Dual-energy x-ray absorptiometry (DXA) as an imaging tool in bone and metabolic research

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INTRODUCTION AND PURPOSE

Imaging methods can answer fundamental research questions in bone and metabolic diseases. However, it can be challenging to evaluate what methods to choose. Most commonly used imaging methods employed include dual-energy x-ray absorptiometry (DXA), peripheral quantitative computed tomography (pQCT) and micro-computed tomography (µCT) in bone research, and DXA and nuclear magnetic resonance (NMR) in metabolic research.

The purpose of this study was to evaluate the advantages of different most commonly used imaging methods in bone and metabolic research and provide positioning for DXA within other commonly used imaging techniques in these research fields.

METHOD

In this study, we summarize key advantages and provide a positioning for DXA as an imaging tool. We compared technical specifications of DXA, pQCT, µCT and NMR. The features compared include: 1) measurement readouts, 2) possibility for repeated measurements, and 3) time from imaging to results.

SUPPORTING INFORMATION

- **Dual energy X-ray Absorptiometry (DXA):** An imaging technique for measuring bone mineral density (BMD) using spectral imaging. Two X-ray beams of different energy are used for separating bones (hard tissue) from soft tissues. Using the difference in absorption or two different energy X-rays it is possible to separate BMD from fat and lean mass (body composition analysis). Dual-energy X-ray absorptiometry is the most widely used and most thoroughly studied bone density measurement technology and a gold-standard in osteoporosis diagnostics.
- **Nuclear Magnetic Resonance (NMR):** An imaging technique using strong magnetic fields to generate information about body composition. Certain atomic nuclei such as hydrogen can absorb energy when placed in a magnetic field, which results in a signal that can be detected. As hydrogen atoms are naturally abundant in water and fat, the method can be used to analyze fat composition in the body.

Reference image of a small-animal DXA

- **Peripheral Quantitative Computed Tomography (pQCT):** An imaging technique that measures BMD using a standard X-ray CT scanner with a phantom-based calibration standard to convert Hounsfield Units (HU) of the CT image to BMD values. The phantoms contain materials such as calcium hydroxyapatite or potassium phosphate that contain different equivalent bone mineral densities.
- **Micro-computed Tomography (µCT):** An imaging technique that uses cross-sectional X-rays to create a 3D model object of the imaged specimen providing information about bone volume (BV) and detailed structural information about bone architecture. The prefix 'micro' prefers to pixel size that is possible to analyze with this imaging technique.

DXA is a rapid and accurate imaging method that can be utilized in bone and metabolic research. Key advantages over other imaging methods include whole-body imaging capability and analysis of user-selected multiple ROIs during the study.

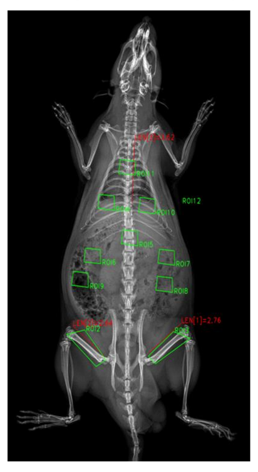
COMPARISON OF IMAGING METHODS

In bone research, DXA and pQCT can be used for analyzing BMD and bone mineral content (BMC). The analysis is done from 2D images in DXA and 3D images in pQCT. With pQCT the analysis can be done separately from cortical and trabecular bone areas of imaged bones. The benefit of DXA is the whole-body imaging and analysis from selected Regions of Interest (ROIs). µCT imaging is used for analyzing total bone volume from trabecular and cortical bone compartments separately. DXA and pQCT allow repeated measurements in longitudinal studies while µCT is commonly an endpoint measurement, although relatively accurate in vivo µCT equipment are today available. The time from imaging to analysis is lowest with DXA (1 minute per animal) compared to more laborious pQCT (15 minutes) and µCT (30 minutes). In metabolic research, both DXA and NMR can be used to analyze fat and lean mass. The benefit of DXA is the analysis of specific ROIs from whole-body images whereas NMR only provides results per animal.

Table 1: Summary of comparison of advantages of imaging techniques commonly used in bone and metabolic research.

TABLE 1	Bone research			Metabolic research	
Imaging technique	**DXA**	**pQCT**	**µCT**	**DXA**	**NMR**
Measurement readouts	Total or ROI specific BMD and BMC, and bone area	Total or cortial and trabecular BMD and BMC	Bone volume and bone structural paramers separately for cortical and trabecular bone	Total and ROI specific fat and lean mass (g and %) and total mass and tissue area	Total fat and lean mass (g) and free body fluid
Longitudinal studies	Yes	Yes	No (yes, with in vivo µCT)	Yes	Yes
Anesthesia	Yes	Yes	No (yes, with in vivo µCT	Yes	No (immobilization during measurement)
Time from imaging to results	Low	Medium	High	Low	Low
Imaging/ analysis time	25 sec/ 30 sec	10 min/ 5min	20 min/ 10 min	25 sec/ 30 sec	1 min/ 0 sec

Table 2: Summary of readouts obtained from DXA. All parameters can be analyzed from the whole body or ROI separately.



Parameter	Unit	Description
BMC	g	Bone Mineral Contents (Bone Mass) = bone density x bone area
FAT	g	Fat Mass
FAT	%	Fat Ratio = Fat Mass/Total Mass
LEAN	g	Fat free mass
Total Mass	g	Total Mass = Fat + Lean + Bone mass
BMD	g/cm^2	Bone Mineral Density
Bone Area	cm^2	Bone Area in Image
Tissue Area	cm^2	Tissue Area in Image

Table 3: Summary of readouts obtained from imaging techniques commonly used in bone and metabolic research. * = less accurate than DXA, ** = provided as an optional setup

Function	DXA	pQCT	µCT	DXA	NMR
3D Image	No	No	Yes	No	No
2D DR Image	Yes	Yes	Yes	Yes	No
BMD (g/cm^2)	Yes	Yes	Yes*	Yes	No
BMC (g)	Yes	Yes	Yes*	Yes	No
FAT (g)	Yes	No	Yes**	Yes	Yes
LEAN (g)	Yes	No	Yes**	Yes	Yes
FAT (%)	Yes	No	No	Yes	Yes
Bone Area (cm^2)	Yes	Yes	No	Yes	No
Free Body Fluid (Water)	No	No	No	No	Yes
Heavy Animals (~1000 g)	Yes	No	No	Yes	No
Price	Low	Middle	High	Low	Middle

CONCLUSIONS

Whole-body imaging, ROI analysis and short imaging and analysis time are the main advantages of DXA in both bone and metabolic disease research. Supporting methods such as µCT can be used to access more detailed structural information of bone when needed.

SELECTED REFERENCES

1. Yeu J, et al., *Evaluation of iNSiGHT VET DXA (Dual-Energy X-ray Absorptiometry) for assessing body composition in obese rats fed with high fat diet: a follow-up study of diet induced obesity model for 8 weeks*. Lab Anim Res. 2019
2. Baek KW et al., *Validation of Dual Energy X-Ray Absorptiometry and Nuclear Magnetic Resonance in the Analysis of Body Composition in Mice.* J Bone Metab. 2020
3. He Q, et al., *Sanhuang Jiangtang tablet protects type 2 diabetes osteoporosis via AKT-GSK3β-NFATc1 signaling pathway by integrating bioinformatics analysis and experimental validation.* J Ethnopharmacol. 2021
4. Kim MY et al., *Metabolic activities affect femur and lumbar vertebrae remodeling, and anti-resorptive risedronate disturbs femoral cortical bone remodeling.* Exp Mol Med. 2021 Jan;53(1):103-114. doi: 10.1038/s12276-020-00548-w. Epub 2021

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