BMD Equipment

DXA and BMD results

MRT Program

Methods and Techniques

- Radiographic absorptiometry (RA)
- Single-energy photon absorptiometry (SPA)
- Dual-energy photon absorptiometry (DPA)
- Single-energy x-ray absorptiometry (SXA)
- Dual-energy x-ray absorptiometry (DXA)*
- Quantitative computed tomography (QCT)*
- Quantitative ultrasound (QUS)*

*Most commonly used modalities

Dual Energy X-Ray Absorptiometry (DXA)

- Measure of bone density requires separation of the x-ray attenuating effects of soft tissue and bone
- Mass attenuating coefficients of soft tissue and bone differ and depend on the energy of the x-ray photons
- Both high and low energy(dual energy x-ray) ranges are used optimizes the differentiation of soft tissue and bone.

GE Lunar and Norland Scanners

- Use rare earth filtered x-ray source,
- Primary beam passes through selected rare earth filters to produce spectrum with peaks near 40 keV and 70 keV with usual continuous spectrum with one peak near 50 keV.
- Sophisticated pulse counting detectors are used to separate and measure low energy and high energy photons.
- Calibration must be performed externally by scanning a calibration phantom on a regular basis (daily in most places)

Hologic Scanners

- Energy switching system that synchronously switches the x-ray potential between 100 kVp and 140 kVp
- This system produces primary beam with two photon energies peaks near 40 keV and 80 keV
- This energy switching system continuously calibrates the beam by passing it through a calibration wheel or drum containing three sectors for an open air gap, a soft tissue equivalent and a bone equivalent

Hologic Scanners

- Each sector is divided so that it can differentiate and measure the low energy and high energy photons.
- Permits the use of relatively simple current integrating detector that does not have to separate the photons

DXA Results

- Low energy and high energy x-rays are attenuated differently within each patient, producing a unique attenuation pattern at the detector which is transmitted electronically to a computer
- Mathematic computations are performed to subtract the soft tissue signals, producing a bone profile
- Proprietary bone edge detection algorithms are next applied and a two dimensional area is calculated

BMD Results (Cont.)

- The average BMD is calculated for all areas and finally BMD is calculated as BMD=BMC/Area
- The three bone densitometry parameters reported on DXA printouts are :
  - Area (cm2)
  - BMC (g)(bone mineral content)
  - BMD g/cm2

BMD is mostly used as it reduces effect of body size

A decrease in BMC results in a decrease in BMD

A decrease in area results in increase in BMD

If BMC and area move proportionally in same direction BMD remains unchanged

DXA Results

- A BMD measurement from a patient is most useful when compared with appropriate sex-matched reference population
- Two standard scores used are T- score and Z-score
- Z-score indicates the number of SDs the patients BMD is from the average BMD for the patients respective age and sex group.
- Z-score= (measured BMD-age matched mean BMD)/age matched SD

BMD T-Scores

- T-Scores indicates the number of SDs the patient's BMD is from the average BMD of young, normal, sex-matched individuals with peak bone mass
- T score= (measured BMD-young adult mean BMD)/young adult SD
- Both may be adjusted for ethnicity and weight
- World Health Organization bases BMD results on T Score

T-Score Classifications

Classification	T-Score
Normal	No lower than –1.0
Osteopenia	Lower than –1.0 but higher than –2.5
Osteoporosis	–2.5 or lower
Severe osteoporosis	–2.5 or lower(combined with one or more fractures present)

- On the next slide there is an example of a BMD report
- Can you review the results and classify the results?

Dual-Energy X-ray Absorptiometry (DXA)

Results Summary:

Total BMD: **0.797 g/cm²**

Peak reference: **76%** T score: **-2.3**

Age matched: **94%** Z score: **-0.4**

Region	Area [cm²]	BMC [g]	BMD [g/cm²]	T score	%PR	Z score	%AM
L1	10.47	6.18	0.591	-3.0	64%	-1.4	79%
L2	11.77	9.47	0.805	-2.0	78%	-0.2	97%
L3	12.15	10.37	0.853	-2.1	79%	-0.2	98%
L4	15.03	13.37	0.889	-2.1	80%	-0.1	99%
Total	49.43	39.39	0.797	-2.3	76%	-0.4	94%

DXA Results

- A change in area could be technologist not reproducing baseline positioning or form a change in software bone edge detection.
- Changes in area over time should be investigated and corrected if possible
- BMD values from scanners made by different manufacturers cannot be directly compared.

Pencil Beam Techniques

- Original DXA scanners used this system
- A circular pinhole x-ray collimator produces a narrow stream of x-ray photons received by a single detector
- The pencil- beam moves in a rectolinear fashion across or along the length of the body
- Good resolution and reproducibility but lone scan times (5-7 mins)

Array Beam Techniques

- Also known as fan-beam has a wide "slit" x-ray collimator and a multi element detectors
- Scanning motion is reduced to one direction which greatly reduces scan time and permits lateral lumbar spine scans to be performed
- Introduces geometric magnification and a slight geometric distortion at the outer edges careful centering is necessary to avoid parallax (altering direction of beam path affecting BMD)
- Software adapts and produces an estimated BMC and area

Accuracy and Precision

- Three statistics are important in BMD
- Mean- the average and is the sum of the data values divided by the number of values
- SD (Standard Deviation)- measure of the variability that measures the spread of the data values around their mean. The goal is smaller SD in BMD
- The %CV (percent coefficient of variation) is a statistic that allows the comparison of variability between different data sets whether or not they have the same mean. A smaller %CV means less variability and is preferred in BMD.

Accuracy and Precision (cont.)

- The goal with BMD is accurate and precise quantitative measurement by the scanner
- Accuracy and precision are two important performance measures
- Accuracy- relates to the ability of the system to measure true value of an object and determined primarily by the calibration of the scanner which is set by the manufacturer (preventative maintenance once or twice a year)
- Precision- relates to ability of the system to reproduce the same (not necessarily accurate) results in repeat measurements of the same object

Precision and Accuracy

- Precision is followed closely because it is easy to determine and is most important performance measure in following patients BMD over time
- Precision is measured in %CV and a smaller value indicates better precision
- Primary factors affecting precision is reproduction of positioning acquisition parameters(e.g. Mode, speed, current) and ROI placement
- Anatomical variations and pathology

Precision and Accuracy (cont)

- Body habitus (excessive thickness or thinness)
- Geometric factors on array scanners
- Large weight changes over time
- Stability of scanner calibration and bone edge detection.
- Manufacturers provide a unique phantom to ensure quality control system to detect shifts or shifts in calibration

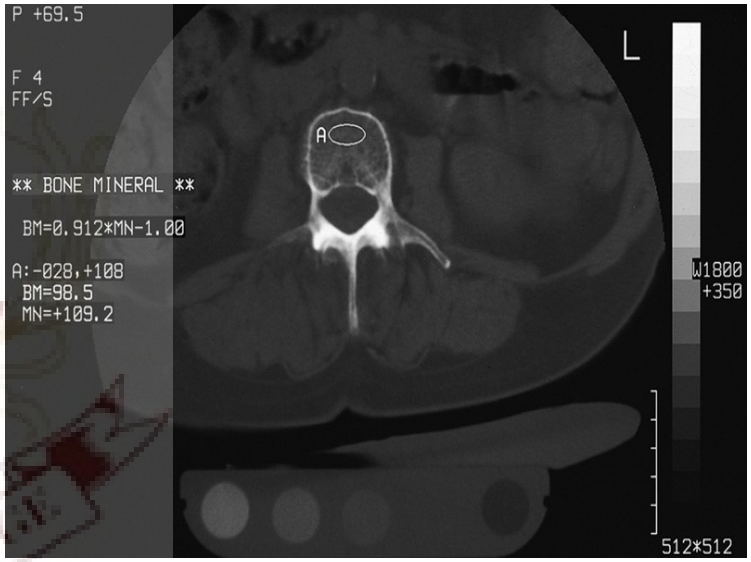
Performing Precision Assessment

- Determined by DXA lab its precision error and calculate the Least Significant Change (LSC)
- This determines the magnitude of change in BMD that must occur over time to ensure the change is due to a change in patients BMD and not to the precision error of the technologist and scanner
- Manufacturer sets precision error for equipment, department sets precision error based on technologist or average of staffed technologists

Quantitative Computed Tomography (QCT)

- 8- to 10-mm slices—through four separate vertebral bodies

  OR
- 20 to 30 continuous 5-mm slices over two to three vertebral bodies between T12 & L5
- Evaluates both trabecular and cortical bone
- Can produce 3D or volumetric analysis of data
- Cost and radiation dose is higher



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Quantitative Ultrasound

- Used since late 1990's
- -non-ionizing used to assess in peripheral sites (os calsis most common)
- Quick assessments and simple measurements
- Used with obese ++ patients
- Ultrasound beam is directed through the specified site
- Velocity and attenuation of sound demonstrates modifications as it passes through variations in structural components

Vertebral Fracture Assessment VFA)

- Software to diagnose current and potential vertebral fractures
- Vertebral fractures are most common in patients over age 70.
- During VFA, a single- or dual-energy scan of the lumbar spine is performed.
- Software measures vertebral heights and compares them with reference values.