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Quantitative Musculoskeletal MRI for Tumorous Conditions

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Quantitative MRI has become an essential tool for the non-invasive characterization of musculoskeletal tumors, offering complementary biomarkers that extend beyond conventional morphologic imaging. This lecture will highlight three advanced approaches—diffusion-weighted imaging (DWI), dynamic contrast-enhanced MRI (DCE-MRI), and chemical shift–based imaging (including proton-density fat fraction, PDFF)—and discuss their role in evaluating tumor biology and treatment response.

DWI exploits the random motion of water molecules to estimate tumor cellularity. Apparent diffusion coefficient (ADC) values provide a surrogate biomarker for differentiating benign from malignant lesions, characterizing histologic grade, and predicting proliferative activity. Evidence suggests that ADC changes can also reflect therapeutic response, both in soft tissue sarcomas and in primary and metastatic bone tumors.
DCE-MRI assesses tissue perfusion and vascular permeability by modeling signal changes after contrast administration. Quantitative parameters such as K^{trans}, k_{ep}, and v_p can help distinguish benign from malignant lesions, stratify sarcoma grades, and monitor therapy-induced vascular alterations. In bone and soft tissue tumors, reductions in perfusion parameters after chemotherapy or radiotherapy have been associated with necrosis and improved outcomes.

Chemical shift–based water-fat imaging provides quantitative assessment of tumor fat content. Signal intensity ratios, relative fat fraction, and PDFF mapping are particularly useful in distinguishing benign from malignant marrow lesions and in assessing vertebral compression fractures. While PDFF provides valuable diagnostic information, its accuracy can be affected by technical issues such as T1 bias, T2* decay, and the complex fat spectrum. Refinements including the use of long TR and low flip angle to minimize T1 bias, T2* correction, and multi-peak spectral modeling, are essential to ensure robust and reproducible measurements.

Together, these quantitative MRI methods provide complementary insights into tumor cellularity, angiogenesis, and fat composition. Incorporating multiparametric MRI into clinical workflows may enhance diagnostic confidence and enable early assessment of treatment response.

Keywords: *Diffusion-weighted imaging, Dynamic contrast-enhanced imaging, Chemical shift imaging, Musculoskeletal tumors, Quantitative MRI*