Redefining MRI:
From Image to Insight

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Updates in Multinuclei MR Imaging

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Multinuclear MRI extends beyond conventional ^{1}H imaging to capture biochemical and physiological information that structural sequences alone cannot provide. This talk introduces two emerging multinuclear applications in musculoskeletal imaging—^{23}Na-MRI of the lumbar spine and dynamic ^{31}P-MRS of skeletal muscle—highlighting how each offers an early window into tissue degeneration, well before changes become visible on standard imaging.

We begin with the intervertebral disc, where loss of proteoglycan content is one of the earliest signs of degeneration but is not directly visible on T2-weighted imaging. Because sodium ions are electrostatically bound to proteoglycans, ^{23}Na-MRI provides a quantitative, non-invasive way to assess disc matrix health directly. Using apparent tissue sodium concentration (aTSC) as a quantitative marker, we show that sodium-based measures correlate with conventional degeneration grading, decline with age, and relate to patient-reported back pain—suggesting that ^{23}Na-MRI can capture biochemical changes in the disc that complement, and may precede, what is seen on routine morphological imaging.

Turning from the spine to skeletal muscle, a similar principle applies: metabolic change often precedes structural or functional decline. This is especially relevant to sarcopenia, where early detection is essential for timely intervention, particularly in patients with chronic systemic disease such as liver cirrhosis, in which impaired liver energy reserve drives compensatory muscle breakdown. Dynamic ^{31}P-MRS allows real-time, non-invasive tracking of muscle energy metabolism during exercise, capturing subtle shifts in phosphocreatine and inorganic phosphate that reflect the health of different muscle fiber types. In cirrhotic patients without clinically overt sarcopenia, this technique revealed metabolic differences linked to liver reserve capacity—demonstrating that ^{31}P-MRS can detect muscle-level vulnerability before conventional criteria for sarcopenia are met.

Together, these two techniques illustrate a common theme in multinuclear MR imaging: the ability to detect biochemical and metabolic change at a stage when conventional ^{1}H imaging still appears normal. Rather than replacing standard MRI, ^{23}Na-MRI and ^{31}P-MRS are best understood as complementary tools that add a physiological dimension to structural assessment, opening the door to earlier diagnosis and more individualized management strategies.

Looking ahead, broader clinical adoption of multinuclear MRI will depend on continued improvements in scanner hardware, coil design, and acquisition efficiency, as well as larger validation studies linking these biomarkers to long-term clinical outcomes. As these barriers are addressed, ^{23}Na-MRI and ^{31}P-MRS are well positioned to move from research settings into routine musculoskeletal practice—supporting earlier detection of disc degeneration and sarcopenia risk, and ultimately enabling more proactive, personalized patient care.

Keywords: *23Na MRI, 31P MRS, Lumber spine disc degeneration, Sarcopenia, cirrhosis*