Bone Densitometry
Radiation dose: what you need to know

John Damilakis, PhD
Associate Professor and Chairman
University of Crete, Iraklion, Crete, GREECE
Estimation of bone status using X-rays

- Assessment of low energy fractures
- Dual-energy X-ray absorptiometry (DXA)
- Quantitative Computed Tomography (QCT)
- High Resolution CT imaging
- Peripheral QCT (pQCT)
Spinal Radiography

Spinal radiography is used for identification of vertebral fractures

The dose from a lateral radiograph of the thoracic and lumbar spine is about 600 µSv

Vertebral Fracture Assessment

VFA is a low dose technique with doses reported to be from 1 to about 50 µSv

Fracture assessment of the spine is possible without any additional radiation burden by routinely performing sagittal reformations in 3D CT of the thorax and abdomen which have been performed for other clinical indications.

Estimation of bone status using X-rays

Assessment of low energy fractures

- Dual-energy X-ray absorptiometry (DXA)
- Quantitative Computed Tomography (QCT)
- High Resolution CT imaging
- Peripheral QCT (pQCT)
Dual energy X-ray absorptiometry

For the first generation pencil-beam devices the patient effective dose was negligible i.e. up to 1 μSv for a spine and femur DXA.

For fan-beam DXA devices, patient effective doses vary between systems of different models and manufacturers depending on a number of variables.

Effective dose from spine DXA

Hologic DXA scanners (scan lengths adjusted to the child’s body size)

Blake G et al, Bone 38:935-42, 2006
Effective dose from hip DXA

Hologic DXA scanners (scan lengths adjusted to the child’s body size)

5-22 µSv
3-9 µSv

Blake G et al, Bone 38:935-42, 2006
Physical phantoms and TLDs
Radiation dose from DXA

GE-Lunar makes use of a fan-beam with a 4.5° angle orientated parallel to the longitudinal body axis.

A filter splits the X-ray spectrum into high- and low-energy components and provides energies of 38 keV and 70 keV.

Radiation dose from DXA

Hologic uses a linear fan-beam with a detector array sufficiently wide to image an entire vertebral column in a single sweep.

Hologic uses rapid switching between high and low tube potentials e.g. from 70 to 140 kVp.
Effective dose from DXA: Comparison with other examinations

- **Chest radiography**
- **Dental panoramic radiography**
- **Spine + hip DXA (Hologic)**
- **Spine + hip DXA (GE)**
- **Intra-oral radiography**

ED (µSv)

30

18

6
Risk coefficients for cancer

Source: BEIR VII
Risks for cancer

50-year-old female patient

Dose per screening: 20 μSv (Hologic)

\[ \text{Risk} = 0.074 \times 20 \times 10^{-6} = 1.48 \times 10^{-6} \]

1.5 cases of cancer / 1 million patients (Hologic)

Effective doses from DXA and potential risks are negligible compared with the benefits
Exposure during flights

The worldwide average effective dose from natural Bg radiation is 2.4 mSv/y
Conceptus dose from DXA

DXA: How to reduce patient dose

Patient preparation is important for reducing the radiation dose

Avoid patient movement during imaging

Select the most appropriate acquisition protocol

Use dose reduction tools such as SmartScan©

The length of the DXA should take into account patient’s body size
Estimation of bone status using X-rays

Assessment of low energy fractures

Dual-energy X-ray absorptiometry (DXA)

Quantitative Computed Tomography (QCT)

High Resolution CT imaging

Peripheral QCT (pQCT)
QCT using body CT

Technical Report

Vertebra Analyzed: L3
Volume (cm³): 4.31
Area (cm²): 4.79
Width (cm): 3.13
Height (cm): 1.95
Depth (cm): 0.90
Nv: 120
SFOV: 400.00
FUC: 1.030
Table Height: 190.00

Sensation 16
Ex: 1
Contours: 603
Se: 500/3
Im: 2/4
Acc: 1
Acq: 1
Acq Im: 11/58/56,334293

36 YRS
OXTRO ORAL
0/12 x 5/12
E311

120.0 kV
294.0 mA
10.0 mm/0.1
Tilt: 0.0
0.5 s

WinDCM/WinDCM/4/ID
W.370 H.L.30

DFOV 33.8 x 33.8 cm
Estimation of bone status using X-rays

Assessment of low energy fractures

Dual-energy X-ray absorptiometry (DXA)

Quantitative Computed Tomography (QCT)

High Resolution CT imaging

Peripheral QCT (pQCT)
High-Resolution CT imaging

Important information can be obtained from structure analysis of high-resolution image data.

Effective dose of about 3 mSv

Parameters that affect CT dose

Beam shaping filter

Collimation

kV, mAs

Filtration

Detection system efficiency

Scanning length, scanner geometry, beam collimation, rsw, pitch, algorithms, dose reduction tools
The body is not irradiated uniformly
Patient-specific MC Simulation

Allows machine-specific and patient-specific calculations of the dose distributions

J. Damilakis et al, Radiology 257:483-9, 2010

Estimation of bone status using X-rays

Assessment of low energy fractures

Dual-energy X-ray absorptiometry (DXA)

Quantitative Computed Tomography (QCT)

High Resolution CT imaging

Peripheral QCT (pQCT)
Peripheral QCT

Isotropic voxel size in the order of 80 μm which allows direct or indirect evaluation of cortical and trabecular bone architecture

Effective dose lower than 3 μSv

Occupational doses and shielding

Dose rates at 1m from the central axis of the imaging table range from about 0.01 $\mu$Sv/h to about 5 $\mu$Sv/h, depending on the model. Examine isodose curves provided by the manufacturer!
Radiation doses associated with DXA are very low
Pencil beam: less than 1 µSv/scan
Fan beam: up to 25 µSv/scan

VFA is associated with considerably lower exposure than lateral spine radiography (1-50 µSv vs. 600 µSv)

Emphasis must be on dose optimization, especially for paediatric examinations
Protocols used to examine vertebral microstructure using HR MDCT provide an effective dose of 3 mSv.

2D QCT of the lumbar spine is a low-dose technique with doses reported to be from 60 to about 90 µSv.

The effective dose from pQCT is negligible i.e. from 3 to 10 µSv.

Examine isodose curves provided by the manufacturer.
Thank you!

Ευχαριστώ!