THE USE OF COMPUTERISED TOMOGRAPHY IN DISLOCATION OF THE HIP AND FEMORAL NECK ANTEVERSION IN CHILDREN

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Computerised tomography is useful in the diagnosis of abnormalities of the hip in children, particularly in assessing the size and shape of the acetabulum, the position and congruity of the femoral head relative to the acetabulum, and the degree of femoral anteversion or retroversion. It is most useful when limited hip movement and previous operations preclude adequate clinical examination and assessment by routine radiographic techniques. It is not recommended for routine use in screening congenital dislocation of the hip or in diagnosis or follow-up of Perthes' disease or slipped capital femoral epiphysis.

The use of computerised tomography (CT) of the trunk and extremities is rapidly expanding. The procedure is of proved value in delineating the location and extent of tumours, infections and fractures but has been little used in the assessment of congenital abnormalities, the most notable being those of the spinal column. There are even fewer reports concerning its use in abnormalities of the hip (Lasda et al. 1978; McLeod et al. 1978; Weiner et al. 1978; Padovani et al. 1979). This paper describes our attempt to apply computerised tomography to problems of the hip in children and to identify appropriate criteria for the procedure. The instruments and methods used in this study have been previously described (Sheedv et al. 1976).

TECHNIQUE
The child is placed in a supine position in the gantry, with legs together and knees vertically oriented. Only three scanning slices are necessary to visualise the entire hip if they can be precisely localised through the superior, middle and inferior regions of the acetabulum (Fig. 1). Proper correlation with surface anatomy makes it possible to obtain the desired three slices without unnecessary exposure to radiation above and below the hip.

The angle of femoral neck anteversion can be measured directly if the orientation of the knee is known. If precise determination of anteversion is desired, a fourth slice through the patellae and femoral condyles is made (Fig. 2). Rotation of the legs must not

Fig. 1
Levels of slices to be obtained.

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occur between exposures. By constructing a line through the femoral head and neck and another line through the transcondylar plane of the distal portion of the femur, the exact angle of anteversion can be obtained.

Additional information concerning hip stability and range of rotation can be gained by obtaining slices through the hips, with the legs in maximal medial and lateral rotation (Fig. 3).

The femoral head and a large portion of the opposing acetabulum is cartilaginous in the newborn child and infant (Fig. 4). As in routine radiography, this cartilage does not produce an image on the CT scan. Thus, only limited information can be gained until adequate ossification has occurred to delineate the anatomical structures (by approximately 18 months of age).

Exposure. The amount of useful information to be gained must be weighed against the obvious disadvantage to the patient of exposure to radiation. Each slice of a CT scan requires three to four rads. Because there is ideally no overlap from one slice to the adjacent slice, the exposure from additional slices is not additive (Fig. 5). When multiple slices are taken, the total exposure remains between three and four rads per slice (but may be up to 50 per cent higher on some scanners). This can be compared to radiation exposure incurred with other standard procedures (Table I).

**CLINICAL MATERIAL**

Whole-body computerised tomography was introduced at the Mayo Clinic in October 1975. During the next three years, we selected 12 children with one or both hips dislocated (see Table II). Eight of the dislocations were congenital, two were due to meningomyelocele, and one each was from congenital coxa vara and fracture
of the acetabulum. The only criterion for selection for this study was that the child had a difficult hip problem, other than tumour or infection, and that we believed the procedure might give information that could not be obtained by standard radiographic techniques, including stereography, tomography, and arthrography. The study has helped us define more specific criteria.

Of the 12 children, five were boys and seven were girls. The ages at the time of the CT scan ranged from 1 year 5 months to 14 years 2 months. CT scans for congenital dysplasia of the hip without dislocation in older adolescents gave little useful information and were excluded from this evaluation.

**ILLUSTRATIVE CASE REPORTS**

For purposes of orientation, the normal adult anatomy is shown in this 37-year-old man with clinically and radiographically normal hips (Fig. 6). The slice, 13 millimetres thick, through the superior portion of the joint includes bone from both the acetabulum and the femoral head, effectively obscuring the joint space (Fig. 7). The next slice lower shows a large posterior acetabular lip, with a somewhat smaller, but very adequate, anterior lip (Figs 8 and 9); these lips together enclose approximately half the femoral head. The femoral head is completely round and well seated in the acetabulum. The joint “space” comprising the two opposing articular cartilaginous surfaces is narrow because there is relatively little cartilage (Figs 10 and 11). In children

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**Table I. Radiation exposure from various diagnostic procedures in children**

<table>
<thead>
<tr>
<th>Examination</th>
<th>Exposure (maximal estimates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT scan</td>
<td>3 to 4 rads each cut (ideally, same for the total)</td>
</tr>
<tr>
<td>Plain radiographs</td>
<td>About 250 mrads per film</td>
</tr>
<tr>
<td>Anteroposterior radiographs of the abdomen, the pelvis, the hips and the spinal column</td>
<td>About 250 mrads per film</td>
</tr>
<tr>
<td>Lateral radiographs of the pelvis, the hips and the spinal column</td>
<td>About 500 to 750 mrads per film</td>
</tr>
<tr>
<td>Intravenous pyelogram</td>
<td>Average 6 to 8 films (1.5 to 2 rads per examination)</td>
</tr>
<tr>
<td>Arthrogram (one hip)</td>
<td>Fluoroscopy, 2 rads per minute (5 minutes = 10 rads)</td>
</tr>
<tr>
<td></td>
<td>Film, 250 mrads per film (4 films = 1 rad)</td>
</tr>
<tr>
<td>Anteroposterior tomogram</td>
<td>250 mrads per film (12 films = 3 rads)</td>
</tr>
<tr>
<td>(one hip)</td>
<td></td>
</tr>
<tr>
<td>Radionuclide scan using **Tc</td>
<td>About 0.30 rad</td>
</tr>
</tbody>
</table>

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**Fig. 5**

Each slice of the scan receives three rads of exposure with very little overlap of adjacent slices.
Normal hips of a 37-year-old man with anterior sacral meningomyelocele. For description, see text.
this space is wider, depending on the amount of cartilage. The knees were pointing straight ahead at the time of this exposure. Because a line through the femoral neck is horizontal, these hips show no anteversion.

Case 2. A boy (6 years 8 months old) had congenital dislocation of the right hip. He had previously had an open reduction, innominate osteotomy (Salter), and proximal femoral derotation osteotomy (Fig. 12). The leg lengths were equal. Adductor and iliopsoas tenotomies were performed. Skeletal traction was applied distally to the right femur, and a spica cast was applied to the left hip for countertraction. After 17 days of traction progressing to 9.1 kilograms, the femoral head was slightly caudad to the level of the triradiate cartilage. Open reduction and Chiari osteotomy were accomplished (Fig. 13). Fifteen weeks later, the CT scan showed adequate but much less medial displacement of the inferior fragment than expected from the anteroposterior radiographs (Figs 14 and 15). The femoral head was displaced posteriorly, abutting against and blunting the posterior acetabular column (Figs 16 and 17). The acetabulum was shallow and empty, except for a small amount of heterotopic bone anterior to the head. The pelvic outlet was narrowed slightly. Open reduction was repeated. The femoral head seated into the acetabulum only after the femur was laterally rotated by 60 degrees. Reduction was maintained with a Steinmann pin. A spica cast was applied, with both legs in 60 degrees of lateral rotation. Ten weeks later, the top portion of the cast was removed, and an anteroposterior radiograph was taken, with a grid in place for use as a guide to determine the precise site of the CT scan (Fig. 18). Thus, a slice at only one level was necessary. The cast reduces the quality of the image of routine radiography, but it does not alter the quality of the CT scan (Fig. 19). The scan, taken with both knees in 60 degrees of lateral rotation, showed the femoral head well seated in the shallow right acetabulum.

Case 2. A boy with congenital dislocation of the right hip. Figure 12—Leg lengths are equal after three operations. Figure 13—At the time of open reduction and Chiari osteotomy.
Case 2. Figures 14 and 15—Fifteen weeks after osteotomy there is approximately 50 per cent of medial displacement of the inferior portion of the right ilium. Figures 16 and 17—Note that the slice through the normal left hip contains epiphysial and metaphysial bone which produce an opaque image, precluding evaluation of the physis. There is retroversion of the right hip and anteversion of the left hip. Figures 18 and 19—After repeat reduction, with both femora in 60 degrees of lateral rotation, the right hip is in 30 degrees of retroversion and the left hip in 10 degrees of anteversion. The cast is seen posteriorly.
Case 9. A boy (7 years 4 months old) with meningomyelocele had previously had bilateral iliopsoas transfers of the Sharrard type. The right hip was stable, the left hip was subluxing and there was marked pelvic obliquity (Fig. 20). With the hips in maximal abduction, the left hip was reduced. A CT scan of the left hip in maximal medial rotation and neutral abduction-adduction showed the femoral head well seated in the acetabulum, with the femoral neck medially rotated 30 degrees from the horizontal (Fig. 21). A concurrent CT scan taken at the knees showed the transcondylar plane in 85 degrees of medial rotation (Fig. 22). Thus, the patient had 55 degrees of anteverision. When the leg was maximally rotated laterally, the femoral neck was in 60 degrees of lateral rotation from the horizontal (Fig. 23), but the distal portion of the femur was in only five degrees of lateral rotation (Fig. 24), again indicating 55 degrees of anteverision. Pelvic obliquity precluded the evaluation of both hips on one slice.

Case 9. Figure 20—Radiograph showing pelvic obliquity. Figures 21 and 22—The CT scan of the femoral head and neck in maximal medial rotation with concurrent CT scan of the knees shows that femoral anteverision is 55 degrees. Figures 23 and 24—The same scans in maximal lateral rotation (see text).
Case 1. Figures 25 and 26—The slice of left hip shows the femoral capital epiphysis with a smaller outline than the femoral metaphysis, but although the slice contains the physis evaluation of it is not possible. Figures 27 and 28—The CT scan through the acetabulum shows that the triradiate cartilage is open.

Case 1. This boy was 5 years 11 months old when his complete, unilateral congenital dislocation was first discovered (Fig. 25). The CT scan showed the dislocated head abutting against the side of the ilium (Fig. 26) and an empty but adequate acetabulum (Figs 27 and 28). Although this scan was interesting, it did not add useful information to that supplied by plain radiographs.

Case 3. This girl, aged 1 year 11 months, had an open reduction and innominate osteotomy of the right hip. On the CT scan a single Kirschner wire obscured the image of the tissue surrounding the metal (Fig. 29). A slice immediately caudad or cephalad to the metal, however, was completely free of artefact.

Case 3. Internal metal obscured the right hip. The normal left hip is poorly visualised because of incomplete ossification. (This is the second youngest child in the series.)
RESULTS
We judged the scan to be "useful" if it provided information that could not be obtained by clinical examination or routine radiographic techniques or if it altered the course of management (Table II). By this criterion we found that the initial scan was useful in seven of the 12 patients (Cases 2, 4, 5, 7, 9, 10 and 11). Each of these seven patients had had previous surgical treatment, and none was doing well. This useful information consisted of determining the size and shape of the acetabulum (particularly the posterior lip), the femoral head–acetabulum congruity, the position of the femoral head relative to the acetabulum, and the degree of anteversion or retroversion of the femoral neck. In several patients, anteversion or retroversion could be accurately determined only by CT scan because limited movement of the hip precluded adequate clinical evaluation or because the hip could not be properly positioned for radiographic evaluation.

The CT scans of the five remaining patients were interesting, but only confirmed known information. Four of these patients (Cases 1, 6, 8, and 12) had had no previous operation. Their range of movement was adequate enough to assess the position of dislocation, the joint congruity and the anteversion by clinical and radiographic examination. Although knowledge of the size and shape of the acetabulum was enhanced by the scan, it did not alter the recommendation for treatment. Two of the four patients (Cases 1 and 8) had a subsequent operation, followed by scans that were of benefit. The scan of the fifth patient (Case 3) was obscured by metal (Fig. 29).

In five patients (Cases 1, 2, 4, 5, and 8) the scan was repeated, at a time varying from one week to 23 months after the first scan, to determine the changes that had resulted from the intervening treatment (Figs 17 and 19). In three patients (Cases 1, 4, and 8) the scan was useful in determining that no additional operation was necessary.

DISCUSSION
CT scans of hips have many desirable features. A radiographic image can be obtained in a transverse plane. This allows unique evaluation of anatomical structures, particularly the anterior and posterior lips of the acetabulum, its transverse diameter, and its contents.

Femoral anteversion can be accurately determined without the use of special leg-holding devices or computation tables. If the hip is mobile, other techniques are available to obtain the same information with less radiation and less expense. Although computerised tomography is the most accurate method available, we do not recommend it for routine anteversion studies, as has been proposed elsewhere (Weiner et al. 1978).

The procedure is non-invasive and, unlike arthrography, there is no danger of introducing infection. The quality of CT scans is not altered by ankylosis. In contrast to routine radiography, the presence of a cast does not alter the image of the CT scan (Fig. 19). Its use precludes the need for tomography to confirm reduction in the cast. However, if the legs are fixed in wide abduction, the patient may not fit in the gantry. This problem is being partially solved by newer machines with larger gantries. The procedure is painless. Anaesthesia is not necessary, as it usually is for arthrography in children. Computerised tomography would show anterior or posterior slipping of the femoral capital epiphysis in excellent profile; however, routine anteroposterior and oblique radiographs are usually adequate for these determinations.

Computerised tomography has some shortcomings. The patient must be co-operative and remain motionless for 20 seconds (newer machines have reduced this to 4.6 seconds) while each slice is taken and preferably should not move between the taking of slices. The noise of the machine may frighten a young child, and sedation may be necessary.

Each slice produced by the machines used in this study was 13 millimetres thick. In infants and young children, a relatively large amount of cartilage produces poor image detail (compare Fig. 4 with the normal left hip shown in Fig. 29). A single slice would include the entire cartilaginous femoral head of a newborn child. The scanning of infant hips at one-centimetre intervals instead of the usual 1.5 centimetres improves the study but increases the radiation dose by approximately 30 per cent. Thus, at present, the CT scan should not be used as a screening or a diagnostic technique in congenital dislocation of the hip. Even when ossification of the femoral head and acetabulum are present, the 13-millimetre thickness of the slice causes overlap of these two structures so that the superior joint space is not accurately imaged (Figs 6 and 7). The slice includes enough bone to produce an opaque image, thus making it difficult to assess any area of avascularity of the femoral head. Thus, the CT scan is not useful for diagnosis, assessment, or prognosis in Perthes' disease. The slice includes bone on each side of the physis, thus precluding evaluation of the physis (Figs 16 and 17; Figs 25 and 26). Thus, computerised tomography does not aid in the evaluation of disorders of the epiphyseal growth plate, such as premature partial closure. The presence of internal metal obscures surrounding structures (Fig. 29).

Radiation exposure and the cost of the procedure may be an advantage or a disadvantage, depending on the alternative procedures available. If the scan can substitute for arthrography, which in children requires hospitalisation, general anaesthesia, and the use of an arthrography room, it may be less expensive. Radiation exposure may also be less than that of arthrography or tomography, especially if the problem is bilateral (Table I). The insertion of radiopaque dye intra-articularly may
### Table II. CT scans in children with hip problems

<table>
<thead>
<tr>
<th>Case</th>
<th>Side</th>
<th>Date of scan</th>
<th>Age at scan (y + m)</th>
<th>Findings</th>
<th>Additional treatment</th>
<th>Scan useful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M</td>
<td>None</td>
<td>25 Oct 76</td>
<td>5+11</td>
<td>Shallow acetabulum</td>
<td>Poas and adductor release, traction; open reduction, innominate osteotomy (Salter). varus derotation osteotomy plus shortening. None necessary.</td>
<td>No</td>
</tr>
<tr>
<td>2 M</td>
<td>R</td>
<td>8 Nov 76</td>
<td>7+1</td>
<td>Hip posterior</td>
<td>Open reduction</td>
<td>Yes</td>
</tr>
<tr>
<td>3 F</td>
<td>R</td>
<td>2 Dec 76</td>
<td>1+11</td>
<td>Detail obscured by K wire</td>
<td>Innominate osteotomy (Salter). left; derotation osteotomies, bilateral</td>
<td>No</td>
</tr>
<tr>
<td>4 M</td>
<td>None</td>
<td>18 Jan 77</td>
<td>9+10</td>
<td>Antversion, adequate anteroposterior location</td>
<td>None necessary</td>
<td>Yes</td>
</tr>
<tr>
<td>5 F</td>
<td>None</td>
<td>25 Jan 77</td>
<td>2+2</td>
<td>Hip dislocated, antversion</td>
<td>Hips casted in abduction and internal rotation</td>
<td>Yes</td>
</tr>
<tr>
<td>6 F</td>
<td>None</td>
<td>7 Feb 77</td>
<td>5+7</td>
<td>Adequate acetabulum</td>
<td>Skeletal traction, open reduction innominate osteotomy (Salter). shortening varus osteotomy, left femur</td>
<td>No</td>
</tr>
<tr>
<td>7 F</td>
<td>None</td>
<td>1 Apr 77</td>
<td>1+5</td>
<td>Left hip subluxated posteriorly; posterior lip of acetabulum flat; antversion bilaterally</td>
<td>Innominate osteotomies (Salter). right; derotation osteotomy, right</td>
<td>Yes</td>
</tr>
<tr>
<td>8 F</td>
<td>None</td>
<td>4 Apr 77</td>
<td>6+2</td>
<td>Antversion, shallow acetabulum</td>
<td>Bilateral femoral shortening varus derotation osteotomies with innominate osteotomies (Salter). Abduction brace, no operation necessary</td>
<td>No</td>
</tr>
<tr>
<td>9 M</td>
<td>None</td>
<td>15 Mar 78</td>
<td>7+6</td>
<td>Severe antversion</td>
<td>Closed reduction and femoral derotation osteotomy, left</td>
<td>Yes</td>
</tr>
<tr>
<td>10 F</td>
<td>None</td>
<td>20 Jun 78</td>
<td>10+8</td>
<td>Adequate acetabula, no antversion</td>
<td>Recommended—innominate osteotomies and arrest greater trochanter</td>
<td>Yes</td>
</tr>
<tr>
<td>11 F</td>
<td>None</td>
<td>7 July 78</td>
<td>14+2</td>
<td>Acetabulum small in anteroposterior diameter, head displacement superriorly</td>
<td>Left femur varus osteotomy and shortening innominate osteotomy (Chiari)</td>
<td>Yes</td>
</tr>
<tr>
<td>12 M</td>
<td>None</td>
<td>5 Dec 78</td>
<td>11+10</td>
<td>Fragments off superior acetabulum; superior dislocation; false acetabulum; femoral head flat</td>
<td>Skeletal traction, open reduction, internal fixation of acetabulum</td>
<td>No</td>
</tr>
</tbody>
</table>

*Proved dislocation of one or both hips was present at some time in each case.*
add additional information, but it was not used here.

With improved technology it is possible to produce thinner slices with an equivalent or reduced dose of radiation. Thus, newer scanners may be of greater value in several conditions, particularly in assessing the extent and area of avascular necrosis.

On the basis of this study, our present criteria for the use of computerised tomography are problems in the hips of children older than 18 months of age whose range of movement is limited or who have osseous changes that make examination and assessment by standard radiographic techniques incomplete. Thus, in addition to evaluating tumours, computerised tomography is most useful in evaluating obscure subluxations of any cause, certain fractures such as separations of and fragments within the acetabulum, residua of infection, and unusual femoral anteversion. It is not recommended for routine use in screening congenital dislocation of the hips or femoral anteversion, for diagnosis, or for follow-up of Perthes' disease or slipped capital femoral epiphysis, and it has no use in evaluation of the epiphysial growth plate.

Joel E. Gray, PhD, Department of Diagnostic Radiology, provided the technical data on radiation doses and critically reviewed the manuscript.

REFERENCES


