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Multinuclear Imaging of the Liver: Clinical Roles of ^{31}P-MRS and ^{23}Na-MRI

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Multinuclear magnetic resonance imaging (MRI), which uses nuclei other than protons (^{1}H), has undergone a dramatic transformation with the advent of regulatory-approved radiofrequency coils. These multinuclear imaging techniques offer unprecedented insights into cellular metabolism and tissue viability that extend far beyond conventional anatomical imaging. This presentation explores the clinical potential of phosphorus-31 (^{31}P) magnetic resonance spectroscopy (MRS) and sodium-23 (^{23}Na) MRI of the liver as emerging biomarkers for early disease detection and treatment monitoring.

^{31}P-MRS directly measures cellular energy metabolism through adenosine triphosphate and inorganic phosphate (Pi), and—via the chemical shift of Pi—tissue pH, providing non-invasive insight into hepatic bioenergetics. Beyond energy metabolism, phosphomonoester (PME) and phosphodiester (PDE) levels provide crucial insights into phospholipid membrane metabolism, enabling assessment of cellular metabolic activity and metabolic cycling in cancer cells. Altered PME/PDE ratios reflect changes in membrane turnover and cellular proliferation, offering novel biomarkers for cancer metabolism that can detect malignant transformation before morphological changes become apparent. In hepatocellular carcinoma, these phospholipid membrane alterations enable early detection and monitoring of treatment response through dynamic evaluation of cellular metabolic cycles. Non-invasive assessment of hepatic metabolic function through ^{31}P-MRS provides valuable diagnostic information for diffuse liver diseases, potentially reducing the need for liver biopsies.

^{23}Na-MRI provides unique assessment of cellular integrity through total sodium concentration and intracellular/extracellular sodium distributions, enabling novel applications in oncology and lymphatic system evaluation. Malignant tissues demonstrate elevated total sodium concentration and altered sodium gradients, which may help differentiate benign from malignant lesions. Additionally, ^{23}Na-MRI offers innovative capabilities for detecting lymphatic leakage and evaluating lymphatic dysfunction, providing non-invasive alternatives to conventional lymphography.

Recent advances in ultra-high-field MRI technology and approved coils have significantly improved the clinical feasibility of multinuclear imaging, bringing these metabolic and ionic biomarkers closer to routine hepatic practice.

Keywords: Multinuclear imaging, Phosphorus (^{31}P), Sodium (^{23}Na), Liver, Magnetic resonance imaging