsion allow only an approximation which ranges up to 15 degrees from the true value. For this reason a technique using computerised transverse tomography (CT) for measuring torsion of long bones has been developed with the goal of achieving the same accuracy as the direct measurements in necropsy specimens.

Fig. 1
Torsion in long bones is measured by the angle between the transverse axes determined in CT cuts of the proximal and distal juxta-articular areas.

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MATERIAL AND METHODS
This method of determining torsion of long bones is based on computerised transverse tomograms of the proximal and the distal juxta-articular areas. The angle defined by the two transverse axes gives the tibial torsion (Fig. 1).

The patient is positioned supine on the sliding table of the whole-body scanner*. The legs are strapped onto an adjustable plexiglass support so that movement during the procedure is avoided. In measuring tibial torsion the examiner determines the proximal reference line by taking the axis through the widest transverse condylar diameter and draws this in on the tomographic picture. The distal reference line is the transverse axis through the lower end of the tibia which bisects the anteroposterior diameter and also passes through the anterior half of the lateral malleolus. The angle between the two axes corresponds to the tibiofibular torsion.

Over the last two years 63 CT measurements of tibiofibular torsion have been carried out. Of these, 18 were on patients with clinical problems of rotation and 45 were on cadavers to provide normal values. The entire series was measured by one of the authors (RPJ). Random measurements were also made on several patients and on cadaveric specimens by two independent examiners.

As a further control an intensive computer study was done on six cadavers; this latter study involved two different methods for independently determining the axes on the tomograms without interaction with the examiner. All calculations were based on cross-sectional pictures which were taken at multiple levels along the tibia and fibula. In the first method the centre of gravity of the tibia and that of the fibula were determined separately. The axes were given by joining the two centres of gravity at the relevant level (Fig. 2). In the second method the axes were determined by the main axis of inertia as delineated by the computer both from the tibia alone and from the tibia and fibula together (Fig. 2). In both methods tibiofibular torsion is given by the deviation of the axes as seen in the proximal and the distal tomograms.

RESULTS
The mean value of lateral tibial torsion in the 45 cadaveric tibiae was 30 degrees, as measured by hand from the computer printouts by one of the authors (RPJ). On those specimens which underwent intensive computerised study, the readings showed up to five degrees of variation from those made by hand.

The patients, all of whom presented with obvious deformities, showed a range of 2 to 82 degrees of lateral torsion as measured by one of the authors. The control measurements made by two independent examiners deviated by an average of five degrees.
DISCUSSION

A statistical analysis and comparison of the necropsy results with Le Damany's series showed, with a 95 per cent confidence level, that despite a six-degree mean difference of lateral tibial torsion, both series belonged to the same statistical population. The difference between Le Damany's mean value of 23.7 degrees and the 30.3 degrees of the present series could be attributed to the fact that when the tibia and fibula together are used in making the distal measurements the value of lateral torsion is increased as compared to those values obtained by using the tibia alone. The computerised analyses using the tibiofibular axis confirmed these results (Fig. 3). Since the direct calculations made by hand on the computer printouts were within five degrees of the computerised analyses, one can confidently accept the former method. Neither the present study nor that of Le Damany showed any significant difference between the right and the left leg.

In several cadaveric specimens further CT cuts were made in an attempt to demonstrate the level of maximal torsion (Figs 4 to 6). This was shown to be in the proximal quarter, a finding which is supported by Grammont (personal communication).

A clinical advantage of the CT method is that both extremities can be measured simultaneously. This is especially valuable for the determination of a unilateral deviation in torsion, for example after malunited fracture of the tibia (Figs 7 to 9). Another clinical application is the measurement of the abnormal tibial torsion associated with genu varum after injury or in Blount's disease or rickets (Figs 10 to 15). Further clinical use is found in patients with congenital deformity of the foot which may be associated with marked lateral rotation of the ankle (Wynne-Davies 1964; Swann, Lloyd-Roberts and Catterall 1969; Dunn and Samuelson 1974). In clubfoot deformities and in cavus feet the lateral tibiofibular torsion, which may be as great as 80 degrees, may be the explanation for the "apparent flat-top talus" seen in the radiograph taken when the foot is in the resting position (Figs 16 to 21). Antversion of the femoral neck can also be determined by computerised tomography by comparing the axis of...
A patient with a lateral rotational deformity of 32 degrees after intramedullary nailing of a fractured tibia. Figure 7—Deformity measured by eye. Figures 8 and 9—Measurement confirmed by CT.

A 60-year-old patient with pain associated with marked genu varum and medial rotation after a fracture of the proximal tibial diaphysis. Figures 10 and 11—Lateral tibiofibular torsion measured 36 degrees on the right and 12 degrees on the left. Operation on the left leg achieved 10 degrees of valgus correction and 25 degrees of lateral rotation. Figures 12 and 13—Radiographs before and after operation. Figures 14 and 15—Clinical pictures before and after operation.
Pes cavovarus in a 12-year-old boy. Figures 16 and 17—Ordinary lateral radiographs of the feet show an "apparent flat-top talus" and a marked rotation of the fibula toward the back of the tibia. Figures 18 and 19—Lateral tibiofibular torsion measured 52 degrees on the right and 62 degrees on the left. Figures 20 and 21—Repeated lateral radiographs with the ankle in medial rotation with the fibula superimposed over the tibia show a normal shape of the talus.

the femoral neck with the axis of the distal femoral condyles. This method is particularly helpful in patients with a stiff knee in whom "Dunn" views cannot be obtained (Dunn 1952).

The initial results show that this is a clinically useful and reproducible method for measuring torsion of long bones and that it has the same accuracy as cadaveric measurements. In centres in which computer tomography is available this measurement of torsion is no more time-consuming nor expensive than conventional methods. Further studies will be carried out to clarify the interdependence of angular deformities and rotational deviations in relation to operative correction in both planes. The method also promises to be useful in examining spontaneous partial correction of rotational malunion in growing children.

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