Title

Advances and Shortfalls in MRI Evaluation of Osteoporosis.

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New Title: Advances and Shortfalls in MRI Evaluation of Osteoporosis

Osteoporosis is a major risk factor for bone fracture. Bone mineral density (BMD) is often evaluated with dual-energy x-ray absorptiometry (DXA) to determine the fracture risk (1), but DXA alone maybe insufficient to evaluate bone quality or different compartments such as cortical and trabecular bone. CT, including multi-detector CT and high resolution peripheral quantitative CT (pQCT), provide detailed information about bone microstructure (2). Furthermore, recent advancements in MRI, utilizing ultrashort echo time (UTE) or zero echo time (3) sequences to acquire rapidly decaying MR signal from the bone, has enabled direct MRI evaluation of bone without the use of ionizing radiation.

In this issue of Radiology, Jones et al. (4) report on a "solid"-state MRI technique (5) that uses hydrogen 1 UTE and phosphorus 31 zero echo time acquisitions at 3-T to determine bone water content, mineralization, and morphologic characteristics in postmenopausal women. The MRI measures were compared between treatment-naïve women with osteoporosis and an age-matched control group without osteoporosis, and correlations with BMD values from DXA and pQCT were assessed. The authors found significantly higher total and pore water content and lower bone mineralization and cortical thickness in women with osteoporosis. Additionally, the water contents correlated negatively and mineralization and cortical thickness correlated positively with BMD values from DXA and pQCT.

This in vivo study has significant clinical implications for a wider use of MRI to assess osteoporosis by providing measures of bone water as well as mineralization, with a minor inconvenience of requiring the use of calibration phantoms during imaging. The findings of the

study agree with those of past studies using UTE-based techniques such as bicomponent UTE T2* analysis to determine free and bound water in the cortical bone, which correlated with porosity at micro CT and mechanical strength (6). Conventional high resolution MRI techniques have also been used, aimed at acquiring images depicting trabecular microstructure for finite element analysis (7). The study by Chang et al (7) revealed that postmenopausal women with fragility fracture had lower elastic modulus in the proximal femur compared to control subjects without fracture but similar BMD. Studies such as these collectively suggest that multifaceted MRI approaches may provide information unavailable in DXA alone.

Despite significant recent advances, challenges to MRI bone evaluation remain. Scientifically, relative roles of bone "quantity" vs. "quality" in bone fracture is still under active investigation (8), leading to an ever-increasing number of imaging targets (e.g., collagen cross-linking, composition, cellular activity), particularly for the bone "quality" biomarker where MRI has the greatest potential to make an advancement. MRI-specific issues include non-standard hardware (e.g., coil) and methodology, high cost, long scan time, and complex post-processing. This leads to smaller-scale studies that are difficult to generalize to a large population as was possible for DXA (9).

The study by Jones et al demonstrates that MRI evaluation of bone is feasible for clinical translation, albeit with many shortcomings. Improvements are needed in many areas, including collaboration with clinicians and basic researchers to better define imaging targets and corresponding MRI biomarkers, hardware to acquire images with higher signal-to-noise more quickly, approaches for facilitating deployment of new MRI methodology, and larger-scale studies.

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