THE TRABECULAR PATTERN OF THE CALCANEUM AS AN INDEX
OF OSTEOPOROSIS

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Radiographs of the foot and hip in 61 patients with fractures of the upper end of femur have been studied, noting the progressive loss of bone trabeculae with age. The trabecular pattern in the calcaneum (expressed as the calcaneal index) closely parallels that in the upper end of the femur (Singh's index) and is easier to assess. Both indices have a significant correlation with age.

All weight-bearing cancellous bones include trabeculae disposed in two arches intersecting each other at right angles. These correspond to the compression and tensile stresses produced in bone during weight-bearing (von Meyer 1867). As the bone mass diminishes with increasing age, the orderly loss of bone mass can be studied radiologically, and one method of doing so is to observe the trabecular pattern of the upper end of the femur. Singh and his colleagues (Singh, Nagrath and Maini 1970; Singh et al. 1972) have divided the progressive loss of these trabeculae into seven grades, from that in the normal healthy adult (Grade VII) to that in severe osteoporosis (Grade I).

The calcaneum is a cancellous, subcutaneous, weight-bearing bone. Its trabeculae, like those of the femoral neck, are arranged along the lines of compression and tensile stress produced during weight-bearing and it seems ideal for the study of osteoporosis. It is curious that, though the mineral content of the calcaneum has been used to study osteoporosis (Goldsmith et al. 1971), radiological methods have not hitherto been employed.

In this present study an attempt has been made to observe the progressive changes that occur in the trabecular pattern of the calcaneum as the normal bone becomes progressively more osteoporotic with age. These changes have also been compared with those occurring in the trabecular pattern of the upper end of the femur.

The normal trabecular pattern of the calcaneum has been described by Lockhart, Hamilton and Fyfe (1959). In a sagittal longitudinal section the trabeculae are arranged in two groups corresponding to compression stresses and to tensile stresses.

Compression trabeculae are disposed in two sets. One originates at the subtalar articular surface and diverges downwards and backwards through the waist of the calcaneum; the trabeculae become finer and more numerous as they pass backwards to fan out over the entire posterior surface and reach the inferior border slightly in front of the posterior tubercle. The second set of compression trabeculae pass anteriorly from the subtalar articular surface to the articulation with the cuboid.

Tensile trabeculae start in front of the tuberosity of the calcaneum and sweep both backwards and forwards between the two compression struts. Another set of trajectory trabeculae is seen in the line of pull of the calcaneal tendon; it is a thick compact group of parallel trabeculae along the subcutaneous part of the bone.

Between the anterior and posterior groups of compression trabeculae is an area which contains only a few thin vertical trabeculae and is known as the foramen calcanei.

MATERIAL AND METHODS

The present study was conducted in the Departments of Orthopaedics and Anatomy, Jawahar Lal Nehru Medical College and Hospital, Ajmer. Sixty-one consecutive patients over the age of 30 with fractures of the upper femur were admitted between January 1 and November 15, 1979. Each patient had two radiographs taken: an anteroposterior view of the pelvis including both hip joints in slight medial rotation; and a lateral view of the foot on the unaffected side.

All the available radiographs were analysed by three people independently and the results compared; the analysis was repeated three months later and the results were found to be similar. Each calcaneum was graded from V (the normal) to I (severely osteoporotic).
Grade V (normal). Lateral view of the calcaneum and diagram showing the trabecular pattern. Compression and tensile trabeculae are uniformly distributed.

Grade IV (normal). The posterior compression trabeculae are divided into two pillars separated by a radiolucent area due to recession and disappearance of the middle portion of these trabeculae.

Grade III (borderline). There is also recession and disappearance of the posterior tensile trabeculae which now cross only the anterior pillar of the posterior compression trabeculae.

Grade II (osteoporotic). The anterior tensile trabeculae have disappeared and the posterior tensile trabeculae have receded.

Grade I (severely osteoporotic). There is complete disappearance of both sets of tensile trabeculae; the compression trabeculae are reduced in number and are thin.
Grade V (Figs 1 and 2). This shows the normal trabecular pattern of the calcaneum in a healthy young adult. The compression and tensile trabeculae are uniformly present and cross each other, and the bone appears to be packed with cancellous tissue. The foramen calcanei shows a few thick dense trabeculae comparable in density with those in other parts of the bone.

Grade IV (Figs 3 and 4). The posterior compression trabeculae are seen as two pillars separated by a well-marked radiolucent area which is due to recession and disappearance of the middle part of the posterior compression trabeculae.

Grade III (Figs 5 and 6). Here, in addition to the above changes, there is recession and disappearance of the posterior tensile trabeculae, which stop short at the anterior pillar of the posterior compression trabeculae. This grade represents the borderline between a normal and an osteoporotic bone.

Grade II (Figs 7 and 8). Here the changes have progressed still further, with disappearance of the anterior tensile trabeculae. A thin sheaf of the posterior tensile trabeculae can still be seen; it crosses the anterior pillar of the posterior compression trabeculae. This bone is definitely osteoporotic.

Grade I (Figs 9 and 10). Both sets of tensile trabeculae have disappeared completely and there is also generalised thinning, disappearance and reduction in the number of compression trabeculae. The bone appears empty and not much denser than the soft tissues; this represents an advanced stage of osteoporosis.

RESULTS

Once the basic trabecular pattern had been appreciated and a radiographic scale formulated, all the available films were graded independently by three people. The average Singh’s index and the average calcaneal index of all age groups were calculated. Table I clearly shows that with increasing age both the Singh’s index and the calcaneal index decrease; thus the average Singh’s index drops from 4.3 in the youngest group to 2.5 in the oldest, and the calcaneal index drops from 4 to 1.75.

Table II shows that there is a highly significant inverse correlation between age and Singh’s index and between age and the calcaneal index. There is also a significant positive correlation between Singh’s index and the calcaneal index. Figure 11 shows how closely the two indices agree with each other.

![Graph showing the relationship between age and Singh's index and the calcaneal index](image)

The average Singh’s index and calcaneal index over the various age groups has been plotted. The two indices show a linear regression ($r=0.99$) and significant correlation ($P<0.001$) between each other.

DISCUSSION

It is clear that changes in the trabecular pattern of the calcaneum can be used as an index for diagnosing and grading osteoporosis. The results of calcaneal indexing show a significant inverse correlation with age ($r=-0.92; P<0.05$) similar to that found with Singh’s index ($r=-0.91; P<0.05$). The method also has a significant correlation with Singh’s index ($r=0.99; P<0.001$).

Histological, densitometric and radionuclear methods of diagnosing and measuring bone mass are too complex for routine use, require sophisticated instruments and can only be carried out at well-equipped centres. In routine day-to-day practice, most clinicians diagnose osteoporosis by morphological studies of the skeleton such as analysis of spinal radiographs (Barnett and Nordin 1960; Devlin and Goldman 1966; Smith and Rizek 1966) and measurement of the cortical index of peripheral long bones (Bernard and Laval-Jeantet 1962; Meema 1963; Anton 1969). These methods have their shortcomings; thus, analysis of spinal radiographs has many difficulties (Doyle et al. 1967); and the cortical index does not correlate well with spinal osteoporosis (Fourman and Royer 1968).

It is said that radiographically detectable trabecular bone loss is an earlier and better manifestation of
osteooporosis than these other methods; this is why a study of the trabecular pattern of the proximal end of the femur was chosen by Singh and his co-workers (Singh et al. 1970, 1972). But radiography of the hip also has difficulties and these affect the accuracy of the results; thus, grading is affected by rotation of the limb (Roh, Dequeker and Mulier 1974), and by abnormalities of the neck–shaft angle. Moreover the mass of soft tissue surrounding the hip may affect the quality of the radiographs, a problem which does not arise in the calcaneum.

Calcaneal indexing, as evolved in the present study, could provide an effective method of surveying osteoporosis so as to predict the population at risk of sustaining fractures. It could also be used to assess the efficacy of methods of treating osteoporosis. The procedure is cheap, technically simple and the gradings are easily reproducible.

REFERENCES


Meema HE. Cortical bone atrophy and osteoporosis as a manifestation of aging. AJR 1963;89:1287–95.


