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## Standards and Guidelines for Performing Central Dual X-Ray Densitometry from the Canadian Panel of International Society for Clinical Densitometry

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### Abstract

The International Society for Clinical Densitometry (ISCD) is a multidisciplinary nonprofit global organization formed to ensure excellence in densitometry imaging, interpretation, and application. The Canadian panel of the ISCD represents ISCD in Canada and oversees Canadian bone densitometry certification programs. The standards of care from the Canadian panel of the ISCD have been developed in order to establish the minimum level of acceptable performance for the practice of bone densitometry in Canada. A variety of techniques are available for skeletal assessment of bone mineral density, which vary in accuracy, precision, and clinical utility as well as availability. This article focuses on central dual X-ray absorptiometry in adults and does not address densitometry in the pediatric population. Other technologies will be addressed in a subsequent article.

**Key Words:** Bone densitometry; Canadian standards; diagnosis; osteoporosis.

### Role of Bone Mineral Density in Fracture Risk Assessment

Osteoporosis, a common condition, is associated with an increased risk of fracture, morbidity, and mortality (1). Formerly, the diagnosis of osteoporosis was made in its advanced stages, usually following a fracture. Both vertebral and appendicular fractures are associated with an increased risk of subsequent fractures (2). Accurate and precise skeletal

assessment is now possible enabling early detection of osteoporosis prior to fracture.

Currently, the most widely used method for bone mass measurement and fracture prediction in North America is X-ray absorptiometry (DXA) utilizing measurement of the differential attenuation of high- and low-energy X-ray beams to quantify calcium content. Central DXA generally obtains that measurement from the spine or the hip although other sites can be measured if the appropriate software is available.

The relationship between bone density and fracture risk in untreated patients has been evaluated prospectively in a number of large well-designed studies (3–9). A metaanalysis of 11 prospective cohort studies confirmed that a decrease in bone mineral density (BMD) is associated with an

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increased risk of fracture (4). The predictive power of BMD for hip fracture is similar to the predictive power of blood pressure for stroke and better than the predictive power of serum cholesterol for cardiovascular disease (4). The relationship between BMD and fracture risk is a continuous one; there is no bone density threshold above which low-trauma fractures do not occur. In postmenopausal women, for each age-adjusted SD (Z-score) decline in femoral neck bone density, the risk of hip fracture increased by a factor of 2.6 (3,4). Measurements of BMD at any site (radius, calcaneus, hip, or spine) have been shown to have a similar ability for fracture prediction at all sites for each SD decrease in bone density with the exception of measurements at the hip, which have a better predictive ability for fractures of the hip (4). Diagnostic thresholds utilizing DXA have been best validated at the hip (10).

The Working Group of the World Health Organization (WHO) provided a definition of osteoporosis, based on the relationship between BMD and fracture risk, which was developed on a population basis for postmenopausal Caucasian women (11). There are insufficient data regarding the relationship between BMD and fracture risk in non-Caucasian women or in men for a specific definition of osteoporosis.

Differences in biomechanics of falls, bone size, and bone geometry, as well as differing patterns of age-related bone loss for men in comparison with women may affect the BMD-fracture relationship (12). Currently, the data regarding the BMD-fracture risk relationship in men is contradictory, and large prospective studies are needed to clarify this relationship. It is at present unclear whether it is appropriate to use the WHO Working Group criteria in men, and whether the T-score should be calculated based on a young male reference population or employ the same absolute threshold as in women. Similarly, the relationship between BMD and fracture risk is not well defined for non-Caucasian ethnic groups, and use of the WHO Working Group criteria may not be fully appropriate. Differences in skeletal size will contribute to differences in apparent bone density; as well, differences in geometry and hip axis length may contribute to racial differences in hip fracture rates (13). Consensus statements from the International Society for Clinical Densitometry

(ISCD) bone densitometry forum (Denver, 2001) will further address the appropriate reference data for males and non-Caucasians.

The precise relationship between BMD and fracture risk in younger patients is currently not well defined because fracture data have been obtained predominantly in the elderly over the age of 65.

In evaluating fracture risk, bone density should be considered in conjunction with other clinical risk factors for fracture (14). Important independent risk factors include low body weight, history of postmenopausal fracture, family history of fracture, and poor neuromuscular function (5). Intervention should be based on combined assessment of BMD and clinical risk factors for fracture.

## Qualifications for Practice of Bone Densitometry—Physician

In Canada, standards and licensing are a provincial responsibility. Optimal clinical application of bone densitometry technology requires supervision by a physician with appropriate specialized knowledge and training. A prerequisite should be Royal College certification in a specialty traditionally involved in the diagnosis and care of patients with osteoporosis, such as diagnostic imaging, endocrinology/metabolism, geriatric medicine, internal medicine, nuclear medicine, obstetrics/gynecology, orthopedics, or rheumatology. Currently, only nuclear medicine and endocrinology/metabolism list bone densitometry as a training requirement. A period of supervision under a physician qualified in bone densitometry is desirable to consolidate knowledge and apply learned principles. For current practitioners, the ISCD course is valuable for continuing medical education. ISCD certification provides a detailed overview of osteoporosis and complements the training of both clinicians and diagnostic imagers, but it does not replace Royal College training and certification. It is recommended that physicians involved in bone densitometry obtain formal certification by the ISCD or undergo similar equivalent training. The required knowledge for performing bone densitometry includes the following.

1. Understanding bone metabolism and the clinically relevant pathophysiologic entities.
2. Understanding the physics of X-ray absorption and radiation protection.

Table 1  
Common Indications and Contraindications for Bone Densitometry (14)

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Indications

- Menopausal women considering hormone replacement therapy
- Hypogonadism in adult men and women prior to menopause: to decide about hormonal therapy
- Vertebral fractures or radiologic evidence of osteopenia
- Long-term glucocorticoid therapy: to adjust therapy
- Primary hyperparathyroidism: to identify candidates for surgery and to monitor BMD
- Strong family history of osteoporosis, or the presence of other risk factors: to decide about hormone replacement therapy or other preventive treatment options
- Monitoring of efficacy of therapy for osteoporosis

Contraindications

- Pregnancy
  - Recent gastrointestinal contrast studies and nuclear medicine test; suggest wait at least 72 h before central DXA scan (longer for long-lived isotopes such as gallium)
  - Body weight exceeding limit for DXA scanners
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3. Understanding the process of DXA data and image acquisition (proper patient positioning, identifying regions of interest (ROIs), artifacts, and anatomic abnormalities).
4. Understanding the reporting parameters and their clinical significance.
5. Understanding the criteria for accurate and precise comparison of serial measurements.
6. Understanding the limitations of comparing measurements by different techniques and devices.
7. Understanding the statistical methods used for the determination of precision.
8. Understanding the equipment quality control programs.

### Qualifications for Practice of Bone Densitometry—Technologist

In Canada the charge technologist overseeing the DXA program should be certified in radiography or nuclear medicine technology by the Canadian Association of Medical Radiation Technologists. These certification requirements are applicable for Canada and may not be applicable for other countries. The charge technologist should attain and maintain certification by formal certifying bodies such as the ISCD or equivalent. In addition, the charge technologist should receive manufacturer training on the specific equipment used, either directly from the manufacturer or from

a technologist who is fully familiar with that equipment.

### Indications and Contraindications for Bone Densitometry

The routine use of BMD assessments is currently not justified, and national and international guidelines suggest that screening be targeted at evaluating individuals who have clinical risk factors for osteoporosis or those with conditions or disorders associated with bone loss (see Table 1). The Study of Osteoporotic Fractures provided a detailed analysis of risk factors for hip fractures (5). This study identified risk factors for hip fracture independent of BMD and when taken with calcaneal BMD enabled prediction of the annual risk of hip fracture (5).

### DXA Examination Procedure

Preparation of patients for DXA includes screening for pregnancy, recent examinations utilizing radiographic contrast medium or radionuclides, surgical implants or fractures in the field to be examined, and discontinuation of radiopaque supplements such as calcium. Accurate height and weight should be recorded. The proper positioning of patients is also critical to DXA examinations. Although the instrument can be very precise when used to measure a perfectly positioned phantom (16), patient

positioning can be much more challenging. Comparison of DXA measurements to standard databases (17) is based on the premise that the patient has been positioned similarly to patients in the reference population (20,21). More important is the impact of variability in positioning on precision when measurements are used for serial assessment. Variation in positioning can frequently be detected when, on serial testing, images from the previous scans are compared with the current scan. Any variability in positioning should be noted when reporting, and the validity of comparing scans with different positioning should be questioned. Pillows and positioning aids should not appear in the scan field. DXA examinations are performed with the patient lying supine on the table. Variability in positioning can represent a major source of imprecision. Consequently, particular attention must be paid to consistent and reproducible positioning.

### **Hip**

Of the three central DXA examinations, precision is most difficult to achieve at the hip because of variability in positioning. The total hip assessment comprises several subregions (femoral neck, Ward's region, trochanter, and shaft) and evaluates a larger sample, reducing error and giving greater precision. It is therefore recommended that routinely the total hip BMD should be reported, in particular for serial assessments since the precision is greater than the femoral neck. The femoral neck site is also used for the diagnosis of osteoporosis and in assessing fracture risk (18).

Hip positioning attempts to place the femoral neck in a plane parallel to the DXA table, giving optimal and standardized bone density estimation for all hip sites. The patient is positioned at the centre of the table, and the hip is abducted to the edge of the table. Positioning is manufacturer dependent. The hip is then internally rotated and positioning stabilized with a block and straps. Under- or overrotation will result in a false increase in measured femoral neck density. Hip osteoarthritis commonly interferes with hip internal rotation and, in conjunction with a true increase in bone mass from "buttressing" of the femoral neck, can increase measured hip density. Severe osteoarthritis can elevate the measured BMD at the femoral neck, Ward's region, and total hip but

not usually at the trochanter. Appropriate positioning can best be gaged by evaluating the lesser trochanter on the image; it should be only barely visible as a slight elevation. Ward's triangle is anatomically defined as the region of the femoral neck where trabecular bundles intersect to form a triangle. The DXA instrument will automatically determine Ward's area to be the region where the femoral neck is narrowest and the measured BMD is the lowest. This region has the most variability of all hip sites and should not be used for diagnosis or serial comparisons. Leg dominance is not important in determining the appropriate side to measure (15). It is most useful for a DXA facility to determine a standard side to routinely measure in order to avoid errors on remeasurement. Measurements of both hips do not generally contribute to risk assessment. If performed, both measurements should be reported and the lower side used for diagnosis and repeated on follow-up. Some devices can measure both hips simultaneously. Severe scoliosis can elevate measured hip BMD, usually on the side of the concavity.

### **Lumbar Spine**

Positioning for lumbar spine examination is easier to reproduce. Since a larger skeletal region is being evaluated the precision is greater than that of the hip site. Probably the greatest errors are in determining segmentation and variability in manual placement of the cursors to assign the vertebral levels (19). The patient is positioned comfortably, supine on the DXA table. Positioning is manufacturer dependent. Hips are flexed to approx 80° and maintained in this position with the use of a large foam block. This aids in straightening the lumbar lordosis. In identifying lumbar segments, labeling should always start from lower levels (caudad) and proceed up (cephalad). This results in less confusion when lumbar vertebrae are atypical or when the lowest rib emerges from a level other than T12. The lumbar vertebrae are identified by their characteristic shapes as well as the level of the iliac crests.

Positioning for lateral spine examinations is similar to the posteroanterior spine. Patients should not be examined in the lateral decubitus position because this cannot be standardized and is not reproducible. L4 may be inaccurate owing to overlapping pelvis (15% of patients), and L2 may have

overlapping ribs (93% of patients). This may lead to overestimates of BMD at these sites, making L3 most reliable.

The lateral spine assessments enable exclusion of the artifact caused by vascular calcification as well as degenerative changes around the facet joints with exclusion of the posterior elements and are of value in these circumstances.

### **Total Body**

The patient is positioned supine on the table with the legs extended. There is minimal positional variability in measurements at this site. Not all DXA instruments can perform total-body measurements. This measurement may be used as an alternative when spine or hip measurements are not available or reliable but has not been fully evaluated for clinical application.

## **Serial Assessments—Accuracy and Precision**

Physicians often question how much confidence they can place “in a number.” The performance of quantitative tests, such as bone density measurements, is in part characterized by their accuracy and precision. *Accuracy* refers to how closely a measured result approximates the “true” value and is of critical importance when comparing an individual patient with a reference population. Thus, the diagnosis of osteoporosis and estimation of fracture risk requires that measurement error be small relative to the range of values in the population, something that is generally the case with all current bone density technologies. In general, small accuracy errors are of little consequence as long as they remain constant. *Precision* (also referred to as reproducibility) is the ability of a system to obtain the same results in repeated measurements of the same individual. A technique must have good precision if serial measurements are to be used in identifying bone loss and assessing an individual’s response to treatment. Greater precision makes it possible to detect smaller changes in a subject and to detect these in a shorter follow-up time (22).

Given a series of repeated measurements, precision can be stated as either the standard deviation (SD) or the percent coefficient of variation ( $[\%CV]$ ,

defined as  $100 \text{ SD}/\text{mean}$ ). The former is an absolute measurement expressed in units of areal bone mass, whereas the latter is a dimensionless percent value that is independent of the scaling of the measurement. The smallest change that must be present before one can conclude (with 95% confidence) that the change is not related to measurement error is  $2.77 \times \%CV$ .

It is necessary to know a laboratory’s testing precision before deciding whether any change in bone density is significant. Reproducibility can vary greatly among different laboratories. Therefore, each facility should determine its own precision in a sufficient number of subjects evaluated under conditions that reflect “real-life” conditions (26) and make this information available. Machine vendors frequently cite short-term in vivo precision as 1.0% for modern DXA instruments. Most published studies suggest that this significantly underestimates long-term imprecision when the instrument is used in nonresearch, clinical patient populations. In routine clinical settings, the following reproducibilities ( $\%CV$ ) have been reported: lumbar spine (1.8–2.3%), femoral neck (2.3–3.6%), total hip (1.7–2.5%) (27–29). DXA reproducibility is influenced by instrument-, operator-, and subject-dependent factors. The latter two tend to be much more important than the instrument itself.

Current methodologies typically demonstrate precision errors that are on the same order as short-term changes in bone density. In an individual patient it can be challenging to know whether a small change in the bone mass measurement reflects methodological imprecision or a true change in the patient, underscoring the need for careful quality control of the instrument, scanning technique, and analysis in order to optimize clinical performance.

Follow-up bone mass measurements in patients not receiving active treatment can help in the identification of the subset with rapid bone loss (“fast losers”). Repeat testing may also be useful in confirming a positive treatment response. Evidence suggests that the antifracture effect is greater than expected for the relatively small increase in BMD. Although controversial, this may indicate that some of the benefit from current antiresorptive therapies is mediated through mechanisms other than an increase in bone mass (35,36). Larger increases in bone mass are associated

Table 2  
Timing of Follow-up DXA Testing in an Individual Patient<sup>a</sup>

		Rate of bone loss (g/cm <sup>2</sup> per year)				
		0.005	0.010	0.020	0.030	0.05
Machine precision error (SD g/cm <sup>2</sup> )	0.010	6	3	1.5	1	0.5
	0.015	8	4	2	1.5	1
	0.020	11	6	3	2	1
	0.025	14	7	3.5	2.5	1.5
	0.030	17	8	4	3	1.5

<sup>a</sup> Select the column specifying the minimum rate of bone loss (g/cm<sup>2</sup> per year) that you would like to be able to detect. Then select the row containing the precision error (g/cm<sup>2</sup>) for the DXA machine and facility where testing is being performed. These intersect in a cell that indicates the number of years between two bone density measurements that are required to detect significant bone loss (with 95% confidence). A shorter interval would suffice where < 95% confidence is acceptable.

with larger antifracture effect, but the converse may not be true; absence of measurable change in BMD does not necessarily imply therapeutic failure (i.e., lack of antifracture benefit). The optimal time interval for follow-up measurements is a function of machine precision and the expected rate of bone loss. For example, if a subject loses bone mass at a rate of 1%/yr, then it would take 3 yr for this to exceed (with 95% confidence) the precision limits of a machine with optimal performance at the spine (CV: 1%) and 6 yr for a typical machine (CV: 2%).

Patient-related factors including the presence of conditions or medications predisposing to progressive bone loss such as primary hyperparathyroidism or corticosteroid usage also need to be considered in determining the timing of repeat testing and estimation of expected rate of loss. The latter is critical since follow-up bone mass measurements should ideally identify patients who are failing treatment before substantial bone loss develops or fractures occur. Average rates of bone loss are greater in untreated early postmenopausal women (approx 1 to 2%/yr) than in older women (<1%/yr) (37–39). The site of most rapid bone loss also changes with age. Loss of trabecular bone from the spine exceeds that of the hip in early postmenopausal women (37). Similarly, increase in skeletal mass from antiresorptive treatment is usually most evident in the spine owing to the relatively faster turnover of trabecular bone (40). For untreated older subjects, the decline in the hip generally exceeds that of the spine owing

to the development of age-related degenerative artifacts in the spine (30,38). It should be emphasized that measurement imprecision makes it much more difficult to accurately assess loss rates in individuals. Although precision error is most commonly stated as %CV, several reports indicate that error is independent of bone mass and is therefore underestimated in the lower (osteoporotic) range (23–25). This suggests that it is preferable to express precision error and change as an absolute measure rather than a relative (percent) change.

To aid the clinician ordering a repeat bone mass measurement, the relevant parameters have been summarized Table 2, which relates absolute precision (as SD g/cm<sup>2</sup>), maximum expected rate of bone loss, and the minimum time interval between tests required to detect a change of this magnitude (with 95% statistical confidence). Thus, to exclude bone loss from the lumbar spine (laboratory CV: 2%) that is two times an average value of 1%, a follow-up interval of 3 yr is required. Although measurement of bone markers may be of assistance, in general, one can only approximate the rate of bone loss in a given individual. Therefore, not infrequently, on repeat measurement the bone loss will not be significant. This, however, may be clinically helpful because it at least excludes those individuals with rapid rates of bone loss and may affect one's decisions regarding treatment.

Finally, it should not be assumed that patient values will be identical on all instruments. Large cali-

bration differences exist among different manufacturers of DXA instruments. Although factory calibrations for DXA instruments from the same manufacturer generally give comparable phantom measures, some difference will always exist between otherwise identical machines. Such differences are usually small (1 to 2%) but, on occasion, can be clinically significant (exceeding instrument reproducibility). The tendency for instruments to drift can aggravate this problem but should be detected in a properly conducted quality control program. Current techniques for machine cross-calibration may be unreliable for patient follow-up unless the changes are marked. Therefore, it is strongly recommended that, whenever possible, follow-up measurements for a patient be done on the same instrument with the same scanning procedure.

In general, repeat scanning can be considered in 1–3 yr in the presence of concern about progressive bone loss or with new intervention. In exceptional situations of high bone turnover, more frequent assessments may be appropriate. Less frequent scans are appropriate in individuals who are stable or improving.

## Radiation Safety and Protection

Any consideration of radiation safety and protection must take into account both the patient and the technologist (41,42). However, underpinning all radiation safety practice is the requirement that exposures be kept “As Low As Reasonably Achievable” with social and economic factors having been taken into account. The social and economic factors as they relate to medical practice imply that some benefit will accrue to the individuals concerned from the performance of the procedure. For the patient, this means that there will be some impact on clinical management to justify the procedure. Given the state of our knowledge about the potential risks from low-dose radiation and our equally imperfect understanding about health risks and benefits from X-ray densitometry, it is not possible to precisely quantitate the risk-benefit ratio of bone densitometry, and thus a decision to use the test requires the exercise of judgment. Physicians should request a bone density measurement only when the result will influence their advice to the patient.

## The Setting

The clinic or hospital in which bone densitometry is undertaken should have the following.

1. The services of a radiation safety officer responsible for measuring and recording staff exposures.
2. An educational program for staff concerning radiation safety practices.
3. A policy addressing the unlikely event of an exposure exceeding regulatory limits.
4. Signage indicating that the room or facility is one where radiation sources are present.
5. A policy for addressing how to deal with possible pregnancy.
6. A program of inspection to exclude tube leakage or other performance defects in the densitometry system that, along with the quality assurance protocol, will ensure that unjustified radiation exposure to patients or staff do not occur.
7. The use of radiation monitoring tapes on the technicians and in the densitometry room.

## The Patient

When a decision to undertake X-ray densitometry has been made these requirements should be met.

1. A policy shall be in place to ensure that the patient understands the nature of the procedure and the potential risks associated with it.
2. The procedure itself shall be tailored to obtain just as much information as is necessary for care.
3. All research protocols requiring radiation exposure in which the potential benefit is societal rather than to the individual patient must be approved by an appropriate institutional review board at arms length from the investigator and with provision for informed, written consent.

In explaining radiation risk to the patient it is not uncommon to relate the dose from the procedure (effective dose equivalent [EDE] of between 0.5 and 6.0  $\mu$ Sv) to that from background (EDE of 2.5 mSv/yr, although this number varies with altitude and geologic substrate), or from potential everyday occurrences such as flying from coast to coast (0.5 mSv) or having a chest radiograph (0.1 mSv). Except for purely radiographic procedures, it should be recognized that such analogies are qualitative, not quantitative, since radiation risks are related not only

to the magnitude of dose but also to the temporal dose distribution. Of equal doses, those delivered at high dose rates are potentially more harmful than those delivered at low dose rates. Nevertheless, radiation doses from DXA are miniscule compared with other radiologic procedures and even with day-to-day doses.

### **The Staff**

Staff must be certified and registered technologists educated in radiation safety. Individual staff members should bear in mind the cardinal rules of radiation exposure:

1. Limit the duration of exposure to scattered radiation as much as possible consistent with good care.
2. Maximize the distance between themselves and the source of scatter (the patient), again to the extent possible consistent with good care.
3. Use shielding (either mechanical or in the form of a lead apron) to reduce exposure if room configuration dictates this.

In addition, staff shall have access to the following:

1. An educational program for staff concerning radiation safety practices.
2. A policy addressing the unlikely event of an exposure exceeding regulatory limits.
3. A policy for dealing with the declaration of pregnancy by workers.
4. Duly posted records of individual exposures by month or quarter.
5. A fully developed and documented procedure manual.
6. Appropriate education concerning patient positioning and site analysis to minimize repeat procedures ("retakes") dictated by technical failures such as incorrect hip rotation.

### **Quality Control Procedures for DXA**

The goal in densitometry is to produce accurate and precise bone density measurements at a minimum of radiation exposure. The equipment must meet provincial and national guidelines for safety, licensure, and radiation exposure. The average exposure for a standard densitometric examination should be measured at the time of machine acceptance. In

addition, the scattered radiation at a distance of 1 m from the closest edge of the densitometer should be measured while performing a phantom scan. A documented quality control program with procedure manuals and logs should be maintained for each densitometer. This includes the following checks:

1. Current operating manual (from equipment manufacturer).
2. Appropriate positioning devices.
3. Appropriate calibration standard(s).
4. Calibration history for specific densitometer.
5. Precision data and estimates of site-specific precision errors.
6. Maintenance and upgrade records.
7. Software version/upgrade records.
8. Cross-calibration records (in the event of equipment change).
9. Data and database archiving procedures.
10. Local, provincial, and federal licensure of equipment (as required).
11. Medical physicist inspection reports (as required).

To obtain an accurate BMD measurement, it is important that the DXA system be properly calibrated. At the time of manufacture, each DXA scanner is calibrated at the factory to a set of known bone density standards. Over time the system can be expected to drift owing to aging of the X-ray tube, environmental changes, and other factors. To compensate for any potential drifts, the DXA manufacturers have provided ways to monitor and, if necessary, correct for any drifts in scanner performance.

Despite daily calibration checks, drifts in scanner performance can still occur that are not compensated for by the calibration system. As an independent check of scanner stability, each DXA manufacturer provides a quality control phantom to track machine performance over time. This phantom differs from the calibration standard previously described; the results of scanning the phantom are not used by the DXA scanner to adjust the machine calibration if a drift has occurred. Instead, the periodic measurements of this quality control phantom provide an independent monitor of scanner stability.

The different manufacturers have each developed quality control phantoms. It is recommended that these phantoms be measured every day that the machine will be used and at a minimum of 3 d/wk.

The spine phantom should be measured on the DXA system using the same settings as used for patient measurements. The phantom should be placed in the same consistent location near the middle of the scanner table, on top of the table pad. It is acceptable to measure the phantom without a table pad, but it is best to measure the phantom in the same configuration as used for patient measurements. The scan should be started at the same point in the phantom. Consistency when measuring the spine phantom is important, since any changes in procedure may appear as an erroneous change in the phantom BMD.

The phantom should be measured and analyzed using the spine analysis protocol normally used. ROI dimensions and intervertebral markers should be the same for all phantom measurements. BMD results should be recorded and plotted for review, and a baseline BMD should be established for the system by measuring the phantom 10 times on the same day. Subsequent BMD results should not vary by more than 1.5% of the established baseline. If any single measurement is more than 1.5% from the baseline, the phantom measurement should be repeated. If the second measurement is more than 1.5% from baseline, the equipment service representative should be contacted for a more detailed system evaluation. The baseline should be reestablished after any adjustments to the system.

## Reporting of Bone Densitometry Studies

For densitometry facilities that provide a DXA service without also performing a clinical assessment, the reporting physician imparts the maximum benefit in the DXA report to the referring physician by combining data from a patient questionnaire and assessment of the DXA computer printout. A brief report that interrelating these two elements allows the referring physician to make decisions about diagnosis, risk, and interval BMD change.

The patient questionnaire captures relevant information that enhances the BMD T-score/Z-score information provided on the computer printout. Critical information includes age, prior fractures, height loss, prior and current estrogen use and tolerance, other medications, smoking history, calcium/vitamin D

intake, family history, prior and concurrent diseases and/or surgeries, osteoporosis-specific medication exposure, history of breast cancer, frailty assessment, and history of falls. It is also important to ask on the questionnaire the reason for the assessment. It is important to know if a previous study was completed and, if so, on which machine this was performed. If a different machine was utilized, then the standardized BMD (sBMD) correction between machines of different manufacturers may be used. Although DXA instruments are ultimately calibrated against excised bone samples, methodological differences in how this is performed have led to large discrepancies in patient measurements when performed on instruments from different vendors. Efforts to reconcile these differences have led to a consensus on converting DXA measurements to sBMD ( $\text{mg}/\text{cm}^2$ ) to distinguish it from nonstandardized BMD ( $\text{g}/\text{cm}^2$ ). Use of sBMD should ensure that average patient values are similar on different instruments, but other methodological differences exist, and it should not be assumed that patient sBMD values will be identical on all instruments. Because of these limitations with current approaches to machine cross-calibration, small changes in bone density may not be appreciated. Therefore, it is strongly recommended that follow-up measurements use the same instrument, technician, and scanning procedure. Automated commenting is not recommended. Reference to age equivalence of BMD is neither relevant nor clinically meaningful. Although some manufacturers persist in supplying this information with automated report generation, it should not appear in the final report.

BMD reporting should include the following information:

1. Comments on any technical problems that might compromise the validity of the examination (i.e., artifact, degenerative changes, anatomic abnormalities, compression fractures or other skeletal abnormalities)
2. T-score and WHO Working Group diagnosis in the postmenopausal Caucasian female.
3. When relevant, Z-score. For example, a Z-score of  $-2$  or less should be reported with recommendations for more aggressive evaluation for secondary causes of osteoporosis.
4. A qualitative estimate of fracture risk.

5. Serial BMD changes interpreted utilizing the in vivo precision error of the testing densitometer, preferably expressed in site-specific absolute units ( $\text{g}/\text{cm}^2$ ) and a statement of the statistical significance of the change.

## Conclusion

DXA is a proven technology in the diagnosis and management of bone mineral loss and is now in wide application across Canada. Optimum benefit from the technology requires the maintenance of high standards in technical application, medical supervision, and interpretation.

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