CT Determination of Femoral Torsion

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Femoral torsion has been measured in infants and children by computed tomography. The method requires two scans, one through the femoral neck, another through the femoral condyles. A specially designed device and packing about the knees assures immobilization of the legs. Slight variations in the positions of the sections in the neck and condyles do not alter the measurement significantly. Intraobserver and interobserver errors are low, 2° and 3° mean error, respectively. The radiation required involves small tissue volmes at about 1.7 R (4.4×10^{-4} C/kg). Measurements are more difficult when the femoral necks are short or vertically oriented. The method appears to have sufficient accuracy for clinical purposes.

Femoral torsion is the inclination of the axis of the femoral neck with reference to the transcondylar plane of the distal femur. Torsion with anterior inclination anteversion, is thought to be particularly important in congenital dislocation of the hip, Legg-Perthes disease, neuromuscular disease such as cerebral palsy, poliomyelitis, and myelomeningocele, and in some patients with intoeing gait. Determination of femoral torsion by radiographic methods is useful when surgical correction is contemplated. Accuracy of 5°-10° is believed to be clinically sufficient. There are several radiographic methods for measuring femoral torsion. Most are based on geometric and trigonometric calculations [1]. The fluoroscopic method is not a precise and reproducible one.

The orientation of the femoral neck is well suited to be depicted by transverse sections obtained by computed tomography (CT). Three previous reports describe the use of CT for the determination of femoral torsion [2-4]. We describe our modifications for conveniently determining the degree of femoral torsion using CT.

Materials and Methods

An EMI 5005 body scanner was used. The patient was examined in the supine position. Sedation was with chloral hydrate in some of the smaller, uncooperative children, but most of our patients required no sedation.

To facilitate the examination, we devised a special footboard. On one side of this board, shelf brackets are attached in such a way that the board fits the table curvature (fig. 1A). The surface of the other side of the board is covered with Velcro. We have several sizes of shoes with a cut-open front to fit a variety of sizes of children. The soles of these shoes are covered with Velcro so they may be firmly attached to the board (fig. 1B). The board is stabilized by placing a heavy object such as a folded lead apron or a sandbag on the brackets (fig. 1C). The legs are then wrapped so as to further decrease the possibility of motion between the scans of the upper and lower femur. Wrapping also helps prevent hip flexion, which may alter the measurements.

The symphysis pubis of the patient is then palpated, and a section is obtained at this level. Usually, this will produce sections through the femoral necks. The best location of these sections through the femoral neck is where the superior border of the greater

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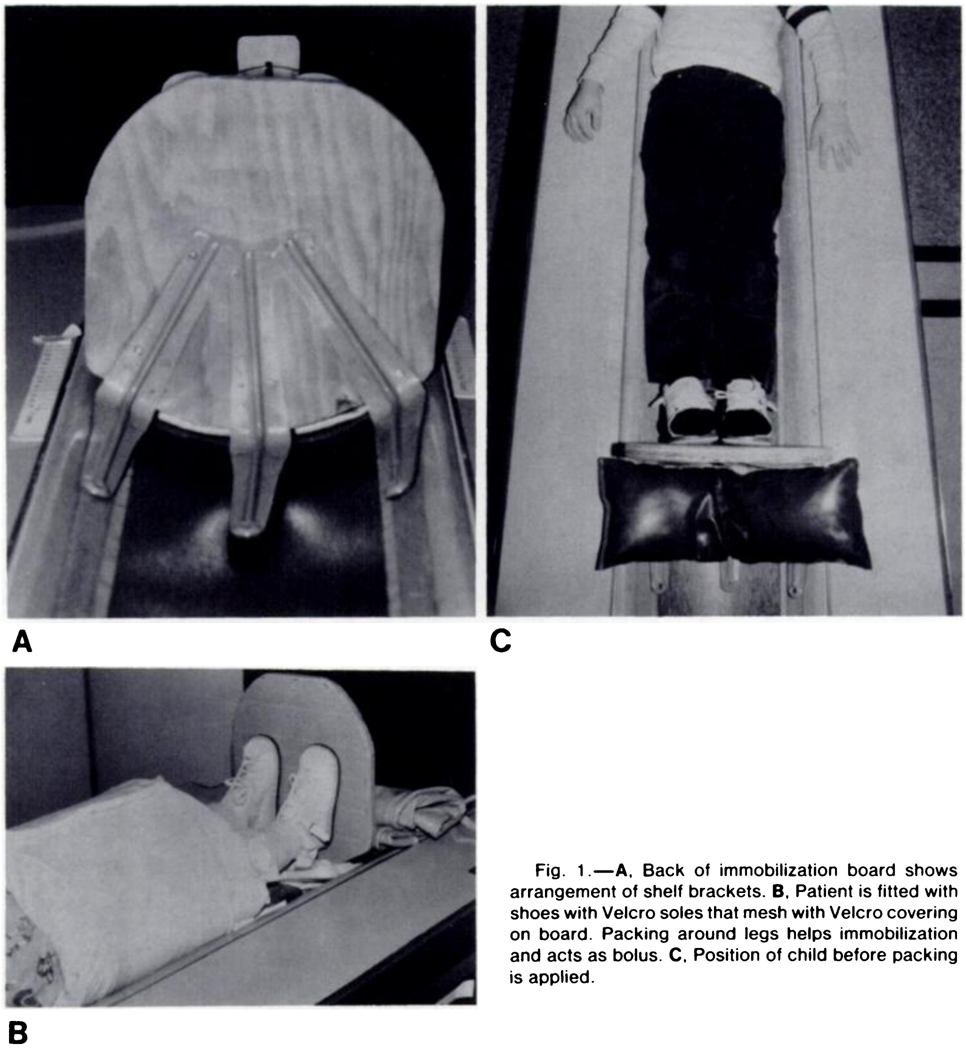


Fig. 1.—**A**, Back of immobilization board shows arrangement of shelf brackets. **B**, Patient is fitted with shoes with Velcro soles that mesh with Velcro covering on board. Packing around legs helps immobilization and acts as bolus. **C**, Position of child before packing is applied.

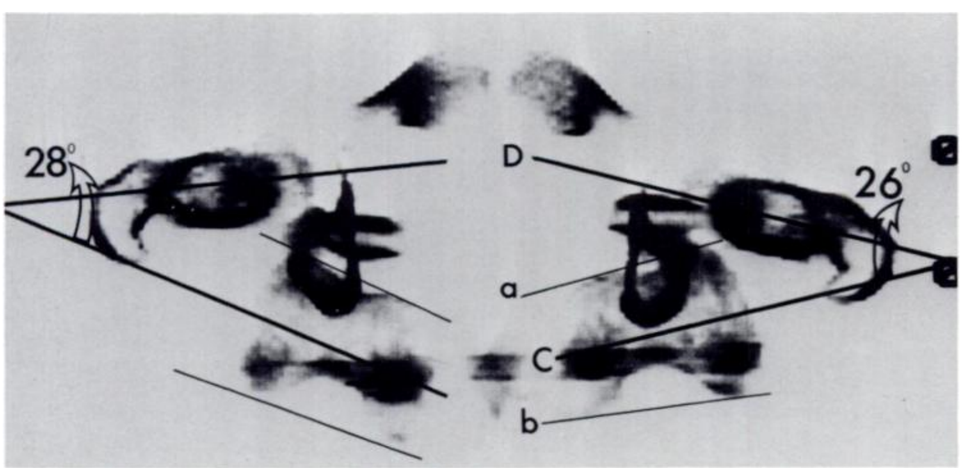


Fig. 2.—Measuring the angles. Both sections of the femurs are superimposed with reverse polarity. Axis of femoral condyle (line C) is bisector of angle between tangents to anterior (line a) and posterior (line b) margins of femoral condyles. Line D is axis of femoral neck. Femoral torsion is angle between line C and line D (in this case, 28° on right, 26° on left).

trochanter is included. The distal section through the condyles is obtained by palpating the patella and obtaining a section just slightly below the upper pole. If the sections are not appropriate, additional sections are obtained at increments of 5–10 mm.

Once the desired sections are obtained, they are depicted with a wide window width of 400 and a level of +200–+300 to eliminate soft tissues and provide only an outline of the bone. The polarity of the video camera is reversed. Sections of the femoral neck and condyles are exposed on the same film (fig. 2).

In most cases, the axis of the femoral neck (line D) is not difficult

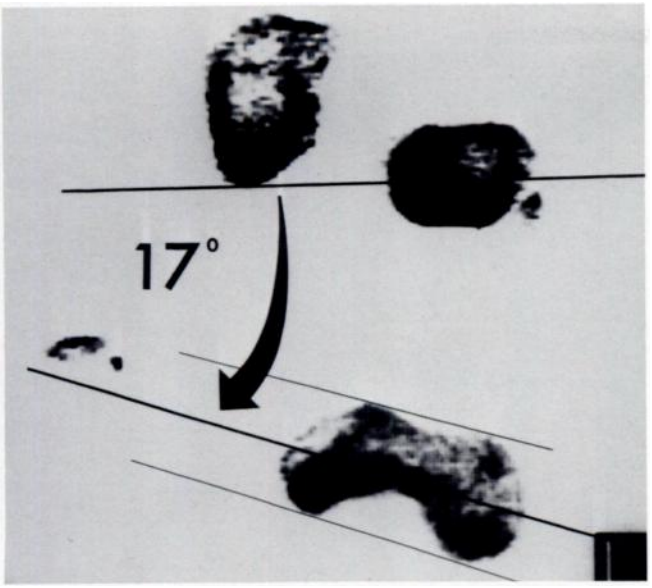


Fig. 3.—Retroversion of femoral neck. Axis of angle between femoral neck and transcondylar plane of left hip lies medially rather than laterally, indicating retroversion, which was proved surgically.

to determine. In infants, where the neck is short, the axis is less clearly defined, and it may also be difficult to determine in children who have had previous surgery to the femur, since the neck may not be straight. The image of the trochanter should not be used in determining the axis of the neck since it lies posterior to it, and a line including the trochanter will not be in the same plane as the neck.

The transcondylar axis is determined by first drawing tangents to the anterior (line a) and posterior (line b) aspects of the femoral condyles. A line is then drawn bisecting the angle between the two lines. This line represents the transcondylar axis. The transcondylar axis was defined as above since it corresponds to the axis used in other methods [3, 5].

The angle between the femoral neck (line D) and the transcondylar axis (line C) is measured and represents the degree of torsion of the femur. If the lines meet laterally (as in fig. 2), the torsion is anterior. If the lines meet medially (as in fig. 3), there is retroversion.

In most cases, both sides can be obtained on a single section. However, leg-length discrepancy or pelvic tilt may require separate sections for each femur (figs. 4A and 4B). If the table height is not changed between the two sections, the upper and lower femur will be at different positions in the film. If, despite this, both sections are superimposed and difficult to separate, areas of each section can be magnified and located at a different position of the film so they are not superimposed (figs. 4C and 4D).

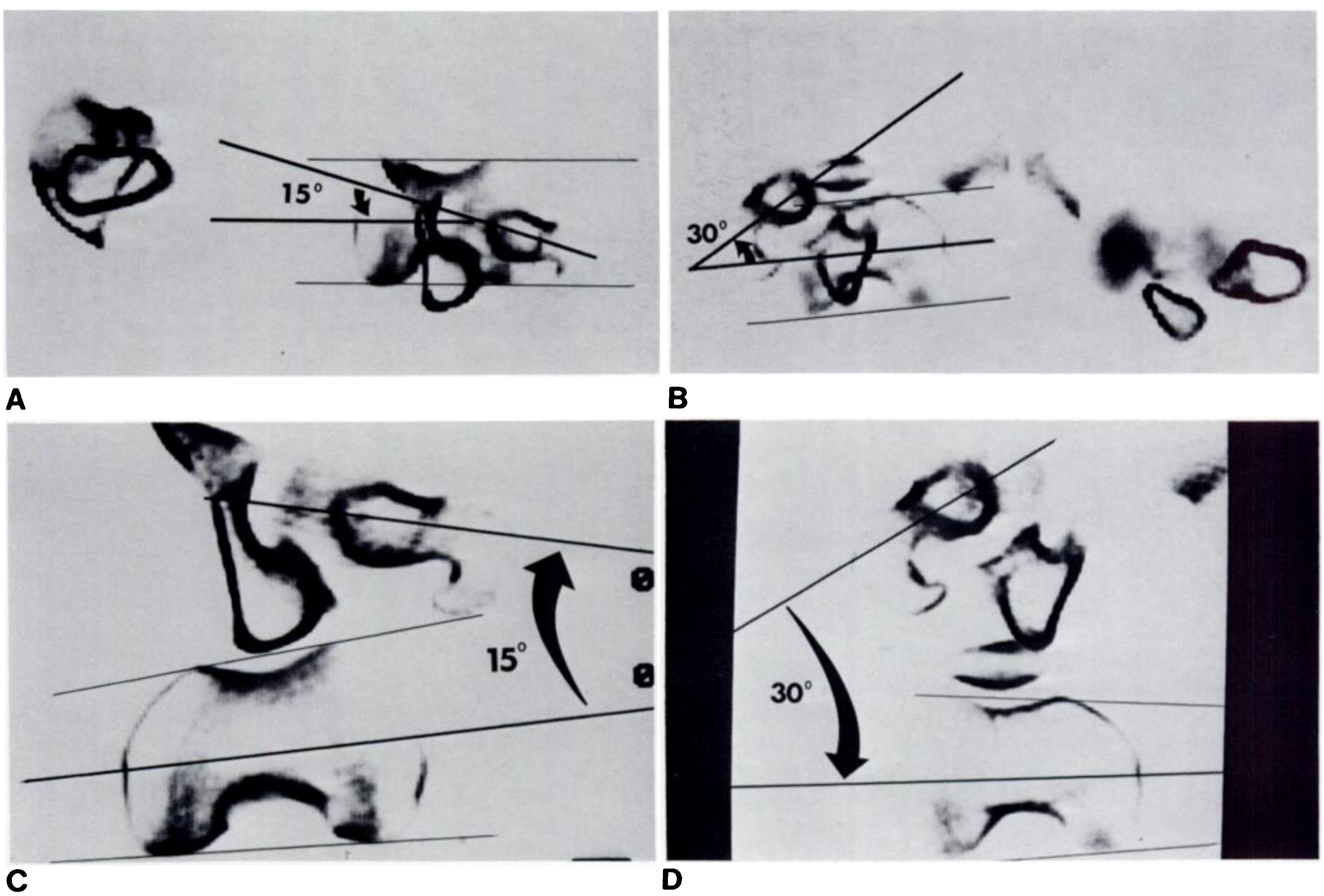
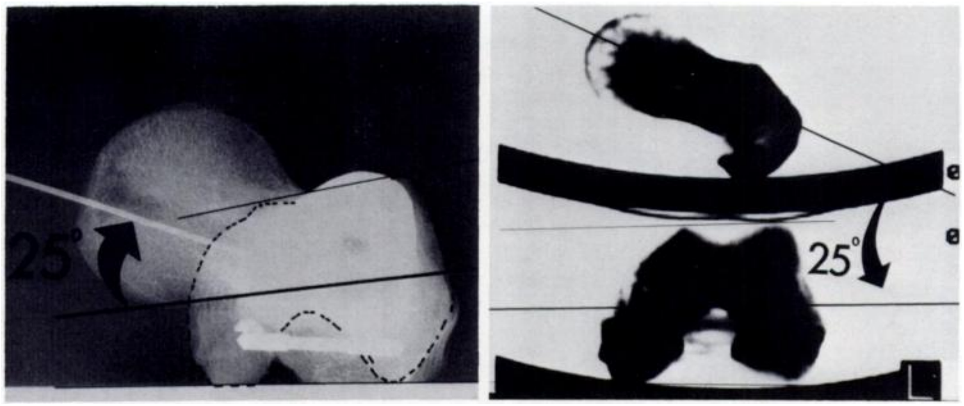
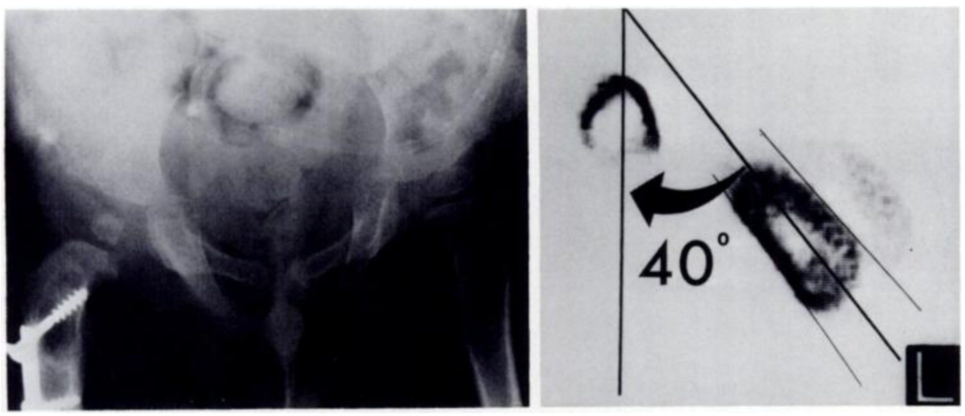


Fig. 4.—Measurement problems. **A** and **B**, If leg-length discrepancy or pelvic tilt exists, consecutive sections have to be obtained since each femoral neck and condyle is at different level. **C** and **D**, If both sections, after being superimposed, are difficult to recognize, areas of each section can be magnified and located at different film positions so they are not superimposed.



A B

Fig. 5.—Adolescent dry femur. **A**, Film aligning x-ray beam with axis of femur. Thin metallic wire has been put through axis of femur. Transcondylar axis determined per Materials and Methods. Angle between femoral neck and transcondylar axis is 25°. **B**, Femoral torsion determined in same femur by method described in text. Angle of femoral anteversion is 25°.



A B

Fig. 6.—Dislocation of hip. **A**, On left, leg is dislocated and held in external rotation; femoral neck has vertical orientation. **B**, With increase in angle of hip, sections of neck have triangular orientation and axis is determined by drawing line bisecting margins of femoral neck.

Results

In order to determine that we are indeed measuring the degree of femoral torsion, a dry femur of an adolescent child was examined by CT using a technique similar to that used in patients (fig. 5B) and a radiograph of the bone was obtained with the axis of the x-ray beam along the bone (fig. 5A). For the radiograph, a thin metallic wire was positioned through the femoral neck. The transcondylar axis was determined as in the Materials and Methods section. The angle as determined by both radiography and CT of the specimen was identical and corresponds to the angle of femoral torsion.

In order to determine the effect of different levels of section on the measurement of the angle of torsion, sections of the femoral neck and femoral condyles were obtained in the specimen at 5 mm intervals. The maximum variation obtained using six levels in the neck was 5°. The same was done for the transcondylar axis, and the variation of the measurements beween the different films was also 5°. To determine the intraobserver error, the degree of femoral torsion was measured twice by the same observer in 10 patients, for a total of 20 measurements. All of the lines were erased from each film after each measurement. The films were measured on different days. The intraobserver variation ranged from 0° to 8° (mean, 2°).

The interobserver variation was determined by having another observer measure the same 10 patients. Again, new sets of lines were drawn by the new observer. The interobserver variation was 0°–8° (mean, 3°). The greatest errors in measurement, both for inter- and intraobserver variation, occurred in children who had severe neck abnormalities and a postsurgical patient.

Discussion

Our method has several advantages over conventional radiographic techniques: it obviates the need for trigonometric calculation and it measures the angle directly. Some of the radiographic projections for determination of the angles are difficult to obtain in small children or in children with deformities. Also, the volume of tissue irradiated with CT is less than with radiography.

The improvement of our method over other CT methods is the special board, which reduces the possibility of motion between the time the upper and lower slices are obtained. The method also obviates the calculations described by Weiner et al. [3] needed to superimpose one femoral section on the other femoral section. The method indicated by Padovani et al. [2] is less reliable since only one part of the femur is imaged, and the method described by Grote et al. [4] appears to be more complicated.

It is difficult to compare the CT radiation dose with the doses obtained with the radiographic technique since the dose distribution is quite different. With our CT scanner, the exposure to the center of a 17.8 cm diameter phantom positioned in the middle of 13 slices was 1.7 R (4.4×10^{-4} C/kg) at 140 kVp and 28 mA. Usually, only one or two slices are obtained at each level, so this dose will be somewhat lower. Also, with newer scanners the dose should be considerably less.

The information on dosage from radiographic methods is not well defined. According to Ruby et al. [5], the exposure calculated to the middle of the pelvis at a depth of 5 cm for the biplanar method of Ryder and Crane was 120 mR (0.3×10^{-4} C/kg); however, a much larger volume of tissue is irradiated with this technique than with CT. With the axial technique of Dunn, the exposure to the surface was 1.5 R (3.9×10^{-4} C/kg). However, we do not know the dose distribution. Exposure for fluoroscopic method was given as 1 R (2.6×10^{-4} C/kg) per minute, but this could be considerably higher, depending on the flouroscopic unit. In all of these radiographic methods, the integral dose was probably considerably higher than with CT, even though the depth dose may have been larger with CT.

In practice, the errors with our method are probably greatest in the infant, when the femoral neck is short and only partly ossified. The femoral neck is also difficult to evaluate when there is external rotation of the femur, resulting in a vertical orientation of its axis (fig. 6A). In this case, the sections are obtained transversely, and an axis may be difficult to find in the triangular image (fig. 6B). The femoral neck axis is determined by drawing a line that bisects the margins of the femoral neck, but is less precise than when an elongated image is available.

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