Bone Mineral Measurements

Abtin Doroudinia, MD, and Patrick M Colletti, MD†*

Abstract: The accurate measurement of bone mineral density using noninvasive methods can be of value in the detection and evaluation of primary and secondary causes of decreased bone mass. This includes primary osteoporosis and secondary disorders, such as hyperparathyroidism, osteomalacia, multiple myeloma, diffuse metastases, and glucocorticoid therapy or intrinsic excess.By far, the largest patient population is that encompassed by primary osteoporosis with increased susceptibility to fractures in the absence of other recognizable causes of bone loss.Primary osteoporosis is a common clinical disorder and a major public health problem because of the significant number of related bone fractures occurring annually. Because the risk of vertebral and femoral neck fractures rises dramatically as bone mineral density falls, fracture risk in individual patients may be estimated. Furthermore, in estrogen-deficient women, bone mineral density values may be used to make rational decisions about hormone replacement therapy, or other bone mineral therapies, and as follow-up in assessing the success of such treatment.In this article, we discuss different methods of bone densitometry and will focus on dual-energy x-ray absorptiometry (DXA) with discussing the factors which should be considered for interpretation of DXA scan.

Key Words: bone densitometry, dual-energy x-ray absorptiometry, osteoporosis, osteopenia

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LEARNING OBJECTIVES

After completing this journal-based CME activity, participants will be able to:

1. Explain different available methods for bone densitometry.
2. Interpret the DXA studies considering factors that may falsely affect the measured bone density
3. Understand specific consideration for interpreting DXA in children, premenopausal women, and underlying medical conditions

INDICATIONS FOR BONE MINERAL DENSITY (BMD) TESTING

- Women aged 65 and older
- Postmenopausal women under age 65 with risk factors for fracture.
- Women during the menopausal transition with clinical risk factors for fracture, such as low body weight, previous fracture, or high-risk medication use.
- Men aged 70 and older.
- Men under age 70 with clinical risk factors for fracture.
- Adults with a fragility fracture.
- Adults with a disease or condition associated with low bone mass or bone loss.
- Adults taking medications associated with low bone mass or bone loss.
- Anyone being considered for pharmacologic therapy.
- Anyone being treated, to monitor treatment effect.
- Anyone not receiving therapy in who evidence of bone loss would lead to treatment.
- Women discontinuing estrogen should be considered for bone density testing according to the indications listed above.[1]

METHODS

Multiple methods have been developed for quantitative measurement of bone mineral mass. These procedures have progressed from the use of radioactive sources such as gadolinium-153 to more rapid x-ray techniques, including CT. Advances also include moving from single- to dual-energy techniques.[2]

Dual-Energy Techniques

Dual-energy techniques are especially important for areas such as the spine and hips, where soft tissues can have considerable impact.

By comparing a lower energy beam or photon that is attenuated by bone and soft tissue with a higher energy source that is affected only by bone (or metal), it is possible to calculate the differential absorption, allowing more accurate assessment of bone density without impact from the surrounding soft tissues.[2]

The DPA (dual photon absorptiometry) and DXA (dual-energy x-ray absorptiometry) beams consist of photons or x-rays of 2 discrete energies, which obviate the need for assumptions about soft-tissue shape and attenuation. It also allows for evaluation of thicker body parts and bones involving complex geometry, such as the femoral neck and the spine. When the spine is examined, the hips are flexed to flatten the normal lumbar lordosis. When scans of the femoral neck are performed, the femur should be in slight internal rotation. By using an x-ray tube rather than a radionuclide source, purchase of replacement radionuclide sources and re-calibration are unnecessary. In addition, scan time is only 2 to 5 minutes for DXA, compared with 20 to 40 minutes for DPA. Precision and image quality are also much better for DXA than for DPA.[2]

For these reasons, DXA has replaced the radionuclide method for determination of bone mineral. DXA uses a highly collimated fan beam of x-rays that passes through the soft tissue and bony components of the body to be detected on the opposite side by a solid state detector. Because absorption by the body part examined (primarily by bone mineral) attenuates the photon x-ray beam, the intensity of the beam exiting the body part is indirectly proportional to the density of the bony structure being evaluated. The intensity of the exit beam is then compared with exit beam intensity from standard phantoms of known density, so that a bone mineral density can be determined. The results are expressed in grams per square centimeter.[1,2]

Based on recommendation of the International Society for Clinical Densitometry (ISCD) in October 2007, the nomenclature has changed from DEXA to DXA (http://www.iscd.org/official-positions/official-positions/).[3]

CT Techniques

Quantitative CT (QCT) can measure cortical and trabecular bone separately. Dual-energy QCT has the additional advantage over single-energy QCT of allowing correction for fat in the marrow space. Both

*A.D. is a Fellow at the Department of Radiology, Division of Nuclear Medicine, University of Southern California, Los Angeles, CA; †P.M.C. is a Professor of Radiology, University of Southern California, Los Angeles, CA.

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From the Department of Radiology, Division of Nuclear Medicine, University of Southern California, Los Angeles, CA.

Correspondence to: Abtin Doroudinia, Department of Radiology, Division of Nuclear Medicine, University of Southern California, Los Angeles, CA. E-mail: abtin.doroudinia@med.usc.edu.

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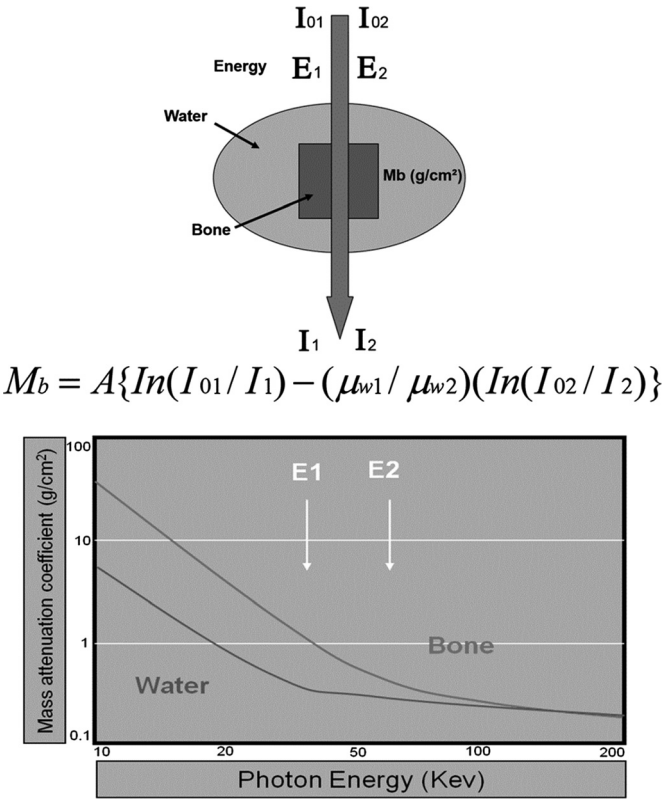


FIGURE 1. Physics principals for dual energy x-ray densitometry.

techniques are quite flexible with respect to body part examined. QCT is an important research tool but is too expensive for population screening.[1]

QCT bone density can be performed very rapidly. If QCT bone densitometry could be efficiently and reliably performed, it would likely be much less expensive to perform BMD by QCT, as 4 or more could be performed in an hour, and practices would not need to occupy an examination room with a DXA scanner. Unfortunately, QCT BMD is not as easy or reliable as DXA.

Ultrasound Techniques

Several ultrasound devices are now approved by the FDA for measurement of bone mass. Sound is transmitted faster in dense bone than in osteopenic bone, and the devices are calibrated against other methods to correlate with bone mass. Application of the technique is limited to peripheral bones such as the calcaneus. The low cost, small size, and ease of use of ultrasound devices make them attractive for population screening, although they may not be as accurate.[2]

TABLE 1. Comparison of Radiation Exposure from Different Sources

Man's Exposure to Ionizing Radiation	
Source of exposure	**Exposure**
Natural radiation (terrestrial and airborne)	1.2 mSv per year
Natural radiation (cosmic at sea level)	0.3 mSv per year
7 hr airplane flight	0.05 mSv per trip
Chest x-ray	0.04 mSv per procedure
Cosmic radiation exposure to a domestic airline pilot	2 mSv per year
DXA LUNAR DXP-L	0.002 mSv per Scan

IMPORTANT FACTORS INFLUENCING BONE DENSITY

Fracture risk markedly increases when bone mineral density is less than 1 g/cm^2. Bone mineral measurements establish baseline diagnostic measurements in the evaluation of patients with suspected osteopenia and osteoporosis and can follow the course of therapy. Risk factors for osteoporosis include female gender, Caucasian or Asian race, smoking, chronic alcohol intake, and a positive family history. Early menopause, long-term treatment with corticosteroids and some nutritional disorders, including malabsorption, are also risk factors. Obesity is protective.[4]

Falsely elevated bone mineral content when evaluating the spine may result from marked aortic calcification, scoliosis, hypertrophic degenerative disease, compression fractures, calcium or barium within the gastrointestinal tract, renal lithiasis, bone grafts, focal sclerotic bone lesions, or recent intake of aluminum-containing antacids.[2,4]

Falsely low bone mineral results may be obtained in patients who have had a laminectomy or lytic bone lesions. Most of the time, these problems can be identified from the plain radiograph if available before the test.[2,4]

The lateral spine and Ward's triangle region of the hip should not be used for diagnosis because these sites overestimate osteoporosis and results can be false-positive.[3]

In very obese patients, those with primary hyperparathyroidism, or those in whom the hip or the spine, or both, cannot be measured or interpreted, bone density may be measured in the forearm, using a 33% radius (sometimes called one-third radius) on the nondominant forearm.[5] Other forearms ROI are not recommended.

In children, due to the difference in fracture site epidemiology and growing factors, total body less head (TBLH) and spine are the recommended DXA sites for bone health assessment.[6] The diagnosis of osteoporosis in children requires the presence of both a clinically significant fracture history and low bone mineral content or bone mineral density.

Physics Principals for Dual-Energy X-ray Densitometry

As is illustrated in the below diagrams (Fig. 1), different x-ray beams of E_1 and E_2 pass through the tissue, and based on the attenuation constant (which is considered equivalent to the water), the I_1 and I_2 are calculated and their difference would be a reflection of the bone density.[7,8]

Radiation Risks of DXA Scan

Studies of the radiation dose to patients from DXA scan have confirmed that patient exposure is small compared to many other sources of exposure including most radiological investigations involving ionizing radiation (Tables 1 and 2). Here are comparative dates regarding radiation exposure from DXA scan on other common sources of radiation.[7,8] Typical DXA scan can give equal to 6 hours of background radiation equivalent time (BRET).

TABLE 2. Comparison of Radiation Exposure from Different Imaging Modalities

Imaging Modality Type	Model	Patient Exposure, μSv
Body CT scan		5,000–15,000
Head CT scan		2,000–4,000
Lumbar spine x-ray		600–1,700
Lateral spine x-ray		820
Dental bitewing		60
Chest x-ray		50
DXA total body	LUNAR Prodigy	0.37
DXA total body	DPX-L	0.20

INTERPRETATION

The use of bone mineral measurement has been controversial. Some of this controversy is because of the wide variation of measurements in the normal population. Also, the criteria for selecting the optimal skeletal site for evaluation have not been well defined because bone mineral loss does not progress at the same rate at different body sites. Measurement of the hip bone mineral density is done to evaluate the risk for hip fracture, whereas vertebral bodies are regarded as the optimal site for monitoring response to treatment. Care must be taken to look at the images to ensure that extensive degenerative changes or surgical defects are not causing erroneous values.[2]

The most important information to check is the correct identification of the patient, his date of birth, and also the gender and ethnicity which are mandatory to calculate T-scores. Gender is used by all manufacturers to calculate T-scores (ie, T-scores for women are calculated using a female normative database, whereas T-scores for men are calculated using a male normative database). Although all manufacturers use race in calculating T-scores, there is inconsistency in the way race is handled when calculating T-scores.[9] Norland and Hologic are using race in calculating T-scores (ie, T-scores for Caucasians are calculated using a Caucasian normative database, T-scores for Blacks are calculated using a normative database for Blacks); however, GE Lunar and recent Hologic machines use the database for young-normal Caucasians to calculate T-scores, regardless of the race of the subject. The ISCD (International Society for Clinical Densitometry) recommends the latter approach for use in North America (Baim, Wilson et al. 2005)[10] because using race-adjusted T-scores results in a similar prevalence of "osteoporosis" in every racial group, despite the fact that age-specific fracture rates can be very different.[9]

DXA Scan Analysis

The software marks regions of interest in the spine and hip, but the technologist can and should make adjustments if needed. The spine region of interest consists of the L1 through L4 vertebrae.

The inter-vertebral lines can be moved or angled, if necessary. There must be sufficient soft tissue on both sides of the spine; otherwise, BMD will be underestimated. The hip regions of interest include the femoral neck, trochanter, and total hip (Fig. 2). Ward's region and the inter-trochanteric region are not relevant and can be deleted from the results reports. The default hip analysis includes a mid-line that must be placed correctly for the other sites to be identified correctly[9] (Fig. 2).

The preferred position for the rectangular femoral neck box differs for the different manufacturers. For GE Lunar, the femoral neck box is located by the analysis program at the narrowest and lowest density section of the neck; typically, this will be about halfway between the femoral head and the trochanter. For Hologic, the box is on the distal part of the femoral neck (Fig. 2). This induces a large difference among these two measurements because of a gradient of BMD all along the femoral neck (the proximal being the highest, the distal being the lowest). Thus, careful checking of the femoral neck box is mandatory.[9]

The image should be evaluated for artifacts (eg, surgical clips, navel rings, barium sulfate, metal from zipper, coin, clip, or other metallic object) or local structural change (eg, osteophytes, syndesmophytes, compression fractures, aortic calcification). Almost all artifacts and local structural change will spuriously elevate BMD. This is especially true for spinal degenerative change, which can elevate spine BMD by 2, 3, or more T-scores. In the spine, absent bone (laminectomy or spina bifida) or vertebral rotation (idiopathic scoliosis) will spuriously lower BMD. All vertebrae should be used, but vertebrae that are affected by local structural change should be deleted from the analysis and also when there is more than a 1.0 T-score difference between the vertebra in question and adjacent vertebrae. Most agree that decisions can be based on two vertebrae; the use of a single vertebra is not recommended. If all vertebrae are affected, the spine should be reported as "invalid," with no BMD or T-score results given.[9] The lateral spine should not be used for diagnosis but may have a role in monitoring.

In the hip region, the T-score of femoral neck or total proximal femur should be reported, whichever is lowest, and BMD can be measured in either hip.[1]

Finally, physicians must keep in mind to actively look for secondary osteoporosis in front of low BMD value, either by thorough history taking or with biochemical studies before stating about postmenopausal osteoporosis.[9]

Reporting the Results of DXA Scan

The results are so expressed to compare the patient's bone mineral density either to age-matched controls (Z-score) or to a young normal population (T-score) felt to be representative of peak bone mass. These comparisons may be expressed as percentiles or as standard deviations from the normal range.

As determined by the World Health Organization (WHO), a T-score of greater (less negative) than −1.0 (less than 1 standard deviation below young normal controls) is considered normal. Between −1.0 and −2.5 is considered to be evidence of osteopenia. It should be noted that the term "osteopenia" is retained, but "low bone mass" or "low bone density" is preferred. People with low bone mass or density are not necessarily at high fracture risk. T-scores less (more negative) than −2.5 is consistent with osteoporosis.[2,4] Value of −1.0 is considered normal and value of −2.5 is considered osteoporotic.

When reporting BMD in postmenopausal women and in men age 50 and older, the T-scores are preferred and the WHO densitometry classification is applicable.[1]

When reporting BMD in women before menopause and in men younger than age 50, the Z-scores, not the T-scores, are preferred. This is particularly important in children. It should be noted that a Z-score of −2.0 or lower is defined as "below the expected range for age", and a Z-score above −2.0 is "within the expected range for age" for this population and osteoporosis cannot be diagnosed in men under age 50 on the basis of BMD alone.[1]

Z-scores should be population specific where adequate reference data exist. For the purpose of Z-score calculation, the patient's self-reported ethnicity should be used.[1]

There are specific considerations in pediatric population: The diagnosis of osteoporosis requires the presence of both a clinically significant fracture history and low bone mineral content or bone mineral density. A clinically significant fracture history is one or more of the following: long bone fracture of the lower extremities, vertebral compression fracture, two or more long-bone fractures of the upper extremities, low bone mineral content, or bone mineral density is defined as a BMC or areal BMD Z-score that is less than or equal to −2.0, adjusted for age, gender, and body size, as appropriate.[1]

Serial BMD testing can be used to determine whether treatment should be started on untreated patients because significant loss may be an indication for treatment. Serial BMD testing can monitor response to therapy by finding an increase or stability of bone density. Serial BMD testing can evaluate individuals for non-response by finding loss of bone density, suggesting the need for reevaluation of treatment and evaluation for secondary causes of osteoporosis. Follow-up BMD testing should be done when the expected change in BMD equals or exceeds the least significant change. Intervals between BMD testing should be determined according to each patient's clinical status: typically 1 year after initiation or change of therapy is appropriate, with longer intervals once therapeutic effect is established and finally in conditions associated with rapid bone loss, such as glucocorticoid therapy, testing more frequently is appropriate.[1]

As is presented in Figure 3, usually there is a diagram beside the x-ray image with ROIs (regions of interest) which represents the patient's bone density in comparison to normal and age-matched groups. The diagram results are also usually expressed in detail in an

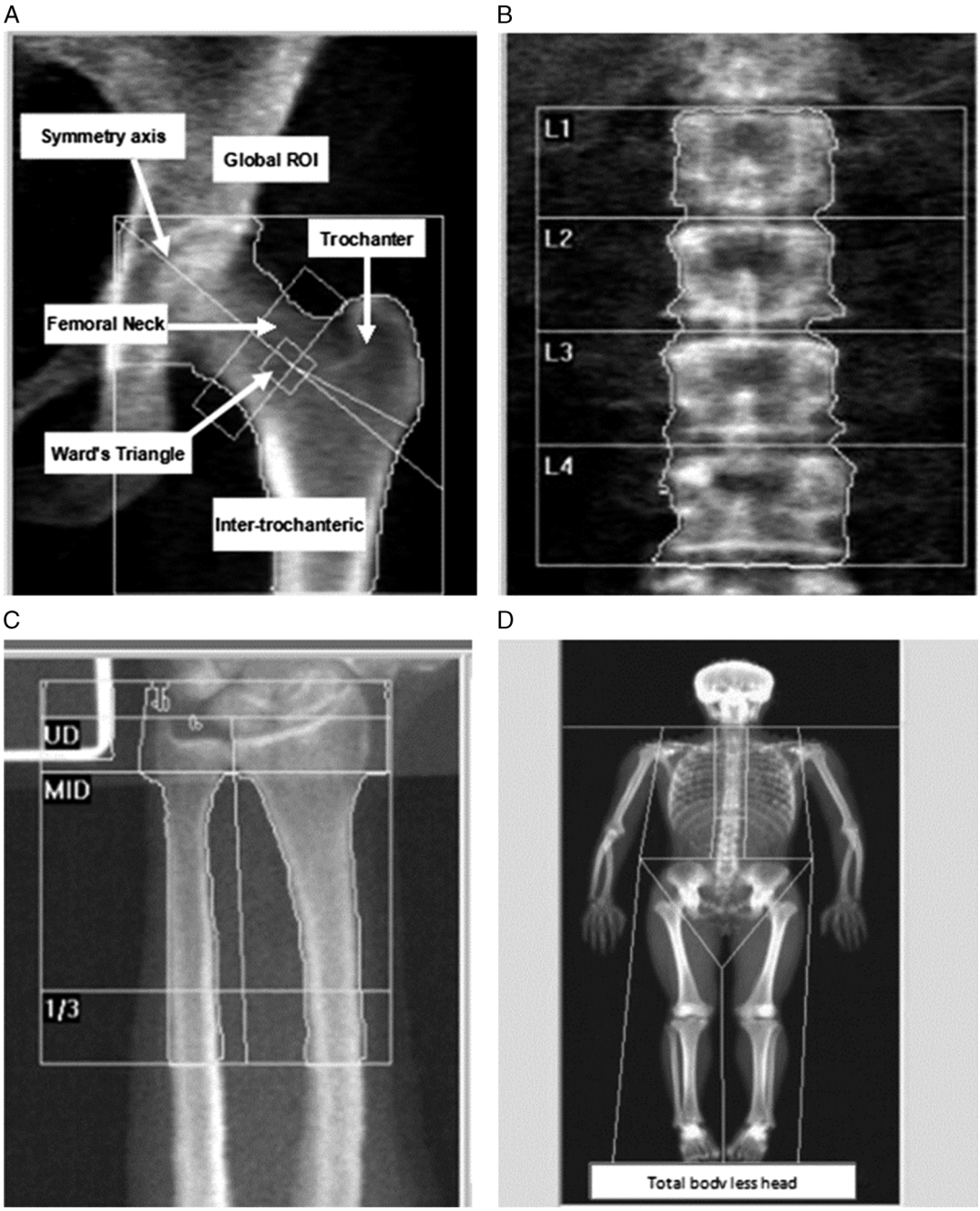


FIGURE 2. Correct positioning and analysis of the proximal femur (**A**), L1–L4 spine (**B**), distal radius (**C**), and total body less head for pediatric age group (**D**).

accompanying table. This table contains the T-scores and Z-scores separately for each ROI. The values are also expressed in percentile comparing to both PR (peak reference) and AM (age-matched) groups.

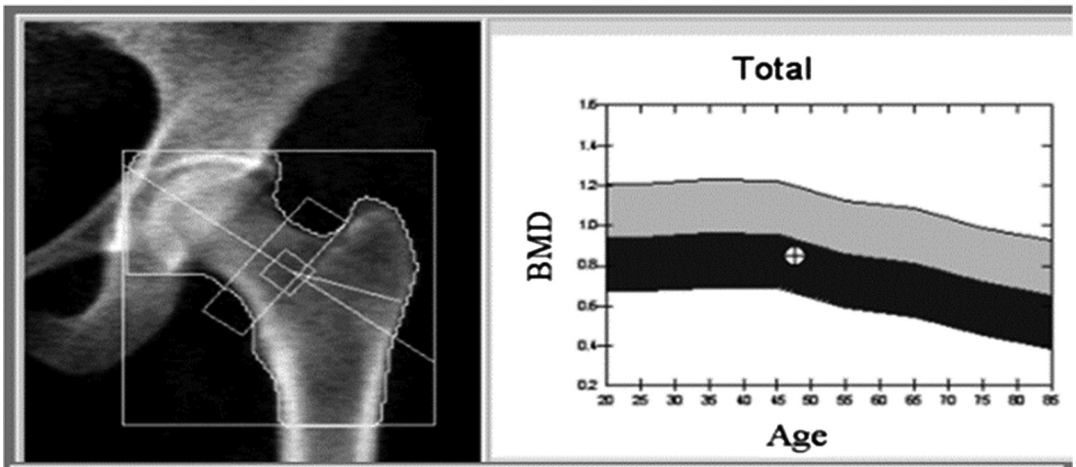
The values of 100 in PR or AM column represent mean average bone density compare to reference groups. Values further more than 100 are consistent with better than average bone density and values further less than 100 represent worse than average bone density.

It should be noted that Ward's triangle is not a true anatomic area but is generated by the DXA scan as the area having the lowest BMD in the femoral head. The measurement of BMD in Ward's triangle should not be used to diagnose osteoporosis. It has been proposed that Ward's triangle have significance for predicting future bone density as femoral head bone turnover evolves.[9]

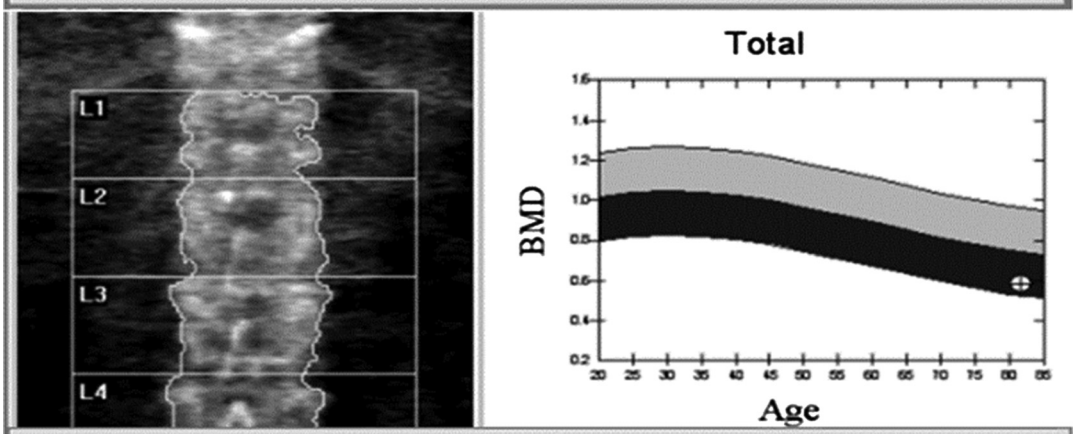
Fracture Risk Assessment

Fracture risk assessment which is reported as percentage is a computer-based algorithm which uses easily obtained clinical risk factors to estimate an individual's 10-year fracture probability. It may be utilized by clinicians to assist in the identification of patients at high risk for fractures.

Required information to calculate a patient's 10-year probability of fracture include country, bone mineral density, age, gender, and clinical



Region	Area [cm²]	BMC [(g)]	BMD [g/cm²]	T - Score	PR (Peak Reference)	Z - Score	AM (Age Matched)
Neck	4.48	3.47	0.776	-0.8	89	-0.4	94
Troch	7.25	4.54	0.626	-0.7	89	-0.5	92
Inter	15.33	14.89	0.972	-1.0	85	-0.8	88
Total	**27.05**	**22.91**	**0.847**	**-0.9**	**88**	**-0.6**	**91**
Ward's	1.29	0.80	0.615	-0.9	84	-0.2	96



Region	Area [cm²]	BMC [(g)]	BMD [g/cm²]	T - Score	PR (Peak Reference)	Z - Score	AM (Age Matched)
L1	9.65	4.70	0.487	-4.0	53	-1.6	74
L2	12.19	6.77	0.555	-4.3	54	-1.6	76
L3	12.61	8.44	0.669	-3.8	62	-0.9	87
L4	14.34	8.58	0.599	-4.7	54	-1.8	75
Total	**48.79**	**28.49**	**0.584**	**-4.2**	**56**	**-1.5**	**78**

FIGURE 3. Densitometry diagrams and tables allow the clinician to compare the patient bone density with control groups.

risk factors (low body mass index, previous fragility fracture, parental history of hip fracture, glucocorticoid treatment, current smoking, alcohol intake, rheumatoid arthritis and other secondary causes of osteoporosis).

The FRAX tool developed by WHO provides this assessment within the primary care setting and is equally accessible by patients. It can play a major role in both targeting treatment appropriately and in education about osteoporosis, the risk factors, and bone health in general. Rather than a gold standard, FRAX should be considered as a platform technology which will continue to build as new validated risk indicators and new country-specific models become available. Notwithstanding, the present model provides an aid to enhance patient assessment by the integration of clinical risk factors alone and/or in combination with BMD.[11,12]

Concordance Between Measured Sites

It is recommended to measure the PA (posterior-anterior) lumbar spine and proximal femur and classifying the patient based on the lowest T-score from 3 sites (lumbar spine, femoral neck, and total hip).

Although the BMDs at different anatomic regions are correlated, the agreement between sites is low when it comes to classifying individual subjects as osteoporotic or not. Thus, T-score discordance between the lumbar spine and hip testing sites is a commonly observed phenomenon in densitometry. T-score discordance is the observation that the T-score of an individual patient varies from one key measurement site to another.[9]

Prevalence and Risk Factors of T-Score Discordance

Various studies have analyzed the prevalence and impact of T-score discordance on the management of osteoporosis (Faulkner, von Stetten et al. 1999[13]; Woodson 2000[14]; O'Gradaigh, Debiram et al. 2003[15]; Moayyeri, Soltani et al. 2005[16]). Only 2 studies focused on risk factors of this commonly observed discordance (Moayyeri, Soltani et al. 2005; El Maghraoui, Mouinga Abayi et al. 2007[17]). Five different causes for occurrence of discordance between the spine and the hip sites have been described (Woodson 2000[14]).

1. Physiologic discordance is related to the skeleton's natural adaptive reaction to normal external and internal factors and forces. Mechanical strain especially related to weight bearing plays a key role in this kind of discordance. The explanation is that weight bearing can cause rise in bone density especially in the hip and femur regions. Moreover, the spine and hips usually start out with different T-scores (the spine is said to reach peak at least 5 years before the hip) (Blank, Malone et al. 2006).[18] Finally, bone loss observed with age in an individual may be more rapid and important in trabecular than cortical bone is another explanation (Agarwal and Camacho 2006).[19] Trabecular bones (typical of lumbar area) are known to have a more rapid rate of deprivation in early postmenopausal state in comparison to cortical bone (typical of proximal femur).
2. The second type of discordance described as pathophysiologic discordance is seen secondary to a disease. Common examples observed in the elderly include vertebral osteophytosis, vertebral end plate and facet sclerosis, osteochondrosis, and aortic calcification. Another important cause in younger patients is ankylosing spondylitis syndesmophytes. The abnormal calcium deposition within the field of the DXA region of interest leads to the falsely elevated spine T-score. A second subtype is a true discordance resulting from a more decreased BMD in the lumbar spine than the hips. Indeed, most of the etiologies of the secondary osteoporosis (such as glucocorticoid excess, hyperthyroidism, malabsorption, liver disease, and rheumatoid arthritis) first affect the spinal column. This will lead to higher prevalence of lumbar osteoporosis.
3. Anatomic discordance is owing to differences in the composition of bone envelopes tested. An example is the difference in T-scores found for the postero-anterior lumbar spine and the supine lateral lumbar spine in the same patient.
4. Artifactual discordance occurs when dense synthetic man made substances are within the field of ROI of the test: eg, barium sulfate, metal from zipper, coin, clip, or other metallic object.
5. And finally, technical discordance occurs because of device errors, technician variability, patient movements, and variation due to other unpredictable sources. With respect to positioning error, some studies showed that either excessive internal or external rotation of the femur during test acquisition resulted in a BMD difference of as much as 10% compared with correct positioning. Also, technical discordance can occur due to the normative reference data used by the device software to analyze the test. This type of discordance occurs when the average BMD of the normative group used to calculate the T-score is significantly different from the average value found for the whole population.[9]

Consequences of T-Score Discordance on Osteoporosis Management

The high prevalence of T-score discordance could induce some problems for the physicians in decision-making regarding these patients. In general, high prevalence of discordance between lumbar spine and hip T-scores suggests some defects in the cut-off values for definition of osteoporosis and osteopenia proposed with the WHO. The inconsistencies in the diagnostic classification of osteoporosis between skeletal sites lend credence to the notion that BMD should be used as only one of the factors in making therapeutic decisions when evaluating patients with osteoporosis.[9]

CONCLUSION

Correct BMD measurements using DXA requires rigorous attention to detail in positioning and analysis. When DXA studies are performed incorrectly, it can lead to major mistakes in diagnosis and therapy. A clear understanding of the interpretation of serial measurements and the statistical principles impacting upon their interpretation is necessary to determine whether a change is real and not simply random fluctuation. Physicians interested in osteoporosis management, even if not directly involved in the performance and interpretation of DXA, should be familiar with the principles outlined here to minimize serious errors and allow proper use of bone densitometry.

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All questions are ABNM Self-Assessment Module (SAM) questions. This module fulfills the requirements of the ABNM Maintenance of Certification program for 2.00 SAM credits in the Nuclear Medicine clinical category. Participants can claim credit for the SAM regardless of the test outcome. Notify the ABNM of the SAM completion by calling 314-367-2225 or visit the ABNM web site at www.abnm.org to set up or log in to your personal database to record the number of SAMs you completed.

SAM-CME Examination

SAM-CME Learning Objectives:

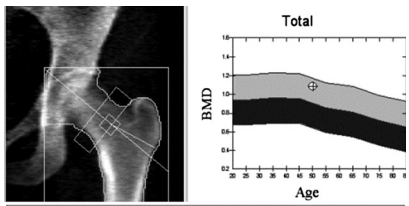
After completing this journal-based CME activity, participants will be able to:

- Explain different available methods for bone densitometry.
- Interpret the DXA studies considering factors that may falsely affect the measured bone density
- Understand specific consideration for interpreting DXA in children, premenopausal women, and underlying medical conditions.

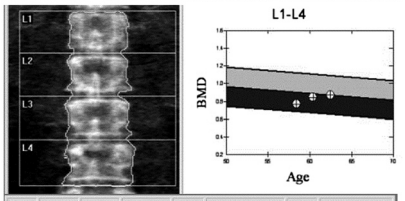
1. Which factor could be potentially protective against osteoporosis?
   (a) Smoking
   (b) Obesity
   (c) Gender
   (d) Steroid therapy

References:
2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*, 6th ed. Philadelphia, PA: Elsevier Saunders; 2012, Chapter 8: 305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*, 4th ed. Philadelphia, PA: Elsevier Saunders; 2014, Chapter 7: 128–130.

2. In these images of lumbar spine and femoral neck from same patient, what is best interpretation?



Region	Area[cm²]	BMC[g]	BMD[g/cm²]	T-score	PR (Peak Reference)	Z-score	AM (Age Matched)
Neck	4.87	3.72	0.763	-1.6	78	-0.7	90
Troch	12.69	9.38	0.739	-0.4	95	-0.0	99
Inter	21.10	24.58	1.165	-0.3	96	-0.1	99
Total	**38.66**	**37.68**	**0.975**	**-0.6**	**92**	**-0.2**	**97**
Ward's	1.07	0.51	0.481	-2.5	58	-0.9	80



Region	Area[cm²]	BMC[g]	BMD[g/cm²]	T-score	PR (Peak Reference)	Z-score	AM (Age Matched)
L1	12.41	10.29	0.829	-0.9	90	0.5	108
L2	13.03	11.77	0.903	-1.1	88	0.4	105
L3	13.96	12.16	0.871	-1.9	80	-0.3	96
L4	16.30	14.33	0.879	-2.2	79	-0.5	95
Total	**55.69**	**48.55**	**0.872**	**-1.6**	**83**	**-0.0**	**100**

(a) Both demonstrate normal bone density
(b) Femoral neck is normal but lumbar spine is osteopenic
(c) Both demonstrate osteopenia
(d) Lumbar spine is normal but femoral neck is osteopenic

References:

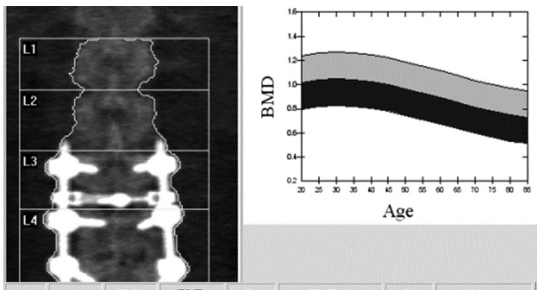
1. Official website of the International Society for Clinical Densitometry (ISCD), http://www.iscd.org/official-positions/official-positions, last reviewed on 1/31/2015.

3. Which of these values would be considered in osteopenic range?
(a) T-score of −0.6
(b) T-score of −1.0
(c) T-score of −1.6
(d) T-score of −2.5

References:

2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*, 6th ed. Philadelphia, PA: Elsevier Saunders; 2012, Chapter 8:305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*, 4th ed. 2014, Philadelphia, PA: Elsevier Saunders; 2014, Chapter 7: 128–130.

4. Considering the below image and bone density results, what is your best conclusion?

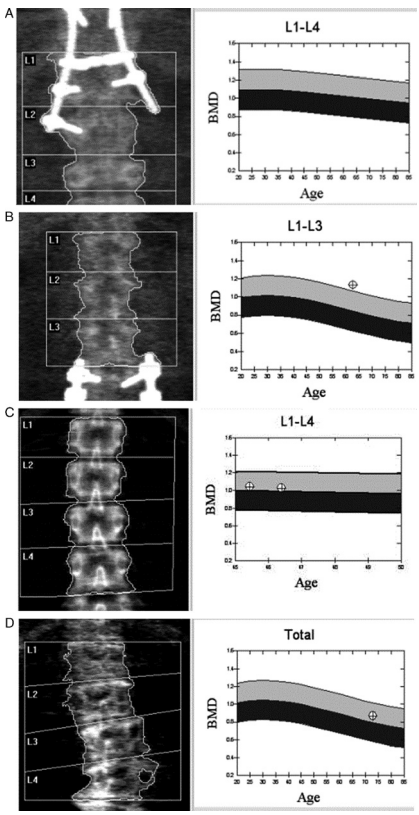


Region	Area [cm²]	BMC [(g)]	BMD [g/cm²]	T-Score	PR (Peak Reference)	Z-Score	AM (Age Matched)
L1	11.43	9.90	0.866	-0.5	94	0.3	103
L2	15.43	14.52	0.941	-0.8	92	0.1	101
L3	22.01	64.06	2.910	16.6	268	17.5	296
L4	29.48	80.69	2.737	14.7	245	15.7	271
Total	**78.35**	**169.16**	**2.159**	**10.1**	**206**	**11.0**	**228**

(a) The overall T-score might be underestimated
(b) Bone density is normal
(c) Regions of interest should be redrawn
(d) There is osteopenia of the lumbar spine

References:
2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*, 6th ed. Philadelphia, PA: Elsevier Saunders; 2012 Chapter 8: 305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*, 4th ed. Philadelphia, PA: Elsevier Saunders; 2014, Chapter 7: 128–130.
9. Maghraoui AE. Interpreting a DXA Scan in Clinical Practice, Dual Energy X-Ray Absorptiometry. Abdelah El Maghraoui (Ed.) 2012, ISBN: 978-953-307-877-9, In Tech, DOI: 10.5772/30574. Available from: http://www.intechopen.com/books/dual-energy-x-ray-absorptiometry/interpreting-a-dxa-scan-in-clinical-practice. Accessed January 31, 2015.

5. Which case will have the most accurate calculated results for bone density?

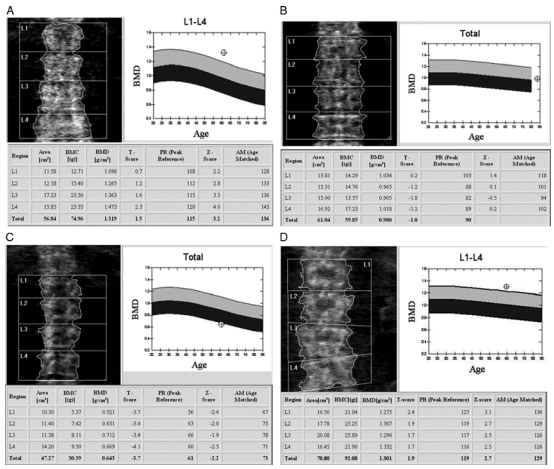


(a) A (b) B (c) C (d) D

References:

2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*. 6th ed. Philadelphia, PA: Elsevier Saunders; 2012, Chapter 8:305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*. 4th ed. Philadelphia, PA: Elsevier Saunders; 2014, Chapter 7: 128–130.
9. Maghraoui AE. Interpreting a DXA Scan in Clinical Practice, Dual Energy X-Ray Absorptiometry. Abdelah El Maghraoui (Ed.) 2012, ISBN: 978-953-307-877-9, In Tech, DOI: 10.5772/30574. Available from: http://www.intechopen.com/books/dual-energy-x-ray-absorptiometry/interpreting-a-dxa-scan-in-clinical-practice. Accessed January 31, 2015.

6. Which patient has the highest risk for future spine compression fracture?



(a) A
(b) B
(c) C
(d) D

References:

2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*. 6th ed. Philadelphia, PA: Elsevier Saunders; 2012, Chapter 8:305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*, 4th ed. Philadelphia, PA: Elsevier Saunders; 2014 Chapter 7: 128–130.
9. Maghraoui AE. Interpreting a DXA Scan in Clinical Practice, Dual Energy X-Ray Absorptiometry. Abdelah El Maghraoui (Ed.) 2012, ISBN: 978-953-307-877-9, In Tech, DOI: 10.5772/30574. Available from: http://www.intechopen.com/books/dual-energy-x-ray-absorptiometry/interpreting-a-dxa-scan-in-clinical-practice. Accessed January 31, 2015.

7. What condition would cause the bone mineral density to be overestimated by DXA?
(a) Recent upper GI study with barium
(b) Multiple myeloma of lumbar spine
(c) Spinal laminectomy
(d) Thyroid metastasis to lumbar spine

References:

2. Mettler FA, Guiberteau MJ. *Essentials of Nuclear Medicine Imaging*, 6th ed. Philadelphia, PA: Elsevier Saunders; 2012, Chapter 8:305–309.
4. Ziessman HA, O'Malley JP, Thrall JH. *Nuclear Medicine: The Requisites*, 4th ed. Philadelphia, PA: Elsevier Saunders; 2014, Chapter 7: 128–130.

8. What is preferred site of densitometry in children and patients with hyperparathyroidism?
(a) Spine and distal forearm
(b) Femoral neck and spine
(c) Spine and total body less head (TBLH)
(d) Total body less head and distal forearm

References:

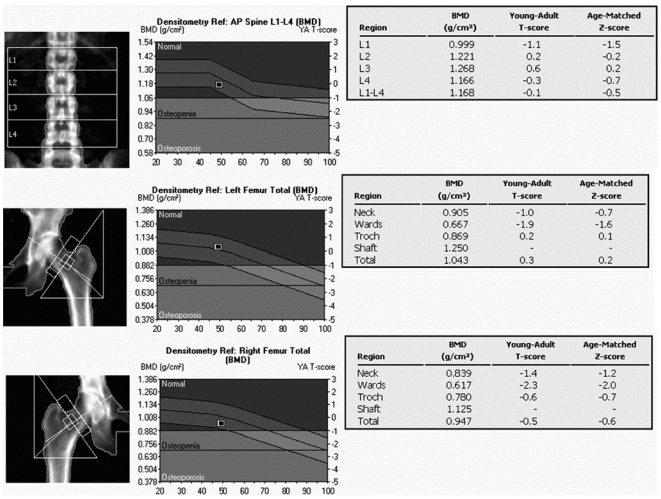
5. Wood K, Dhital S, Chen H, et al. What is the utility of distal forearm DXA in primary hyperparathyroidism? *Oncologist*. 2012;17:322–325.
6. Zemel B, Kalkwarf H, Leonard M, et al. What DXA measurement sites are best for bone health assessment in children? *Bone Abstracts* 2013. doi:10.1530/boneabs.2.OC14.

9. Which statement regarding reporting of DXA results in the femoral neck is correct?

(a) Always report the T-score of the total hip
(b) Report total hip or femoral neck whichever is lower
(c) Report total hip or femoral neck whichever is higher
(d) Report should also include values from Ward's triangle

References:
1. Official website of the International Society for Clinical Densitometry (ISCD), http://www.iscd.org/official-positions/official-positions, last reviewed on 1/31/2015.

10. Considering the below densitometry results, what is the best interpretation?



Region	BMD (g/cm²)	Young-Adult T-score	Age-Matched Z-score
L1	0.999	-1.1	-1.5
L2	1.221	0.2	-0.2
L3	1.268	0.6	0.2
L4	1.166	-0.3	-0.7
L1-L4	1.168	-0.1	-0.5

Region	BMD (g/cm²)	Young-Adult T-score	Age-Matched Z-score
Neck	0.905	-1.0	-0.7
Wards	0.667	-1.9	-1.6
Troch	0.869	0.2	0.1
Shaft	1.250	-	-
Total	1.043	0.3	0.2

Region	BMD (g/cm²)	Young-Adult T-score	Age-Matched Z-score
Neck	0.839	-1.4	-1.2
Wards	0.617	-2.3	-2.0
Troch	0.780	-0.6	-0.7
Shaft	1.125	-	-
Total	0.947	-0.5	-0.6

(a) Lumbar spine: normal, left femur: osteopenic, right femur: osteopenic
(b) Lumbar spine: osteopenic, left femur: normal, right femur: normal
(c) Lumbar spine: normal, left femur: normal, right femur: osteopenic
(d) Lumbar spine: osteopenic, left femur: normal, right femur: osteopenic

References:
1. Official website of the International Society for Clinical Densitometry (ISCD), http://www.iscd.org/official-positions/official-positions, last reviewed on 1/31/2015.