A DIRECT METHOD OF MEASURING FEMORAL ANTEVERSION USING ULTRASOUND

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The measurements of the angle of anteversion of the femoral neck by ultrasound scanning is described. The method was compared with direct measurement in 30 dried femora, and was then used in 18 normal volunteers and eight patients. The method is non-invasive, accurate and easily applicable. Findings in normal subjects included variation of the angle of anteversion from 10 to 34 degrees with a maximal difference between sides of six degrees. The expected rotational deformity of the femur was found in patients with unilateral intœing.

Many methods of measuring femoral anteversion have been described since the early work by Drehmann (1909) who determined anteversion by fluoroscopy. The majority of the methods have been indirect: femoral anteversion was deduced from radiographs, usually biplanar, taken with the patient in a set position. The angles measured on these radiographs were used with tables and graphs to provide an angle of anteversion (Ryder and Crane 1953). The use of computerised tomography has enabled direct measurement, but this technique is not freely available and demands an increased exposure to radiation (Peterson et al. 1981).

Ultrasound scanning can be used for this measurement. The method is non-invasive and requires no jig or leg rest to position the limb, and it can be done on a supine patient anywhere in the hospital—not necessarily in the ultrasound department. No previous report of the use of ultrasound to determine the angle of femoral anteversion has been found. This paper reports an investigation of the use of ultrasound, first in an experimental study using dried femora, and then in a clinical study using normal volunteers and a few selected orthopaedic patients.

EXPERIMENTAL STUDY

One hundred and two dried femora, some paired, were studied to ascertain the normal range of the angle of anteversion and to assess the accuracy of measurement by ultrasound scanning. The first recognised report on studies on dried femora was by Mikulicz in 1878. An excellent review by Dunlap et al. (1953) pointed out that many previous results were not comparable because angles had been measured in different ways, especially since the head was not central on the neck of the femur in many of the specimens and a point on the surface of the head was used as a reference point. Kingsley and Olmsted (1948) found that 68.7 per cent of femoral heads were not centred on the neck, and the central axis of the neck could not be inferred from a point on the femoral head. In this series 630 normal femora were measured and found to have an average angle of anteversion of eight degrees.

METHOD AND MATERIALS

A jig was built which would accept a femur, so that the angle of anteversion could be read directly using two protractors in line—one distally and one proximally (Fig. 1). The distal protractor was set so that the neutral line ran through the intercondylar plane of the femur. The proximal protractor was adjusted so that the angle made with the midline of the femoral neck—the angle of anteversion—could be read

![Fig. 1](image_url)

Photograph of the jig to show the position of the femur and the protractors.

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directly. The shape of the femoral head was not involved in this measurement. One hundred and two femora, all of normal appearance, were measured in this way and 30 of these were then measured by an ultrasound technique.

Ultrasound was used with the femur submerged in a water-bath. The ultrasound equipment was a Technicare, EDP 1000 model, with a calibrated velocity of 1540 metres per second; the probe frequency was in the higher range, at five megahertz, using a 30 millimetre probe. This probe, with its tip submerged in the water, was used to scan two sections: one distally through the condylar region of the femur about 2.5 centimetres above the medial femoral condyle, to produce a base line; and the other proximally through the trochanteric region of the femur, taken along the femoral neck under direct vision. The angle of anteverision was then measured by subtraction between the angles shown by the two scans.

**Table 1.** Angle of femoral anteverision measured in 21 pairs of bones and arranged according to the difference between right and left

<table>
<thead>
<tr>
<th>None</th>
<th>2 degrees</th>
<th>3 degrees</th>
<th>4 degrees</th>
<th>5 degrees</th>
<th>6 degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-20</td>
<td>16-18</td>
<td>8-11</td>
<td>18-22</td>
<td>19-24</td>
<td>24-18</td>
</tr>
<tr>
<td>14-14</td>
<td>24-26</td>
<td>10-14</td>
<td>14-18</td>
<td>6-12</td>
<td></td>
</tr>
<tr>
<td>16-16</td>
<td>12-14</td>
<td>22-26</td>
<td>19-23</td>
<td>24-28</td>
<td></td>
</tr>
</tbody>
</table>

**Results**

Direct measurements using the jig were made on 53 right and 49 left femora. The angle of anteverision varied from 0 to 36 degrees, with an average of 15.38 degrees. In the 21 paired femora there was no difference in angle between left and right in five pairs. Five pairs had a two-degree difference and 11 pairs had between three and six degrees difference (Table 1). In this small series no pair had a difference of more than six degrees.

Thirty of the 102 femora were also measured with ultrasound. The results agreed exactly with those of direct recording in the jig except that in one case there was a difference of one degree. This study was considered to prove the accuracy of the ultrasound method. The ultrasound display for two femora is shown in Figure 2. The picture shows the shapes of both the femoral head, neck and greater trochanter, and of the condylar region of the corresponding knee. The angle of anteverision can then be directly measured. The average figure of 15.38 degrees in this series compares well with a series reported by Parsons in 1914. He studied 300 old dried femora and found an average angle of anteverision of 15.5 degrees.

**CLINICAL STUDY**

Eighteen normal volunteers had their hips and knees scanned by ultrasound. They ranged from 7 to 50 years in age. Six were male and 12 were female. When the technique had been established, eight selected orthopaedic patients were scanned. Three adult patients had suffered fracture of the shaft of one femur, and one child had Perthes' disease. Three children were known to have persistent in-toeing gait patterns. One child was being investigated for repeated falling.

**TECHNIQUE OF SCANNING**

A standard ultrasound machine, as used for scanning in pregnancy, was used. This was a Technicare model, EDP 1000, with a calibrated velocity of 1540 metres per second and a probe frequency of 5.0 megahertz. The most satisfactory probe for this use was one of 13 millimetres. The higher frequencies gave less penetration but a better quality image and were used throughout.

The patients were scanned on an ordinary table or trolley. In this series the measurements were done in the ultrasound room, but it is possible to use a portable machine at a patient's bedside. The ultrasound probe is on an articulated arm, which is light and easily manipulated. Skin contact is made using Aquasonic Gel. This jelly is non-irritant and water-soluble, and is similar to that used for electrocardiography.

Both limbs are placed in neutral rotation with reference to the upper border of the patella, and the probe is moved so as to give a picture of the lower end of femur 2.5 centimetres proximal to the joint line of the knee. The ultrasound display of the intercondylar plane on the television monitor is either put into the memory or photographed with a polaroid camera. With the limb in the same position, a transverse scan is made at the level of the greater trochanter. The correct level is difficult to define clinically but the shape of the head, neck and trochanteric region of the femur can be easily recognised after search with the ultrasound probe.

The procedure can be repeated on the other limb, and provided that the limb is not moved between the knee and the hip scans, the...
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rotation of the limb is not important. The results are seen on the
monitor screen and photographed. An example of the display is shown
in Figure 3, from which it will be seen that the shape of the femoral
condyles in the "knee picture" is easily recognised but the "hip picture"
needs explanation. The skin and soft tissues are seen superiorly, and
below this is a line produced by the anterior surface of the femur at the
greater trochanter, the anterior surface of the femoral neck and the
femoral head.

The intercondylar plane of the femur can be taken from the lower
picture, and used as a base line from which the angle of anteverision
of the femur on the upper picture can be drawn and measured.
An example of these tracings and the measurements is seen in
Figure 4. The angle of anteverision can be measured directly from the
film with a protractor, or with the correct programming a grid can be
set up on the machine which will deliver the angle in numerical form.

**Results**
The results from the 18 volunteers with no hip symptoms
and seemingly normal walking patterns are shown in
Table II. Seven subjects had the same measurement for
each hip, three subjects had a difference of two degrees,
and seven had a difference of four to six degrees between
left and right hips. One gentleman had the surprising
difference of 14 degrees and was therefore examined; he
was found to have a clinically detectable rotation deficit
and an abnormal walking pattern.

Three of the selected orthopaedic patients had
suffered a fracture of the femur, and were measured after
it had healed. None showed a gross rotational deformity
(Table III). Of the younger patients two had no clinical
deformity, one being measured because of undiagnosed
falling attacks, and the other because of a clinical and
radiological diagnosis of Perthes' disease; neither showed
any significant discrepancy in the angle of anteverision.

**Table II. Angle of femoral anteverision in 18 "normal" patients**

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Angle of anteverision (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>F</td>
<td>34</td>
</tr>
<tr>
<td>2*</td>
<td>31</td>
<td>M</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>M</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>F</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>F</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>F</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>F</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>36</td>
<td>F</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>M</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>M</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>F</td>
<td>24</td>
</tr>
<tr>
<td>12</td>
<td>21</td>
<td>F</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>44</td>
<td>F</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>31</td>
<td>M</td>
<td>20</td>
</tr>
<tr>
<td>15†</td>
<td>36</td>
<td>M</td>
<td>20</td>
</tr>
<tr>
<td>16</td>
<td>30</td>
<td>M</td>
<td>30</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
<td>F</td>
<td>24</td>
</tr>
<tr>
<td>18</td>
<td>29</td>
<td>F</td>
<td>10</td>
</tr>
</tbody>
</table>

*The display for this patient is seen in Figure 3
†This patient was found, after scanning, to have a clinical
rotational deformity of the left hip
Table III. Angle of femoral anteversion in eight patients

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Clinical diagnosis</th>
<th>Angle of anteversion (degrees)</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>31</td>
<td>M</td>
<td>Bilateral fracture, shaft of femur</td>
<td>16</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>F</td>
<td>Fractured shaft, left femur</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>20</td>
<td>M</td>
<td>Fractured lowermost third, right femur</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>6</td>
<td>F</td>
<td>Intoeing of left foot and leg</td>
<td>20</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>1.5</td>
<td>F</td>
<td>Intoeing gait</td>
<td>32</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>8</td>
<td>F</td>
<td>Constant falling, no apparent cause</td>
<td>28</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>F</td>
<td>Perthes' disease, right hip</td>
<td>32</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>6</td>
<td>F</td>
<td>Intoeing gait</td>
<td>20</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

Three patients with a clinical diagnosis of intoeing gait, or persistent upper femoral torsion, were selected for measurement because they seemed to have unilateral rotation deformities. Ultrasound scans confirmed the clinical diagnosis in each case with a discrepancy of 16 degrees, 18 degrees and 14 degrees in Cases 22, 23 and 26 respectively (Table III).

**DISCUSSION**

The significance of the angle of anteversion of the femur is widely recognised, especially in persistent upper femoral torsion, congenital dislocation of the hip, cerebral palsy and Perthes' disease (Ruby et al. 1979). There has been no reliable method of measuring the angle of anteversion until recently. Ruby et al. (1979) reported wide discrepancies in the results obtained by various radiological methods.

The value of knowledge of the angle of anteversion is widely appreciated and clinical and radiological estimates are used despite their relative inaccuracy. Benum, Ertresvåg and Heiseth (1979), using Rippstein's method, successfully demonstrated that there was no correction of rotational deformity after fractures of the femur in children. This study was retrospective, since rotation could not be measured at the time of fracture or during healing. The method presented could be used to avoid rotational deformity during fracture healing, and this is now the subject of a prospective study.

Computerised tomography can give an extremely accurate picture, and the results of estimating rotational deformity in the investigation of the hip have been well described in papers by Sheedy et al. (1976) and Weiner et al. (1978). Peterson et al. (1981) showed the excellent pictures obtained with computerised tomography but did not recommend its use for routine screening, giving a table to show the increased radiation in comparison with standard radiography. They recommended the use of computerised tomography only for special investigations and pointed out other technical difficulties, such as patient co-operation and positioning in a gantry acceptable to the machine.

The ultrasound method appears to give a less clear picture but it is totally non-invasive and is used in the same frequencies during pregnancy. It can be used with the patient in any position and does not require total cooperation. The ease with which this method may be used is obvious since all District General Hospitals now have an ultrasound department. We have been able to standardise a method using known angles, and to obtain accurate readings on a series of dried femora, normal volunteers and patients.

The method and the results in this paper allow of tentative conclusions, and it would seem that more normal subjects should be studied in order to establish the range of normal results and the difference between hips in each patient. Our results do show a wide normal variation in the angle of anteversion from 10 to 34 degrees. No normal subject had a variation between the left and right femur of more than six degrees. This method may prove to be of particular value in assessing the angular correction required at operation and to confirm correction after rotation osteotomies of the femur.

We would like to thank Mr T. O'Neil and the staff of the Ultrasound Department at Mansfield and District General Hospital for their help and encouragement in this study, the Photographic Department of the University of Nottingham and our secretary, Mrs S. Parker, for her invaluable assistance.

**REFERENCES**


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