BRADFORD RICHMOND, MD
Department of Radiology, The Cleveland Clinic;
certification instructor, the International Society for
Clinical Densitometry

DXA scanning to diagnose osteoporosis: Do you know what the results mean?

ABSTRACT

Dual-energy x-ray absorptiometry (DXA) provides useful information about osteoporosis and fracture risk that, combined with other risk factors for osteoporosis, helps guide therapy. However, DXA is operator-dependent, making it imperative to refer patients to sites where the operators are experienced in this technology.

KEY POINTS

The T score is the number of standard deviations above or below the mean value for young adult reference data (considered to represent peak bone mass); the Z score is the number of standard deviations below the mean for an age-matched population.

Bone density measurements can vary, depending on the machine, size and placement of the region of interest, overlying material in the region measured, and absence of normal structures (eg, laminectomy).

The National Osteoporosis Foundation recommends drug therapy for osteoporosis in patients with T scores of –1.5 or lower who have other risk factors, and in patients with T scores of –2 or lower without other risk factors.

The DXA report should not just provide precise measurements: it should add value to the decision of how to treat the patient, conveying information the referring physician can use when talking to the patient.

The author has indicated that he serves as a consultant for and is on the speakers' bureau of Merck Pharmaceuticals and Proctor and Gamble.

WHEN YOU SEND a patient for measurement of his or her bone mineral density, do you know what you are getting?

In experienced hands, dual-energy x-ray absorptiometry (DXA) provides accurate, reproducible measurements of bone mineral density and therefore allows the diagnosis of osteoporosis in people without symptoms. But behind the seemingly precise numbers on the report lurk many opportunities for error, and although DXA is high-tech and computerized, the results depend on the operator and specific scanner used.

Moreover, since the bottom-line numbers you need—the T score and the Z score—are indexed to mean values from a database derived from multicenter studies, these can change as new demographic data become available. Further, different interpreters of DXA scans supply different data on their reports, which can either help or confuse the primary care physician.

This article looks at the information DXA provides, what a physician should expect from a DXA report, and how to use this information, along with the patient's age and risk factor profile, to predict risk and guide therapy.

WHY MEASURE BONE MINERAL DENSITY?

Osteoporosis affects approximately 28 million people in the United States[1] and causes 1.5 million fractures each year,[2] posing a major public health problem in terms of morbidity, associated mortality, and economic costs.

In osteoporosis, once a fracture occurs, the risk of a subsequent fracture is high.[3] Therefore, the diagnosis of osteoporosis should be made *before* the first fracture occurs, so that the patient can undertake lifestyle changes

DXA of the hip:
Good scan **"Problem" scans**

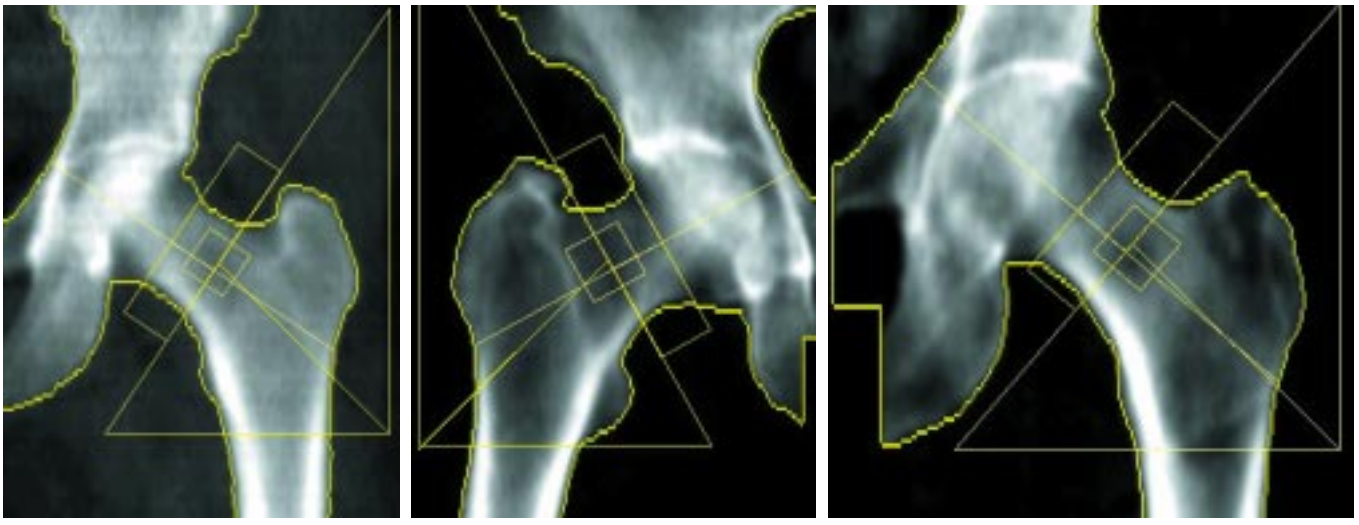

FIGURE 1. Left, normal positioning for DXA of the hip. The lesser trochanter is minimally visualized or not visualized, the diaphysis is parallel to the table edge. The hip is not abducted.
Center, external rotation results in visualization of the lesser trochanter, shortening the femoral neck. The hip is also abducted. Improper positioning results in poor precision on follow-up studies because it is difficult to reproduce the positioning. The exam data are also less reliable since the reference database was presumably collected with proper positioning.
Right, loss of joint space from degenerative joint disease results in cortical thickening of the medial femoral neck region, falsely increasing bone mineral density measurement. Eccentric placement of the femoral neck region of interest does not affect bone mineral density analysis. Reproducibility on subsequent scans is difficult, especially as degenerative changes progress.

IMAGES COURTESY OF GE LUNAR MEDICAL SYSTEMS

and undergo treatment to prevent fractures.

The only way to do this is to measure bone mineral density. Low measurements on DXA predict the risk of fractures of the spine[4] and hip,[5] analogous to the relationship between high serum cholesterol and the risk of myocardial infarction, or between high blood pressure and the risk of stroke.[6]

Driving the demand for DXA is the availability of proven, FDA-approved therapies for osteoporosis, ie, alendronate (Fosamax), risedronate (Actonel), calcitonin (Miacalcin), raloxifene (Evista),[7] estrogen replacement therapy,[8,9] and parathyroid hormone (Forteo).[10]

HOW DXA WORKS, HOW IT CAN GO WRONG

DXA uses x-rays at two energy levels to determine the bone mineral content. This is accomplished by subtracting the difference of absorption of x-rays between soft tissue and calcium bone.

The scanner software calculates the bone mineral density, dividing the bone mineral content by the area of the region of interest. The bone mineral density is compared to reference data specific to the scanner, and the results are expressed as the *T score* and the *Z score* (see below).

Although DXA could be used to measure bone density at many skeletal sites, two sites are typically measured: the first four vertebrae of the lumbar spine posteroanteriorly, and the proximal femur ("hip"), including the femoral neck and the trochanteric areas and total hip measurement (FIGURE 1).

Opportunities for error

Several aspects of the bone density measurements should be evaluated before a study is accepted as accurate.

Placement and sizing of the "regions of interest." Changes in placement can signifi-

DXA of the lumbar spine: Good scan

"Problem" scan

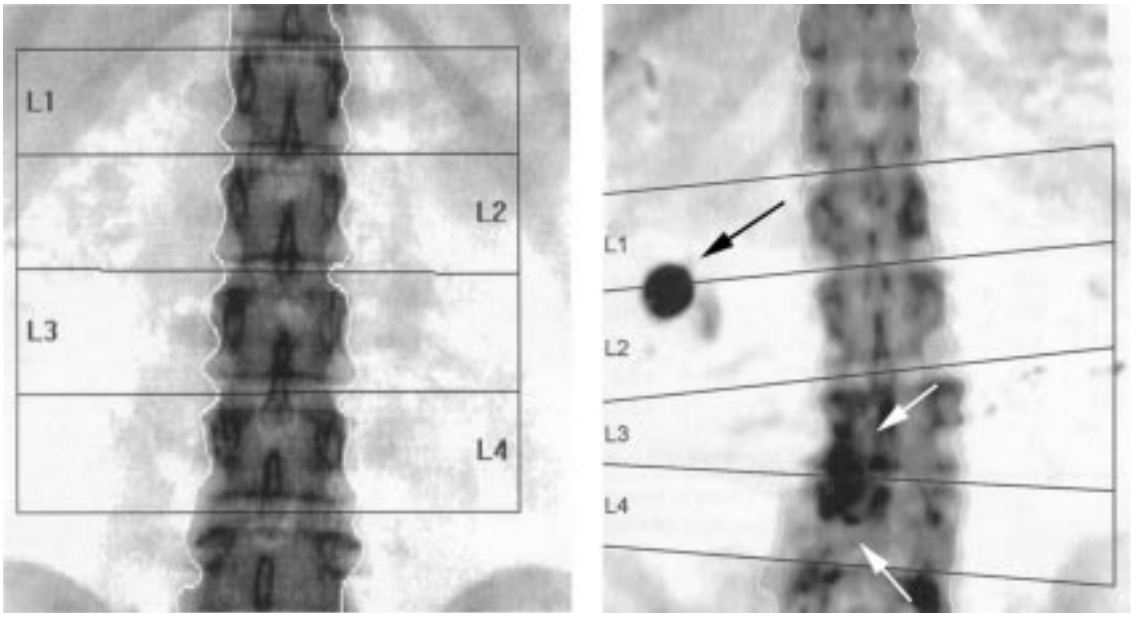

FIGURE 2. Left, normal positioning for dual-energy x-ray absorptiometry (DXA) of the lumbar spine. T12 ribs are visualized, and both iliac crests are identified. The numbering of vertebral levels should be consistent, with the first vertebral body after the last ribs most commonly L1.
Right, DXA scan of the lumbar spine in a patient with scoliosis with degenerative changes (white arrows), which falsely elevate the bone mineral density. Black arrow indicates a renal calculus in the soft tissue region of interest of L1 and L2, which may result in a falsely decreased bone mineral density at these levels.

The aim is to prevent a first fracture

cantly affect accuracy. For example, including more of the femoral shaft, where the bone is normally denser, could result in a falsely high measurement.

Also, since bone mineral density is calculated by dividing the bone mineral content by the area measured, if the area is too small the measured bone mineral density will be falsely high; if it is too big the density will be falsely low.

On follow-up studies the area must be consistent: within 2% of that of the original scan. If the region of interest is not placed correctly each time, no valid comparison can be made.

Overlying material in the region of interest and degenerative changes of the spine add density,[11] as do soft tissue calcifications and any overlying radiodense object. On the other hand, densities adjacent to the area measured can artificially decrease the bone mineral density if they are big enough (FIGURE 2).

Absence of normal structures (eg, after laminectomy) can also affect bone mineral density, since the reference data are based on normal anatomy (intact posterior elements). The person providing the report should be aware of these factors and should note the possible complicating factors in the report.

What is the T score?

The T score compares the patient's bone mineral density with the mean value in young adult white women and is expressed in standard deviations above or below this mean. Male databases are now available on a limited basis.

The World Health Organization (WHO) criteria[12] (TABLE 1) list four diagnostic categories on the basis of the T score:

- Normal: 0 to –0.99
- Osteopenia: –1 to –2.49

TABLE 1

WHO T score criteria for osteopenia and osteoporosis

T SCORE	DIAGNOSIS
0 to –0.99	Normal
–1 to –2.499	Osteopenia
≤ –2.5	Osteoporosis
≤ –2.5 with fracture	Severe or established osteoporosis

- Osteoporosis: ≤ –2.5 (eg, –3.0, –4.0; remember that these are negative numbers)
- Severe or established osteoporosis: ≤ –2.5, with a fragility fracture.

These criteria were based on studies in elderly white women, which presents a problem for nonwhite patients, for men, and for children, in whom this classification system has not been fully evaluated. Reference databases for nonwhite populations exist on some DXA scanners, though the largest database available is still for white women.

Refer patients only to a center with certified DXA technologists and interpreters

The International Society for Clinical Densitometry[13] has recently published position papers stating that a uniform white database should be used to determine T scores in nonwhite women. Male databases, when available, should be used for men. No statement was made concerning Z scores and ethnicity. Manufacturers who currently have ethnic databases will address this issue in the near future.

Another problem: the osteopenic range is quite broad.

The National Osteoporosis Foundation recommends drug therapy for osteoporosis in patients with T scores of –1.5 or lower who have other risk factors for osteoporosis (see below), and in patients with T scores of –2 or lower but no other risk factors. These recommendations emphasize that a patient may experience fragility fractures with a T score in the osteopenic *or* in the osteoporotic range.

Assessing fracture risk with the T score

We can use the T score to estimate the risk of fractures on the basis of two lines of evidence: biomechanical studies of bone strength and prospective epidemiologic studies in specific populations.

Studies in postmenopausal white women found that bone mineral density is associated with an increased risk of fracture that is equal to approximately 1.5 to 3.0 to the power of the decreased standard deviation of the T score.[14]

What is the Z score?

The Z score compares the patient's bone mineral density with the mean value in a population of similar age, sex, and height. This information is useful in determining the likelihood of secondary osteoporosis due to causes such as primary or secondary metabolic bone disease, infiltrating malignancies such as myeloma, and drug-induced decreased bone mass.

If the Z score is –1.5 to –2.0 standard deviations below the mean for age, the patient should undergo an evaluation for secondary osteoporosis.

T score vs Z score in African Americans

Sometimes the Z score is more useful in assessing fracture risk. For example, GE-Lunar scanners (Madison, Wis) use a reference database for calculating the T score that is not ethnically matched for African Americans. Therefore, when using this type of scanner in African American patients, the Z score better reflects the bone mineral density, since it is matched for ethnicity. (Scanner type is usually indicated on the scanning report.)

African Americans have approximately a 10% greater bone mineral density than whites and are believed to have a lower fracture rate. The new position papers from the International Society for Clinical Densitometry recommend that African American women be compared with white databases for these reasons. African American men should be compared with a male database.[13]

OTHER RISK FACTORS

Low bone mineral density is not the only risk factor for osteoporosis and fractures.

Unmodifiable risk factors for osteoporosis include female gender, advancing age, white or Asian ethnicity, family history of osteoporosis, previous fractures, and frail health.

Modifiable risk factors for osteoporosis include estrogen deficiency, calcium deficiency, vitamin D deficiency, low body weight, alcoholism, medications (especially steroids), and smoking.

Risk factors for fractures unrelated to bone mineral density include propensity to fall (especially in patients with low bone mineral density), poor physical function, impaired vision, impaired cognition, and environmental hazards.

All of these factors must be considered in a patient's overall assessment. For example, a patient with steroid-induced osteoporosis would benefit most from stopping the steroid treatment.

To elicit these additional risk factors more fully, we use a questionnaire. This information allows us to create a more complete clinical picture, to which we can add bone density information. The net product is more useful for the treating physician when selecting the most appropriate therapy.

COMPONENTS OF A DXA REPORT

The reports that radiologists send the primary care physician vary widely. Some simply provide the DXA scan data. At our institution, we provide a more complete report that includes:

- The patient's risk factors for low bone mass and fractures.
- The DXA scan data, including the T score and the Z score.
- A diagnosis, based on World Health Organization (WHO) criteria (TABLE 1)
- The patient's relative risk for fracture
- Follow-up recommendations
- The patient's current treatment for osteopenia and osteoporosis
- Treatment recommendations, based on the National Osteoporosis Foundation guidelines, eg, weight-bearing and muscle-strengthening exercise, calcium and vitamin D supplementation, moderate alcohol consumption, smoking cessation, and, in postmenopausal women, consideration of hormone replacement therapy unless contraindicated. Drug treatments are recommended based on the reporting physician's experience, relationship with and expectations of the referring physician, knowledge of the patient, and knowledge of the medications. Recommending treatment in the DXA report is an individual decision by the reporting physician.
- Exclusion of secondary causes of low bone mass. A diagnosis of osteoporosis or osteopenia can only be made clinically after all potential secondary causes are excluded. Metabolic disorders, malignancies, medications (especially steroids), alcohol abuse, smoking, and other factors too numerous to mention here can cause low bone mass.[1]

The bone density report should reflect, to the best knowledge of the reporting physician, the patient's relevant history, diagnosis, change on follow-up examinations, and fracture risk, and should include recommendations about current treatments and factors that might have affected the scan.

A complete DXA report should add value to the decision of how to treat the patient. It should convey information the referring physician can use when talking to the patient about the patient's bone health status and about possible treatment options.[15]

Preset report generators

Most DXA scanners can generate preset, standardized reports. Some of these are good and useful, some less so.

Helpful reports include data from the patient's previous DXA scans, making it easier to track trends. They also include the demographic data on which the patient's T score and Z score are based. A report may also include reminders to assess for adequate intake of calcium and vitamin D and to watch for lifestyle-related risk factors for fracture, such as alcohol intake and smoking. A thorough report should also include the reporting physician's overall impression of the patient's diagnosis and any recommendations for follow-up measurements.

On the other hand, preset generated reports must be used with caution. They may be poorly structured and confusing, providing more technical data than is relevant. They may not be tailored to the individual patient. Such reports tend to simply report numbers and remove the cognitive aspects of diagnosis.

Follow-up scans should be done at the same site as the first

CHOOSING A REFERRAL SITE

Some questions to consider when deciding where to refer a patient for DXA scanning:

- Does the physician who will interpret and report the scan have ample experience with DXA? Has he or she attended a symposium or course regarding bone mineral density studies and the reporting of DXA scans? Is he or she certified by the International Society for Clinical Densitometry?
- Are the technologists trained by the equipment manufacturer, experienced in the use of the equipment, and certified by the International Society for Clinical Densitometry?
- Does the site have a quality-assurance program and proof that the DXA measurements are reproducible? Do the physician and staff know the precision ratings of the scanner and the technicians?
- Are the costs for the examination reasonable? Unless you specify that you desire only the bone mineral density report, referring a patient to a clinical specialist may result in an additional consultation fee.
- What type of report will you receive?

The osteopenia range is quite broad

WHO SHOULD UNDERGO DXA?

Clinical indications for bone densitometry include:

- Estrogen deficiency (the Bone Mineral Measurement Act of 1998 provides Medicare reimbursement for bone densitometry if it is used to decide whether to give hormone replacement therapy in women with estrogen deficiency[16])
- Prolonged glucocorticoid therapy
- Osteopenia
- Fracture
- Primary hyperparathyroidism
- Monitoring antiresorptive therapy

The use of bone densitometry to screen populations at high risk is controversial, but the National Osteoporosis Foundation recommends bone densitometry in all white postmenopausal women under age 65 who have at least one risk factor in addition to menopause, and in all white women after age 65 regardless of other risk factors.

Men also can have osteoporosis.[17–20] The most frequent causes of low bone mineral density in men are idiopathic (35% to 50% of cases), alcoholism, steroid therapy, and low testosterone levels. Smoking decreases bone mass in both men and women.

FOLLOW-UP SCANS

Follow-up scans are recommended on the basis of the cause and severity of the patient's bone loss.

The Bone Mass Measurement Act provides for a follow-up DXA scan every 23 months in Medicare patients. Exceptions are allowed, especially in the case of steroid-induced osteoporosis. However, the physician must write a letter explaining the need for the exception.

Medicare will also pay for a quantitative ultrasound of the heel to assess the risk for fracture during the same 23-month period. However, an ultrasound should only be used initially to identify patients at risk for fracture. Follow-up should be by DXA.

Most experts believe that a patient with a T score of –1.5 standard deviations or lower should have a follow-up study in 2 years (if he or she is treated) to determine the efficacy of treatment.[21,22]

More frequent scans (ie, more often than 6 months to 1 year apart) are generally indicated in patients with drug-induced bone loss and metabolic bone disease. These conditions can generally be treated effectively in a shorter period and may demonstrate a more rapid increase in bone mineral density.

What is a significant change?

Most treatments do not result in a significant increase in bone mineral density during the first year. To be considered significant, the percent change in bone mineral density must exceed the precision (or reproducibility) of the study itself—ie, the precision of the scanner and the operator. A typical precision range is a 1% to 3% change in bone density for measurements of the spine and a 3% to 5% change in bone density for measurements of the hip. These precision ranges may be slightly higher in the elderly population.

This concept is called the *least significant*

change and reflects the error of the scanner and the technologist. To ensure a real increase or decrease in bone density, the least significant change must be exceeded on subsequent scans.

A change in T score does not reflect bone loss or gain: it is relevant only to the specific scan it is calculated for. Changes in bone density related to disease or treatment are reflected by the bone density itself, expressed in grams per centimeter squared, considering least significant change, not the T score.

If the bone density does not change over two to three follow-up scans with therapy, we can conclude that bone loss has stopped. A follow-up scan would then be appropriate to determine if an increase in bone mineral density will follow. The expected increase in bone mineral density for each treatment regimen is beyond the scope of this article.

Use the same scanner for follow-up

Bone mineral density should be measured using the same scanner each time. Attempting to determine change is fraught with problems when using different scanners, even from the same manufacturer. These problems include different reference databases, different precision coefficients of variation among scanners, different measurement techniques, and unfamiliarity with the quality assurance of scanners. Different manufacturers also use different methods of generating the x-rays and different energy levels. In addition, the third National Health and Nutrition Examination Survey introduced a correction factor for hip data when calculating the T score, which some DXA centers use and some do not.

When do you stop following up patients?

An important question is when to stop following patients. Generally, if the patient demonstrates a true increase in bone mineral density after two follow-up examinations, either no more follow-up is necessary or the interval can be increased unless the patient's status or medications change.

For example, if a patient on hormone replacement therapy has a reasonable bone mineral density but decides to stop treatment, she should have a scan within 2 years, during which time her bone mass may decrease to levels that would have existed if she had never started hormonal treatment.[23,24] Patients with multiple risk factors in addition to low bone mineral density may benefit from follow-up scans every 2 years.

BONE DENSITY IN CHILDREN

Measuring bone density in children poses several problems. There are some data for normal values in children, but the T score has little meaning, since T scores are calculated for a peak bone mass that occurs between the ages of 20 to 30 years. Z scores may be helpful in these patients. However, children have different rates of growth. The reporting physician should report the first bone mineral density as baseline, provide information regarding the Z score if it is available, and advise the referring physician that the scan should be considered a baseline to follow the patient to ensure that bone mineral density increases.

How long to follow pediatric patients is more difficult to determine. While we have evidence for effectiveness of various treatments for low bone mass in children, few drugs are approved for pediatric use. Each case should be evaluated independently for expected results.

PERIPHERAL DENSITOMETRY: NOT YET

Peripheral densitometry scans are becoming more common. Perhaps most well known is quantitative ultrasonography of the heel, but other studies include peripheral DXA, peripheral quantitative computed tomography, and radiogammetry. Each reflects a different way of assessing fracture risk.[25–27]

However, these studies have no role in the follow-up management of patients already being treated for osteoporosis. Instead, they should be used to determine fracture risk and who should undergo a central measurement to fully determine bone density status. Further, since ultrasonic measurement may have false-negative test results,[10] risk factors for low bone mass should always be considered in patients who have a normal ultrasound test, in order to determine the need for central measurement.

REFERENCES

1. **National Osteoporosis Foundation.** Physician's guide to prevention and treatment of osteoporosis. Washington, DC, 1998.
2. **Looker AC, Orwoll ES, Johnston CC, et al.** Prevalence of low femoral density in older US adults from NHANES III. J Bone Miner Res 1997; 12:1761–1768.
3. **Ross PD, Davis JW, Epstein RS, Wasnich RD.** Pre-existing fractures and bone mass predict vertebral fracture incidence in women. Ann Intern Med 1991; 114:919–923.
4. **Ross PD, Genant HK, Davis JW, et al.** Predicting vertebral incidence from prevalent fractures and bone density among non-black, osteoporotic women. Osteoporos Int 1993; 3:120–127.
5. **Cummings SR, Black DM, Nevitt, et al, and the Study of Osteoporotic Fractures Research Group.** Bone density and hip fractures in older women: a prospective study. Lancet 1992; 341:72–75.
6. **Melton LJ 3rd.** How many women have osteoporosis now? J Bone Miner Res 1995; 10:175–177.
7. **Faulkner KG.** Bone matters: are density increases necessary to reduce fracture risk? J Bone Miner Res 2000; 15:183–187.
8. **The Writing Group for PEPI.** Effects of hormone therapy on bone mineral density: results from the postmenopausal estrogen/progestin interventions (PEPI) trial. JAMA 1996; 276:389–396.
9. **Genant HK, Lucas J, Weiss S, et al, for the Estratab/Osteoporosis Study Group.** Low-dose esterified estrogen therapy. Effects on bone, plasma estradiol concentrations, endometrium, and lipid levels. Arch Intern Med 1997; 157:2609–2615.
10. **Neer RM, Arnaud CD, Zanchetta JR, et al.** Effect of parathyroid hormone (1-34) on fractures and bone mineral density in postmenopausal women with osteoporosis. N Engl J Med 2001; 344:1434–1441.
11. **Damilakis J, Perisinakis K, Gourtsoyiannis N.** Imaging ultrasonometry of the calcaneus: optimum T-score thresholds for identification of osteoporotic subjects. Calcif Tissue Int 2001; 68:219–224.
12. **Kanis JA, Melton LJ, Christiansen C, et al.** The diagnosis of osteoporosis. J Bone Miner Res 1994; 9:1137–1141.
13. **Binkley NC, Schmeer P, Wasnich RD, Lenchik L.** What are the criteria by which a densitometric diagnosis of osteoporosis can be made in males and non-caucasians? J Clin Densitometry 2002; 5:S19.
14. **Marshall D, Johnell O, Wedel H.** Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ 1996; 312:1254–1259.
15. **Lenchik L, Rochmis P, Sartoris DJ.** Optimized interpretation and reporting of dual x-ray absorptiometry (DXA) scans. AJR Am J Roentgenol 1998; 171:1509–1520.
16. **Federal Register.** Health Care Financing Administration. Medicare program; Medicare coverage of and payment for bone mass measurements. Wednesday, June 24, 1988; Volume 63, Number 121.
17. **Pande I, O'Neill TW, Pritchard C, et al.** Bone mineral density, hip axis length, and risk of hip fracture in men: results from the Cornwall Hip Fracture Study. Osteoporos Int 2000; 11:866–870.
18. **De Laet CEDH, Van Hout BA, Burger H, et al.** Hip fracture prediction in elderly men and women: validation in the Rotterdam study. J Bone Miner Res 1998; 13:1587–1593.
19. **Orwoll E, Ettinger B, Weiss S, et al.** Alendronate for the treatment of osteoporosis in men. N Engl J Med 2000; 343:604–611.
20. **Melton LJ, Atkinson EJ, O'Conner MK, et al.** Bone density and fracture risk in men. J Bone Miner Res 1998; 13:1915–1923.
21. **Cummings SR, Palermo L, Browner W, et al.** Monitoring osteoporosis therapy with bone densitometry. JAMA 2000; 283:1318–1321.
22. **Lenchik L, Watts N.** Regression to the mean: What does it mean? J Clin Densitometry 2001; 4:1–4.
23. **Quigley MET, Martin BL, Burnier AM, Brooks P.** Estrogen therapy arrests bone loss in elderly women. Am J Obstet Gynecol 1987; 156:1516–1523.
24. **Lindsay R, Hart DM, McClean A, et al.** Bone response to termination of oestrogen treatment. Lancet 1978; 1:1325–1327.
25. **Faulkner KG, vonStetten E, Miller P.** Discordance in patient classification using T-scores. J Clin Densitometry 1999; 2:343–350.
26. **Cummings SR, Black DM, Nevitt MC, et al, and the Osteoporosis Study of Osteoporotic Fractures Research Group.** Appendicular bone density and age predict hip fractures in women. JAMA 1990; 263:665–668.
27. **Siris ES, Miller PD, Barrett-Connor E, et al.** Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women. JAMA 2001; 286:2815–2822.

ADDRESS: *Bradford Richmond, MD, Department of Radiology, A21, The Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, OH 44195; e-mail richmob@ccf.org.*