Technical White Paper: Bone Densitometry

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The Conference of Radiation Control Program Directors (CRCPD) Task Force on Bone Densitometry (H-30) was assigned by the Healing Arts Council on Emerging Issues to address issues of bone densitometry. Issues for clarification included the practice of precision testing, in which multiple bone density determinations are performed on one patient; the use of quantitative computed tomographic (CT) densitometry; and radiation dose to patients and operators. This paper is a condensation of the white paper produced by the task force, which addresses the various methods of measuring bone density, the qualifications and responsibilities of personnel, the rationale for precision testing, and the doses patients and operators may receive. The white paper is available in its entirety on the CRCPD's Web site (http://crcpd.org).

Key Words: Bone densitometry, osteoporosis, bone mineral density, single-energy x-ray absorptiometry, dual-energy x-ray absorptiometry, quantitative computed tomography, quantitative ultrasound, ionizing radiation, radiation dose, radiation exposure, precision testing

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INTRODUCTION

Osteoporosis is a highly prevalent and disabling disease characterized by low bone mass, with resultant bone fragility and increased risk for fracture. Osteoporosis is diagnosed if bone density is abnormally low and meets recognized criteria for osteoporosis at 1 or more anatomic sites. The most widely used criteria for evaluating osteoporosis are those of the World Health Organization.

Fractures due to osteoporosis affect 50% of women and 12% of men over the age of 50 years. When these fractures involve the hips or vertebrae, there is significant deterioration in the quality of life, with pain and impaired mobility. The associated costs for hospitalization, surgery, rehabilitation, long-term care, loss of work, and medications exceed $17 billion annually in the United States. Treatments are available to slow or halt bone deterioration and in many cases increase bone density. Because osteoporosis is a "silent" disease, with no signs or symptoms until a fracture occurs, medical diagnostic testing is required to allow for preemptive treatment. The most reliable means of diagnosis is the determination of bone density.

MEASURING BONE DENSITY

There are several methods to measure bone mineral density (BMD) and strength by using ionizing radiation or ultrasound. The accuracy and precision vary between methods. Bone density can be measured centrally (spine and hip) or peripherally on the appendicular skeleton (extremities). Very low dose peripheral x-ray densitometry and heel ultrasound have value as screening tests for osteoporosis, but once a patient is diagnosed with low bone density and put into a treatment or follow-up program, BMD is best followed with either dual-energy x-ray absorptiometry (DXA) or quantitative computed tomography (QCT) of the lumbar spine and hip.

Plain Radiography

Plain radiography was initially used to quantify bone density. However, bone demineralization becomes visually apparent only after a bone density loss of 40% or more. This resulted in highly subjective grading systems based on the evaluation of the trabecular patterns of the bone and the thickness of the vertebral cortex.

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Radiogrammetry

Radiogrammetry is a plain radiographic BMD technique that measures the bones on a hand radiograph. Originally, a fine caliper was used to measure the cortical and medullary width of the metacarpal bones. Several measurements were acquired to calculate bone density. Current digital technology facilitates the computer analysis of bone dimensions. Radiogrammetry has limited precision, and changes in cortical thickness are usually quite small, resulting in poor reliability for the detection of early bone loss or for serial monitoring.

Photodensitometry

Photodensitometry is similar to radiogrammetry but includes an aluminum step wedge that is placed on the film at the time the radiograph is taken. The step wedge provides known densities and enables compensation for variations in exposure settings, beam energy, and film development. The density of the skeletal image is quantified using a scanning photodensitometer.

Radiographic Absorptiometry

Radiographic absorptiometry is derived from radiographic photodensitometry. Two radiographs of the hand are taken with slightly different exposure techniques using a standard radiographic unit, with an aluminum step wedge included on each film. Both films are then sent to a central laboratory, where they are digitized and analyzed by a computer.

Single-Photon Absorptiometry

Single-photon absorptiometry (SPA) is based on the principle that the attenuation of an x-ray beam is proportional to the mass of an object in the path of the beam: the greater the density of the object, the fewer photons pass through it. The difference in radiographic density of body tissues creates the contrast necessary to visualize anatomic structures on a radiograph. In SPA, a radionuclide (usually iodine-125 or americium-241) is the photon source, and a scintillation detector quantifies photon transmission through the body part to determine bone density. Single-photon absorptiometry is valid only when the body part is embedded in a uniform thickness of soft tissue. Consequently, with SPA, the body part to be studied must be submerged in a water bath, thereby limiting the examination to the extremities (usually the forearm or heel).

Dual-Photon Absorptiometry

Dual-photon absorptiometry (DPA) involves the same basic principle as SPA. However, by using 2 different isotopes or one with 2 distinct peaks (eg, gadolinium-153 with energies of 44 and 100 keV), it is possible to mathematically separate attenuation due to soft tissues from that due to bone mineral. The results are then calibrated using standards created from ashed bone. Dual-photon absorptiometry does not require compensation for nonuniform tissue thickness, eliminates the need for a water bath, and enables BMD determination of the spine and hip.

Dual-photon absorptiometry has limitations. The highly trabecular vertebral body cannot be separated from the cortical posterior elements, and the cortical shell of the vertebral body cannot be separated from the trabecular interior. Overlying calcifications in the soft tissues or abdominal aorta may attenuate the beam and spuriously increase BMD values. Also, both SPA and DPA require adjustment for the decay and periodic replacement of the expensive radionuclide source [1]. As the source decays, values obtained by DPA increase by as much as 0.6% monthly. After replacement of the source, bone density readings may fall by as much as 6.2% [2]. Formulas have been developed to compensate for the effect of source decay, but concern regarding precision and accuracy persists. Scan times are long, approximately 30 minutes for central body sites such as the hip and spine, and spatial resolution is limited. Single-photon absorptiometry and DPA have been largely replaced by DXA, which has lower operating costs and greater precision and ease of use.

Single-Energy X-Ray Absorptiometry

Single-energy x-ray absorptiometry is the x-ray counterpart of SPA. Like SPA, single-energy x-ray absorptiometry requires a water bath or tissue-equivalent gel surrounding the region being measured to correct for nonuniform thickness and is therefore used on extremities. Single-energy x-ray absorptiometry is being replaced by portable DXA units to measure forearm and heel BMD.

Dual-Energy X-Ray Absorptiometry

Dual-energy x-ray absorptiometry is similar to DPA but uses x-rays rather than isotopes. Dual-energy x-ray absorptiometry uses the same principle as DPA in that 2 energy peaks are used to separate bone from soft tissue. This is accomplished with K-edge filters at a fixed kilovolt potential or alternating pulses [3]. Dual-energy x-ray absorptiometry units are used to scan extremities such as the forearm and the central skeleton such as the lumbar spine and hip, or they can be operated for whole-body scanning to evaluate the entire skeleton or to measure body composition (eg, fat, bone, and muscle mass). The determination of lean muscle mass and body fat can be useful in competitive athletes to evaluate the effectiveness of training regimens and dietary interventions such as protein supplements. Clinical applications include the

evaluation of patients with wasting diseases or abnormal body composition due to therapies or diseases.

The image of the scanned body part is used for quality assurance in monitoring the accuracy of patient positioning and for noting artifacts and anatomic abnormalities contributing to bone density (eg, metallic joint prostheses, abnormal bone growths, healed fractures). The conventional screening protocol calls for BMD of the first through fourth lumbar vertebrae and one or both hips. If a nonremovable artifact is demonstrated, such as a hip fixation pin or an old fracture, densitometry of the opposite hip may be substituted. If there is a discrepancy between hip and lumbar spine BMD, densitometry of the forearm may be performed.

Dual-energy x-ray absorptiometry offers several advantages over DPA. There is no source decay and therefore no need to replace the source or correct for drift in patient values due to radioactive source decay. Tighter beam collimation is achieved, resulting in less dose overlap between scan lines and thus a lower patient radiation dose, greater image resolution, shorter scan times, and improved precision.

Individual bone densitometry units will yield different BMD measurements because of variations in dual-energy scanning methods, differences in calibration, detectors, edge detection software, regions of interest, and different patient population databases used for comparison [4]. Conversion formulas have been published to normalize BMD measurements from different manufacturers' units [5-8]. Although these equations are useful, errors in these equations are significant. It is recommended that when possible, patients undergoing serial BMD over the course of years have their examinations performed at the same facilities and on the same densitometry units to increase the likelihood that interval changes accurately reflect alterations in bone density.

Pencil-Beam and Fan-Beam Dual-Energy X-Ray Absorptiometry Scanners

Used in the evaluation of the central skeleton, pencil-beam scanners use a collimated x-ray beam (2 to 3 mm) that moves in a rectilinear fashion in tandem with the detector. Fan-beam scanners use a broader fan-shaped beam with multiple detectors. This enables the entire scan line to be quantified instantly and can shorten the scan time to as short as 10 seconds for a posterior-anterior lumbar spine scan, allowing greater patient throughput. Fan-beam scanners generate slightly higher radiation doses than pencil-beam units.

Morphometric X-Ray Absorptiometry

Later generation DXA scanners incorporate special software to detect the presence of vertebral compression fractures by viewing the spine in the lateral projection. This technique has been variously called morphometric imaging, vertebral fracture assessment, instant vertebral assessment, or lateral vertebral assessment and is based on computer analysis of vertebral body dimensions. With computer analysis providing more accurate information, the vertebral heights can be measured to quantitatively diagnose compression fractures.

Peripheral X-Ray Densitometry

Small portable DXA units are used for peripheral densitometry of the finger, heel, and forearm. Their main application is in mobile screening. Although peripheral scanners produce good screening information, they are not as accurate as central DXA at detecting small changes in BMD. Consequently, patients with low BMD detected on peripheral systems should be referred for central DXA or QCT.

Quantitative Computed Tomography

Quantitative computed tomography can be performed with most existing CT units. Adapting an older model CT scanner for the QCT measurement of BMD requires software and mineral reference standards (phantoms), with sophisticated calibration and positioning techniques. The software and reference phantoms are used to convert CT attenuation coefficients to bone equivalent values. Careful calibration and quality assurance programs are mandatory, especially when the instrument is used for both routine imaging and QCT [9]. Dedicated QCT scanners are recommended for BMD.

Unique to QCT is the 3-D or volumetric measurement of bone and the spatial separation of trabecular from cortical bone. A scout view assists in localization and is followed by thin slices through the center of 2 or more vertebral bodies or regions of the hip. A limiting factor is the fat in the vertebral bone marrow. Marrow fat increases with age, resulting in increasing error in the accuracy of spine QCT. The error can be partially corrected by using dual-energy QCT. Although a dual-energy scanner can correct for changes in marrow fat and increase the accuracy of the measurement, it does so at the cost of increased complexity, reduced precision (5% vs 1% to 3% for single-energy scanners), and higher radiation exposures. Because QCT can isolate and measure trabecular bone, which is more metabolically active than cortical bone, measured rates of change in disease tend to be greater with QCT than with DXA. This increased sensitivity of QCT should be weighed against its limitations and increased radiation dose, on the order of 20 to 40 times greater than DXA, depending on technique and number of slices.

Peripheral Quantitative Computed Tomography

The recent availability of a portable, peripheral quantitative CT device has increased interest in its use for the measurement of bone density in the forearm. Measurements of the radius are faster, have good precision and accuracy, expose patients to less radiation, and expose a field that is remote to radiation-sensitive organs.

Quantitative Ultrasound

Ultrasound densitometers, commonly referred to as quantitative ultra-sonometers, provide a measurement of bone properties predictive of fracture risk without the application of ionizing radiation. Quantitative ultrasound measures the distance between 2 points and the time required for a sound wave to travel between these 2 points. Faster speeds correlate with greater bone density and strength or fracture resistance [3]. Depending on the manufacturer, ultrasound densitometry may not produce an image; it provides a quantitative assessment of bone density related properties and elasticity. Both bone density and bone quality determine resistance to fracture. The speed of sound through bone is inversely related to the risk for fracture. The speed of sound and another ultrasound parameter, broadband ultrasound attenuation, can be applied to determine stiffness, another indicator of bone density.

The measurement differences between ultrasound bone densitometers are even greater than those between DXA devices. This is due to the different frequency ranges, transducers, and different regions of interest measured. The most common site for quantitative ultrasound is the calcaneus, but there are quantitative ultrasound devices for evaluation of the radius, finger, or tibia. Quantitative ultrasound has proven to be useful as a screening tool, but because of low measurement precision, it is not recommended for serial monitoring of skeletal changes.

QUALIFICATIONS OF PERSONNEL

Although peripheral, central, and whole-body bone densitometry deliver low radiation doses to patients compared with general-purpose radiographic systems, a level of competency is necessary to minimize unnecessary exposure and to produce accurate results. Operators of bone densitometry equipment using ionizing radiation must have knowledge of anatomy, densitometric techniques, radiation safety, basic statistics, quality control (QC) procedures, data acquisition, scan analysis, and disease processes such as osteoporosis or extra calcifications that could affect the outcome. A DXA operator must also understand the concept of precision and how to measure it. Currently, x-ray machine operators are regulated to some degree in 39 states [10]. Licensed physicians, and radiologic and nuclear medicine technologists who are registered with the American Registry of Radiologic Technologists (http://www.arrt.org) or an equivalent registry or who have state certification or licensure, have the basic qualifications to perform BMD studies. All operators should have training specific to the equipment they operate.

Registered technologists can pursue additional certification in bone densitometry through the American Registry of Radiologic Technologists. The International Society for Clinical Densitometry (http://www.iscd.org) is a nonprofit organization with more than 6,000 members that provides training courses in bone densitometry for physicians and technologists, including a certification examination and registry. Certification by nationally recognized organizations results in greater competency of operators and physician interpreters, more accurate results, and reduced radiation exposure.

RATIONALE FOR PRECISION TESTING IN DUAL-ENERGY X-RAY ABSORPTIOMETRY

To determine whether a change in a patient's bone density is statistically significant, it is necessary to determine the precision or precision error of the measurement process. Precision is the ability to reproduce a quantitative measurement when a test is repeated under identical circumstances. All quantitative clinical tests have some inherent variation and are not perfectly reproducible. Lack of reproducibility of BMD determinations is due to variation in patient positioning by an individual operator or between different operators, a lack of consistency in data analysis, and the inherent precision error of the technique. Common operator errors include poor patient positioning, inconsistent selection of vertebral levels, poor placement of disk markers for the lumbar spine, improper hip rotation, and the inconsistent determination of regions of interest of the hip. Precision testing is an important way of determining reproducibility of bone densitometry examinations in the clinical setting.

Precision testing is a necessary component of a bone densitometry service [11]. Although it involves additional radiation exposure to a few patients, the amount of radiation is low, and patient selection for participation in precision testing minimizes radiation risks. The benefit is enhanced diagnostic accuracy and the ability to monitor serial changes in a patient's BMD. A diagnosis of osteoporosis often commits a patient to years of pharmacologic treatment. Errors in the performance or interpretation of BMD can result in prolonged unnecessary pharmacologic treatment or, conversely, in a lack of or delay in treatment and the possibility of potentially preventable debilitating osteoporosis insufficiency fractures.

Knowledge of the precision of BMD determinations is particularly important in interpreting serial BMD, because the rate of change in bone density is very slow, in the range of 0.5% to 2% per year. The least significant change must be determined to meaningfully analyze serial measurements.

Precision can be expressed as the standard deviation, or as the coefficient of variation or percentage coefficient of variation. These parameters are used to assist clinical assessment by determining the smallest change in bone density that is biologically significant and the minimum time interval for follow-up bone density measurements. It is recommended that a precision assessment be performed for each operator or technician at a facility. The facility's precision error and least significant change are the averages of all operators performing bone densitometry.

CONCEPTS IN PRECISION TESTING

To obtain statistically valid results, multiple determinations of bone density are performed for a specific anatomic site, for example, the hip or lumbar spine. The mean bone density is then determined. The number of bone density measurements that contribute independently to the mean is $n - 1$, where n is the number of bone density measurements. It is recommended that precision testing be performed to allow for 30 degrees of freedom, to ensure statistical significance. Because one of the measurements on a specific patient does not contribute independently to the calculation of the mean BMD for that patient, one would perform 31 BMD scans for 1 patient, 4 BMD scans each for 10 patients, 3 BMD scans each for 15 patients, or 2 BMD scans each for 30 patients. Repeat BMD scans on a patient should be performed within 2 to 4 weeks and are most easily performed on the same day. The patient should be taken completely off the examination table after the initial BMD and repositioned on the table for each subsequent determination.

Although DXA conveys relatively low radiation doses to patients, the bone marrow is exposed, and there is scattered radiation to the gonads. The following suggested guidelines were developed by the New Jersey Commission on Radiation Protection regarding the selection of patients for precision testing:

- Pregnant women, people under the age of 21 years, and radiation workers should be excluded from precision testing.
- Care should be taken to ensure that women of childbearing age are not pregnant.
- Precision testing should be performed on 30 patients, with 2 BMD scans performed per patient, to give an appropriate level of statistical validity while limiting individual patient radiation exposure.
- Informed consent should be obtained for precision testing, including an explanation of why the patient is being asked to undergo additional BMD determination, estimation of radiation dose, and rationale of the need for precision testing.
- No expense should accrue to the patient, because this is a facility quality assurance measure.

Further details of precision testing are included in the Conference of Radiation Control Program Directors white paper at http://crcpd.org. An in-depth discussion of precision and precision testing for bone densitometry is presented by Bonnick and Lewis [1] and Bonnick, Johnston, Kleerekoper, et al. [11].

ACCURACY AND QUALITY CONTROL

Strict quality control (QC), including calibration and standardization procedures, is required to maintain both precision and accuracy for reliable measurements. Other QC measures primarily relate to the mechanical operation or accuracy of the unit. Many DXA models have internal systems and databases with which phantom scans are compared. Some use filtration systems composed of bone, tissue, and air equivalents and an internal calibration reference to monitor calibration at each data point. Central DXA units enter phantom or QC data electronically into a Shewhart chart with a previously established baseline (the mean of 10 initial control scans) and lines $\pm 1.5\%$ from the mean [12]. Should the data points fall outside of the acceptable range (eg, $> \pm 1.5\%$ of the mean) for 2 consecutive QC tests, equipment service is required; patient data cannot be accepted into the computer until the unit is brought back into the acceptable range. Another QC measure uses a cumulative sum chart that similarly tracks the operation of the unit.

DATABASES

Bone mineral density data from hip scans are compared with data from the National Health and Nutrition Examination Survey III. This database was created as a cooperative effort with manufacturers to establish a more uniform comparison for densitometry equipment and patient populations. Anatomic site-specific bone density databases have been developed by each manufacturer and may be classified by the patient's age, race, gender, height, and weight. This reference information is selected for comparison purposes before scanning a patient [13]. The validity of the application of reference values to patients of different demographics, such as race, ethnic origin, and age, is a question of ongoing clinical concern.

Table 1. Noninvasive bone measurement techniques in vivo

Technique	Measurement Site	Precision (%)	Accuracy (%)	Effective Dose (μSv)
RA	Phalanx, Metacarpal	1–2	5–10	~5
SXA/DXA	Radius, Calcaneus	1–2	~5	<1.0
DXA	Spine-PA	1–1.5	4–10	1.0[a]
	Spine-lateral	2–3	5–15	3.0
	Femur (hip)	1.5	~6	1.0[a]
	Total body	<1	3	1–3
QCT	Spine with lateral scan "True density"[b]	2–4	5–14	60
QUS	Calcaneus SOS	3–1.2	Unknown	0
2000	Calcaneus BUA	1.5–4	Unknown	0

Source: Wilson [28].
Note: BUA = broadband ultrasound attenuation; DXA = dual-energy x-ray absorptiometry; PA = posterior-anterior; QCT = quantitative computed tomography; QUS = quantitative ultrasound; RA = radiographic absorptiometry; SOS = speed of sound; SXA = single-energy x-ray absorptiometry.
[a]Compared with the effective dose to an individual in the United States from background radiation of approximately 3,000 μSv per year or 8 μSv per day or 0.33 μSv per hour. DXA effective dose for spine and hip (2μSv) is about the same amount of radiation received from background in 6 hours.
[b]True density is in grams per cubic centimeter for the volumetric measurement with QCT. (The measurement for DXA is in grams per square centimeter.)

RADIATION DOSIMETRY

Patient Exposure

In BMD studies that use radiation, dose is contingent on the method and mode of delivery. The significance of the exposure depends on the body part irradiated. Despite the different methodologies and variables involved in measuring effective dose, BMD testing on adults and children is a low-dose examination in comparison with plain radiography. Very few radiosensitive organs are irradiated during peripheral scanning (skin, red bone marrow, and bone surfaces), resulting in a very low effective dose, in the microsievert range [14-17]. Because of differences in the way dual-energy x-rays are generated by the different manufacturers, DXA doses vary [18, 19]. Table 1 compares dose ranges of the different densitometry modalities [20]. For perspective, the approximate dose from an adult posterior-anterior chest x-ray is 50 μSv, a lateral view of the lumbar spine is 700 μSv, and a dental bitewing is 100 μSv [21]. Fan-beam DXA units deliver a higher dose than pencil-beam devices (Table 2) [3, 22, 23].

Children may require densitometry to evaluate or monitor BMD in the course of chronic illness (eg, inflammatory bowel disease with malabsorption and growth retardation, endocrine disorders) or pharmacologic treatment of disease (eg, chemotherapy for cancer). Bone mineral density determination may result in treatment modification. Lower radiation doses to children can be achieved with altered exposure factors, more tightly collimated field sizes, and faster scan times [24]. Without adjustments, pediatric patients will receive effective doses about triple those of an adult, because of the large field size and less x-ray attenuation by overlying tissue [25]. Different software is required for children, including scanning adjustments and appropriate database comparison.

For QCT, current estimates of effective dose for a tomographic scout and 3 slices are between 200 and 370 μSv using 80 kVp (rather than 125 kVp), depending on the milliamperage. Factors affecting dose are the CT unit, skin dose measurements, weighted CT dose index, patient size, and the volume scanned. Quantitative computed tomography gives doses that are typically higher than plain radiographic examinations and, depending on

Table 2. Effective dose ranges for pencil-beam and fan-beam DXA in microsieverts

Scan Mode	Pencil-Beam DXA	Fan-Beam DXA
PA Spine L1 to L4	0.21–0.5	0.7–2.0
Proximal femur (including ovaries)	0.15–1.4	0.7–5.4
Total body (including ovaries)	4.6	0.6–3.4
Total body (excluding ovaries)	3.6	0.5–2.6
Forearm	0.07	0.01–0.05

Source: Blake et al [3].
Note: DXA = dual-energy x-ray absorptiometry.

settings, may be lower than regular CT imaging [26, 27, 16].

Any attempt at gonadal shielding has the potential to compromise scan results. As with all radiographic procedures, women of childbearing age should be interviewed as to the possibility of pregnancy before the performance of the examination.

Operator Exposure

The exposure to the operator depends on the scan type and mode, the workload, and the relative position of the workstation to the scanning table [28, 19]. For DXA, the potential operator dose from scatter is significantly higher with fan-beam DXA than with pencil-beam DXA. Operator dose can be reduced by the appropriate use of distance and shielding. The operator workstation is best positioned toward the patient's feet, where the dose is lower than at the head or open side of the scanner, keeping a distance of not less than 1 m away from the edge of the scanning table. If the workstation must be placed at the head or open side of the scanner, a minimum distance of 2 m away from the edge of the table should be maintained. Scanning the hip furthest from the operator will reduce some scatter.

The need for additional transparent lead-acrylic shielding for the operator should be based on the scatter exposure per scan at the operator console and the number of scans performed annually. The operator dose evaluation must be made for an annual exposure, with consideration given to scan volumes that fluctuate during the year [21]. Because scatter doses are very low, dosimeters should be worn for at least 3 months to ensure accurate dose determination.

SUMMARY

Osteoporosis is a highly prevalent and disabling disease characterized by low bone mass, with resultant bone fragility and increased risk for fracture. Early diagnosis by bone densitometry (BMD) allows preemptive treatment, which can slow or halt bone deterioration and can often increase bone density. A variety of bone densitometry procedures is available for osteoporosis screening, the most prevalent being DXA, QCT, and ultrasound densitometry. For patients who require serial densitometry and follow-up of treatment, DXA and QCT are more quantitative and are preferred.

Any application of ionizing radiation, including BMD determinations, should be at the written order of a licensed physician or other licensed health care practitioner. The examination should be performed by a qualified individual (ie, a licensed radiologic or nuclear medicine technologist or physician or other appropriately credentialed individual, as required by state regulations) and should be interpreted by a licensed physician trained in bone densitometry. The patient should be counseled about the effects of ionizing radiation to help make an informed decision of whether to undergo the procedure.

Operators of densitometry units require training to perform the examination accurately and reproducibly. The American Registry of Radiologic Technologists and the International Society for Clinical Densitometry provide additional certification in the performance of bone densitometry. The society also offers educational programs on the performance, QC, and interpretation of bone densitometry.

Facilities providing DXA and QCT should perform QC and precision testing to ensure the reproducibility and accuracy of results. Precision testing enables a facility to assess the smallest change in bone density that is biologically significant. Although it involves additional radiation exposure to a few patients, the amount of radiation is low, and patient selection for participation in precision testing minimizes radiation risks. Errors in the performance or interpretation of bone densitometry can result in prolonged, unnecessary pharmacologic treatment or, conversely, in a lack of or delay in treatment and in potentially preventable, debilitating osteoporosis insufficiency fractures.

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