In *vitro* determination of bone mineral content of the femur neck

Use of computed tomography

D. H. VAN PAPENDORP, S. PISTORIUS, F. S. HOUGH

Summary

An accurate method for the *in vitro* measurement of mineral content of femoral bone by means of computed tomography (CT) is presented. The bone mineral content (BMC) of the femoral head in patients with a subcapital fracture was determined and compared with that in patients with osteo-arthritis. There was a satisfactory standard curve and a highly significant relationship between the CT number (Hounsfield number) and a standard bone equivalent reference ($K_2HPO_4$) was obtained at two different energies (96 and 125 kV). The calculated error in the calibration procedure was less than 1.5% and the overall error of the method was 8.8%. The femoral BMC of patients in the fracture group was found to be substantially lower ($P < 0.001$) than that in osteo-arthritis.

Materials and methods

Freshly excised femoral heads were obtained from 100 patients of whom 50 underwent total hip replacement for hip osteo-arthritis (OA) and 50 required a hip prosthesis for subcapital femur neck fracture. All patients were white, aged 60 - 80 years, with a female: male ratio of 2:1. The OA and fracture groups were absolutely comparable with regard to age and sex distribution.

Locomotor disease has changed drastically over the years; nutritional rickets, tuberculosis and poliomyelitis have almost disappeared in the Western world, while fractures and osteo-arthritis in the elderly are now a major burden to individuals and to society. Most victims of femur neck fractures suffer from osteoporosis, a condition known to affect some 25% of white females over the age of 65 years, and characterised by a decrease in quantity of bone without apparent change in its quality. Approximately 20% of fracture cases suffer from osteomalacia, i.e. defective mineralisation of skeletal tissue characterised by excess unmineralised osteoid tissue. These pathological changes result in increased bone fragility and fracture following minimal or no trauma.

Bone mass is the principal, although not the sole, determinant of fractures in the elderly patient. Currently available non-invasive bone mass quantitating methods are, however, unable to discriminate fully between osteoporotic and age-matched normal populations, and the precise roles of single and dual energy photon absorptiometry and quantitative computed tomography (CT) techniques remain to be determined. Moreover, use of CT in the determination of the bone mineral content (BMC) of the femoral neck has not received attention — with reports on axial BMC usually being confined to the spine. Since *in vitro* measurement of BMC has certain inherent difficulties related to the patient, the disease and the methodology employed, it was decided to limit our initial investigation to the *in vitro* determination of femoral BMC.

Results

A typical calibration curve (Hounsfield number v. $K_2HPO_4$ concentration) is depicted in Fig. 1. The standard deviation after triplicate scanning of standard solutions was negligible, and a

Fig. 1. Standard calibration, 96 kV and 125 kV.
Significant difference \((P < 0.001)\) between osteo-arthritis and fracture groups. The mean bone mineral content of the fracture group was 136 \(\pm\) 32 g/l, which is significantly \((P < 0.001)\) lower than the 183 \(\pm\) 40 g/l of the OA group. The calculated error in the calibration procedure was 1.1\% at 125 kV and 1.0\% at 96 kV, with a difference of 0.23.

The mean (\(\pm\) SD) Hounsfield numbers at different energies and the bone mineral content after triplicate scanning of femur neck heads from patients with OA and femur neck fractures are shown in Table I. Significantly lower Hounsfield numbers were obtained in the fracture group compared with the OA group, at both energies studied. The standard deviations expressed as a percentage of the Hounsfield number were 14\% throughout (Fig. 2).

**TABLE I. HOUNSFIELD NUMBERS (MEAN \(\pm\) SD) AT DIFFERENT ENERGIES AND THE BONE MINERAL CONTENT OF PATIENTS WITH OA AND FEMUR NECK FRACTURES**

<table>
<thead>
<tr>
<th></th>
<th>Fracture group</th>
<th>OA group</th>
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<tbody>
<tr>
<td>((N = 50))</td>
<td>((N = 50))</td>
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<tr>
<td>Hounsfield number at 96 kV</td>
<td>256 (\pm) 37</td>
<td>372 (\pm) 53</td>
</tr>
<tr>
<td>Hounsfield number at 125 kV</td>
<td>227 (\pm) 32</td>
<td>330 (\pm) 48</td>
</tr>
<tr>
<td>Bone mineral content (g/l)</td>
<td>136 (\pm) 32</td>
<td>183 (\pm) 40</td>
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</tbody>
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Significant difference (\(P < 0.001\)) between osteo-arthritis and fracture groups.

Discussion

It appears that the measurement of BMC of the femur by CT may provide a useful tool in the diagnosis of osteopenic conditions such as osteoporosis. Femoral CT measurements provided an index of fracture risk by revealing a permissive bone mineral level of approximately 160 \(\pm\) 36 g/l above which fractures are rare and below which fractures may occur. Furthermore, below a BMC of 136 \(\pm\) 32 g/l fractures are the rule and absence of fractures is the exception. The in vitro measurement of femoral BMC was found to be simple and reproducible, with a total error of only 8.8\%, which compares very favourably with the data of Genant et al.\(^6\) and Cann\(^7\) for spinal bone mineral determinations. Moreover, the availability of CT scanners, which can be modified for quantitative measurement at relatively little cost,\(^8\) makes this method all the more attractive.

Although the results of this preliminary in vitro study are encouraging, we have to take due cognisance of many inherent difficulties that may be encountered during in vivo studies of bone mineral content using current CT scanners. These include the X-ray beam hardening effect, patient repositioning and motion artefacts, pathological conditions (e.g. tissue calcification, arthropathies, compression fractures), as well as radiation exposure.\(^9\) If these technical problems can, however, be overcome the use of CT scanning will certainly prove to be a most valuable tool in the screening and long-term follow-up of patients with the osteopenic femur neck fracture syndrome.

REFERENCES