Specialty Area: Clinical Interpretation and Advanced Imaging

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Highlights:

- Magnetic resonance (MR) imaging has been increasingly used to evaluate the musculoskeletal system in the presence of metal hardware.
- Knowledge of the general principles behind the artifacts seen with MR imaging in the setting of metal hardware allows for an understanding of the limitations of conventional sequences, even with protocol optimization.
- Multiple vendors are releasing product sequences, which utilize many innovative techniques, such as view angle tilting (VAT) and multispectral imaging (MSI) techniques, including slice encoding for metal artifact correction (SEMAC) and multi-acquisition variable-resonance image combination (MAVRIC).
- Familiarity with these techniques allows the radiologist to be comfortable implementing these next-generation sequences and for confidence in the diagnosis of pathologies that are now visible.

Talk Title: Metal Artifact Suppression

- **Target Audience**: Radiologists, technicians, and scientists who encounter patients presenting for MR imaging in the setting of metal hardware.
- **Outcome/Objectives**: This lecture will improve understanding of the general principles behind the effects of metal on MR imaging, various MR techniques that are available or have been recently described in the literature, and pathologies that can be encountered on MR imaging related to metal hardware.

Abstract:

In the past several decades, there has been increased use of orthopaedic hardware, in part as a result of our globally aging population. Due to the superior soft tissue contrast of MR imaging compared with radiography or computed tomography, it has become an established modality for the evaluation of musculoskeletal structures. However, MR imaging is based on the presumption that the main magnetic field (B_0) is homogenous and this condition is violated in the presence of metal hardware.

The presence of metal creates large perturbations in the local magnetic field, with the precise disturbance influenced by implant size, shape, and orientation. These inhomogeneities cause three main types of artifacts on conventional, clinical MR images: T2* dephasing, displacement artifacts, and failure of fat suppression.

- T2* dephasing occurs due to varying rates of precession inside a voxel and can be corrected with the use of refocusing pulses (spin-echo or fast spin-echo imaging) or minimized by decreasing effective echo time.
- Displacement artifacts arise due to frequency variations in both the slice selection and readout directions, which cause signal mismapping. Mild cases show geometric distortions and severe

cases showing signal loss in one region and pile up artifact in another [1]. Displacement artifacts can be reduced by using phase encoding or, to a limited extent, using stronger imaging gradients.

- Inefficient fat-suppression occurs in the setting of metal. Spectrally selective ("chemical") fat-suppression techniques fail due to artifactual frequency shifting of the water and main fat peaks. Chemical shift based water-fat separation techniques can also fail, due to broadening of the water and fat peaks as a result of intra-voxel dephasing [2].

Advanced metal artifact reduction techniques have emerged. In 1988, the view angle tilting (VAT) method was described, which can be used to reduce in-plane displacement artifacts [1]. VAT relies on the fact that magnetic susceptibility artifacts cause displacements in both slice selection and readout directions. By viewing the slice from an angle (accomplished by re-applying the slice selection gradient during the readout period), these displacements can be made to cancel each other. Slice Encoding for Metal Artifact Correction (SEMAC) utilizes the VAT-compensation gradient to suppress in-plane displacements, but also adds additional phase encoding steps in the slice selection direction to correct through-plane displacements [4]. Multiacquisition Variable-Resonance Image Combination (MAVRIC) utilizes limited bandwidth frequency selective excitation to suppress in-plane displacements and phase encoding to resolve displacements in the through-plane direction [5]. Specifically, narrow spectral bandwidth imaging is performed for the on-resonance frequency and repeated for multiple partially overlapping offset frequencies, each regarded as individual "spectral bins." Both SEMAC and MAVRIC combine sub-images to form the final composite images. More recently, Koch and colleagues have introduced the MAVRIC-SEMAC hybrid technique (MAVRIC SL) [6], which adds a through-plane gradient to the multiple spectral acquisitions of MAVRIC. This gradient is applied during excitation, thereby adding slice selectivity, and during readout, thereby adding VAT. MAVRIC has also been combined with ultrashort echo time acquisition (UTE-MAVRIC) [7], which allows imaging of short T2/T2* structures such as ligaments, tendons, cortical bone, polyethylene spacers of implants, or peri-prosthetic fluid collections laden with metal debris.

References:

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4. Lu W et al. SEMAC: Slice Encoding for Metal Artifact Correction in MRI. Magn Reson Med 2009;62(1):66-76.

5. Koch KM et al. A multispectral three-dimensional acquisition technique for imaging near metal implants. Magn Reson Med 2009;61(2):381-390.

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