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Women's Health: Osteoporosis

Osteoporosis: Radiologic and Nuclear Medicine Procedures

BARBARA N. WEISSMAN, MD

Dr. Weissman is Chief, Section on Bone Radiology, Brigham and Women's Hospital, and Associate Professor of Radiology at Harvard University Medical School, Boston, MA. This paper is based on her presentation at the National Conference on Women's Health, held in Bethesda, MD, June 17–18, 1986.

Synopsis

A number of radiographic and nuclear medicine techniques are available for the assessment of patients suspected of having osteoporosis or at risk for the development of osteoporosis.

Spinal radiographs are insensitive indicators of osteoporosis. They can document the presence of metastatic tumors or other lesions that may produce compression fracture.

The Singh index assesses the trabecular pattern of the proximal femur. As bone loss occurs, the trabeculae disappear in a definite sequence.

Radiogrammetry refers to the measurement of bone and cortical widths in the peripheral skeleton, usually the second metacarpal. The method is low cost and

most useful for population studies. It does not reflect early osteoporosis.

Photodensitometry entails radiography of a part of a bone with inclusion of a standard reference wedge on the radiograph. The density of the bone is compared with the wedge. In some laboratories, precision is good (1.5 percent) and the radiation dose is low. Peripheral cortical bone is measured primarily, which is a disadvantage.

Single photon absorptiometry uses the transmission of 27.5 keV photons emitted from an iodine-125 source to assess bone density. In most instances, measurements of the radial shaft are made, which reflect primarily cortical bone rather than the more reactive trabecular bone. The distal end of the radius and the calcaneus may also be measured; these areas contain primarily trabecular bone. Radiation dose is low (< 10 mrad), but when cortical bone is evaluated, the results correlate poorly with spinal bone mineral. Thus, the test is an insensitive indicator of spinal osteoporosis.

Dual energy photon absorptiometry uses a gadolinium-153 isotope source to emit photons of two different energies. The spine, hip, or total bone mineral can be evaluated. The radiation dose is low (< 20 mrem). Although the axial skeleton can be assessed, the scan reflects the density of both the cortical and the trabecular bone and any adjacent calcification.

Quantitative computed tomography (QCT) uses a reference phantom that is scanned adjacent to the patient to correct for scanner variations. The study allows the trabecular bone of the spine to be evaluated separately from the cortical bone. Precision is 1-3 percent. Accuracy is decreased by the presence (in older individuals) of vertebral marrow fat that makes the measured values of bone mineral spuriously low. CT scanning, using two X-ray energies, can improve accuracy, but decreases precision.

OSTEOPOROSIS is a clinical syndrome in which a decrease in bone mass results in the occurrence of fracture with minimal trauma (*1*). A number of techniques have been developed for evaluating bone mass and for detecting decreases in bone mass before fractures occur. This discussion will provide an overview of some of these radionuclide and radiographic procedures, beginning with some general concepts necessary for evaluation of these procedures and concluding with a review of each of the most frequently used methods.

The first question to be asked is: Why measure bone mass? Bone mass is evaluated because a decrease in bone mass is the major factor responsible for the loss of bone strength. Also, although other factors such as poor eyesight and muscle control contribute to increased fracture occurrence in the elderly, bone strength, and hence bone mass, is the most important.

Next, we should consider whether cortical bone or trabecular bone should be evaluated. Bone is composed of both cortical (compact) and medullary (trabecular or cancellous) components. Cortical bone makes up the peripheral portions of bones and is particularly thick in the midshaft regions of long bones. In the femoral neck, an area frequently affected by osteoporotic fracture, cortical bone makes up 75 percent of the total bone mass (*2*). Cortical bone also makes up 80 percent of the body's total bone mass. For these reasons, measurement of cortical bone is important.

Trabecular bone is comprised of a network of bony spicules, with a large surface area. The ends of long bones and the axial skeleton are rich in trabecular bone. For example, trabecular bone makes up 60 percent of each vertebra. Trabecular bone is the first to be affected by metabolic bone disease, in particular, the trabecular bone of the spine. Cann and coworkers (*3*) studied women after oophorectomy and noted that spinal bone loss occurred well before peripheral changes were detected.

For the early detection of osteoporosis, trabecular bone measurements, particularly of the spine, seem to be of importance. Since cortical bone makes up so much of the femoral neck and since it represents so much of the body's total bone mineral in normal individuals, cortical bone measurements are probably also of importance.

"Fracture threshold" refers to a level of bone mineral content above which fracture occurrence is rare and below which fracture occurrence is more common. For example, when evaluating spinal osteoporosis by quantitative computed tomography (QCT), bone mineral levels above 100-110 mg per cubic centimeter are not usually associated with vertebral fractures, whereas measurements below 65

mg per cubic centimeter are more likely to accompany vertebral fractures, which are often severe (*4*).

Finally, for evaluation of the available tests, the terms accuracy and precision require definition. Accuracy is a measure of the test's ability to determine the actual mineral content (*5*) and is expressed as a coefficient of variation (CV), which represents the difference between the actual and the measured calcium. High accuracy is important for the detection of osteoporosis compared with a normal population, but it is not necessary for following patients over time. Precision refers to the repeatability of the study results under identical test conditions, and is expressed as a CV of repeated measurements, in percent. High precision is necessary for following patients over time. The precision that is necessary depends on the degree of change to be measured. Most of the studies reviewed here have, at best, a 1 percent precision, which allows detection of changes of about 2.8 percent in bone mineral. Postmenopausal cortical bone loss, however, occurs at a rate of 1–2 percent per year (*6*), although spinal bone loss is greater (3 percent per year as measured by dual photon absorptiometry (DPA), or between 5 and 6 percent per year as measured by QCT (*4*).

The first radiographic test to be described is standard radiography of the dorsal and lumbar spine, which is easily done and readily available. Standard AP and lateral radiographs mirror the findings that are shown on gross pathology in cases of severe osteoporosis. When a normal vertebra is contrasted with a severely osteoporotic one, the latter demonstrates loss of vertebral body height, thin, sharp cortical margins, prominence of the vertical trabeculae, and a paucity of horizontal trabeculae. Although radiographs do not detect early bone loss, they can confirm the presence of compression fracture in patients suspected of having osteoporosis and this can obviate the need for other, more sophisticated tests. In addition, standard radiography may detect metastatic tumors (particularly metastatic breast carcinoma) that may result in compression fracture. Thus, standard radiographs are of importance in documenting compression fractures and in helping to exclude the presence of malignancies or other disorders that may produce vertebral compression fracture and clinical findings simulating osteoporosis.

The next radiographic method to be considered was developed by Singh and colleagues (*7*) and utilizes the trabecular pattern of the femur to assess bone loss. As bone loss occurs in osteoporosis, the trabeculae of the proximal femur disappear in a definite sequence, with the least stressed areas resorbed earliest. Seven radiological grades have been defined, and patients with grade 4 or less are considered to have an abnormal degree of bone loss. Although Singh et al. (*7*) noted that 100 of 102 patients with compression fractures had grade 4 or less, other authors (*8*) feel that the precision of this test is limited, and the accuracy is poor. The Singh index does not appear to be able to predict hip fracture (*9*).

Another technique that uses standard radiographs for estimation of bone mineral is radiogrammetry, in which measurements are made of bone and cortical width (*10, 11*). The second metacarpal is usually studied, and the measurements can be compared with those in normal subjects. The advantages of radiogrammetry are that it is relatively easy, readily available, and inexpensive. Disadvantages include its insensitivity and inability to evaluate the quality (in addition to the thickness) of the cortex or trabecular bone. As in all techniques in which cortical bone is measured, early disease is not detectable. This technique appears to be most useful for population studies rather than for assessment of individual patients.

Photodensitometry is a technique in which standardization of radiographs is attempted by including a wedge of known density alongside the bone part to be radiographed. The optical density of the bone is then compared with the wedge using a photodensitometer. The accuracy of the technique is estimated at between 5 and 15 percent (*8*) and the precision at 5 percent, although in some laboratories a 1.5 percent precision is obtained. The cost is that of obtaining and analyzing two radiographs. The radiation dose is approximately 450 mrad.

Single photon absorptiometry (SPA) is a current generation radionuclide and radiographic technique (*12*). With this technique, a well-collimated iodine-125 source emits photons that are directed over the area to be examined, such as the forearm or heel. A detector monitors the transmitted radiation; the amount of transmitted radiation reflects the density of the bone. The results are given in grams of bone mineral in a 1-cm-wide path termed bone mineral content or as bone mineral content per unit area (grams per square centimeter, bone mineral density). Most often, the radius is examined, and depending on the area measured, various amounts of cortical and trabecular bone are studied. The most commonly studied site is the radial shaft, which includes 95 percent cortical bone and only 5 percent trabecular bone. Evaluation of the distal radius can include much greater amounts of trabecular bone. The advantage of SPA is its low radiation dose (less

than 10 mrad). Since cortical bone is most often measured, and since 80 percent of bone mineral is cortical bone, the results of SPA of cortical regions correlate highly with total body calcium. There are, however, several disadvantages. For example, the area to be measured must be surrounded by a water-equivalent substance so that the path is of uniform thickness. Also, when cortical areas are measured, correlation with results from a spinal measurement is poor. Thus, patients with normal values on SPA may still have axial osteoporosis. Decreased values, however, usually mean axial bone mineral loss. More recent studies have compared SPA of the trabecular bone of the calcaneus (the heel) with other methods. In one series, SPA of the calcaneus was the best predictor of nonspine and spinal fracture risk (*13*).

Two methods are currently being tested for evaluating the axial skeleton: DPA and QCT. DPA (*14, 15*) is a technique in which the patient lies on an examining table and an isotope source below scans the lumbar region. A detector above the patient records transmitted radiation. The isotope (gadolinium-153) source used provides two gamma energies. In contrast to SPA, DPA precludes the need for uniform path length and also allows thick body parts to be scanned. The results of scanning, expressed in grams per square centimeter, reflect the density of the entire vertebrae, including both the cancellous and cortical portions, and any calcified tissues in the region such as aortic calcification or spinal osteophytes. The accuracy of the examination *in vivo* is 4–10 percent (*4*) and the precision .7–6 percent. The equipment costs approximately $30,000–$65,000. The radiation dose is less than 20 mrem. The advantages of DPA are the low radiation dose and the ability to measure both the trabecular and cortical bone of the spine, femur, or total body.

QCT is a method introduced by Cann and coworkers (*3*) in which a reference standard, scanned adjacent to the patient, is used to correct for variations in scanning that would otherwise make examination imprecise. Thick CT sections are obtained through the midportions of several vertebral bodies (usually T12, L1, and L2). Areas of interest are then selected that include the trabecular bone of the vertebrae, and CT numbers are derived with reference to the standard. The results are given in milligrams of the mineral standard per cubic centimeter and can be compared to results from a series of normal patients. The accuracy of the technique for young adults is about 5 percent, but decreases in older individuals who have increased amounts of marrow fat. Precision is 1–3 percent. Advantages of the technique include axial anatomical display and the ability to separate cortical and cancellous bone. Disadvantages include the relatively high radiation dose and the expense of the procedure.

The accuracy of CT can be improved by correcting for vertebral fat by using two X-ray energies for CT scanning (*16*). The precision of this dual energy study is, however, reduced and the radiation dose is increased compared with the single energy examination.

In summary, the following conclusions seem justified. First, spinal radiographs can confirm compression fractures and obviate the need for other imaging tests. Second, SPA of the radial shaft is not an early test for osteoporosis since it measures predominantly cortical bone. Third, DPA and CT can assess the mineral of the axial spine and the risk of vertebral fracture.

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Women's Health: Osteoporosis

Osteoporosis: Nutrition

RICHARD S. RIVLIN, MD

Dr. Rivlin is Chief, Nutrition Service, Memorial Sloan-Kettering Cancer Center, and Professor of Medicine and Chief, Nutirition Division, Cornell University Medical College and the New York Hospital, New York, NY.

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Synopsis

Nutrition has important potential for the prevention and treatment of osteoporosis. Ensuring the adequacy of calcium intake is central to any program of osteoporosis control, but it must be considered in the context of the many factors, including other nutrients, diseases, and drugs, which influence calcium absorption, utilization, and excretion. The dietary consumption of calcium by large segments of the U.S. population remains inadequate. More attention must be paid not only to increasing calcium intake, but also to maximizing its availability from food sources and its retention by the body. As individuals age, it becomes increasingly difficult to maintain adequate calcium balance; dietary selection must be made with special care for older persons to ensure that all of the nutrients are consumed in sufficient quantities and that neither excessive weight loss nor weight gain occurs.

IN DISCUSSING THE POTENTIAL role of nutrition in the prevention and treatment of osteoporosis, it is essential first to understand what comprises the science of nutrition. Nutrition is much more than just the study of what constitutes a good diet. Rather nutrition includes the science of how nutrients are used by the body. Utilization of dietary nutrients, in turn, involves intestinal absorption, transport, metabolic transformations and interconversions, storage, and excretion *(1)*. These considerations are particularly relevant to the issue of calcium and osteoporosis, inasmuch as many factors, such as disease, other nutrients, and certain drugs, may interfere in a clinically significant fashion with the utilization of dietary calcium even when its content in the diet may be adequate. When the diet is marginal or deficient in calcium, then the adverse effects of these interfering factors become even more evident.

Many changes occur in our bodies as we age. Nutrition is of universal concern because we all eat and we all grow old. Our challenge is to understand how to design an optimal diet and then to maximize the utilization of dietary nutrients in such a way as to derive the greatest benefits in delaying the degenerative diseases of aging. Osteoporosis is an excellent example of a disease for which nutrition has potential for prevention or reduction of disability and death.

Calcium and Osteoporosis

Calcium is critical to any discussion of osteoporosis, since bone constitutes the major reservoir of calcium, containing 99 percent of the total body supply *(2)*. A number of studies document the fact that the consumption of dietary calcium is inadequate in large segments of the U.S. population. Figure 1 shows the intake of calcium in men and women throughout their lifetimes, according to the results of the recent HANES II study *(3)*. At every age, men have higher intakes than women. The