Metal-Induced Artifacts in MRI

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Purpose: Metallic implants such as dental fillings, spinal fixation or joint replacements are commonly used to treat a variety of conditions. Although many metal implants are classified as "MR-safe," most cause a variety of artifacts in imaging. This presentation provides an intuitive, animated illustration of different metal-induced artifacts in MRI, including descriptions of ways to reduce such artifacts.

Outline Of Content

Origin of Artifacts: The presence of metal causes spatially-varying shifts in the static magnetic field, which in turn cause varying shifts in the resonant frequency in the subject [1]. The first adverse image effect is rapid T2* dephasing within a voxel, which can be corrected by using a spin echo, or in some cases very short echo time [2]. The second and third effects are through-slice and in-plane displacements that result in (a) bulk distortion of shape due to slowly-varying frequency shifts, (b) signal loss when signal is displaced away from a slice or location and (c) bright "pile-up" artifacts when the signal from multiple locations shifts to a single location.

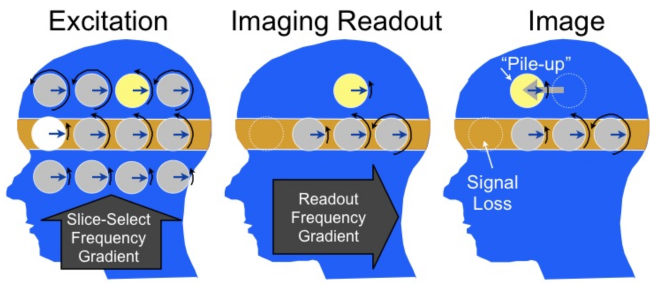

Figure 1: *Displacement artifacts near metal. During excitation, a selection gradient causes a frequency variation (black arrows) but frequency shifts cause off-resonant spins (white, yellow) to be excited in the wrong slice (white excluded, yellow included). During imaging readout, the gradient induces a frequency variation, and the off-resonant spin appears to be at the wrong location. The displacements lead to bulk distortion, signal loss and pile-up effects.*

Figure 1 demonstrates how frequency shifts cause spins to be excited in the incorrect slice (displacement of the slice), and then also displaced in the readout direction. The combination causes distortion, signal loss, and pile-up artifacts as illustrated in Fig. 2.

In-Plane Artifact Reduction: The simple, and most common way to reduce in-plane distortions is to increase readout bandwidth, at a cost of SNR. This increases the readout gradient amplitude, to increase its relative effect compared to metal-induced frequency shifts.

A further approach is view-angle tilting, whereby the slice-selection gradient is replayed during the readout [3]. This maintains the same resonance frequency range excited by the RF pulse during readout, so that the readout shifts are cancelled to about the range of a voxel [4]. Other methods attempt to measure and correct for the background shifts. Although these are effective at correcting the bulk shifts, they do not easily undo pile-up artifacts.

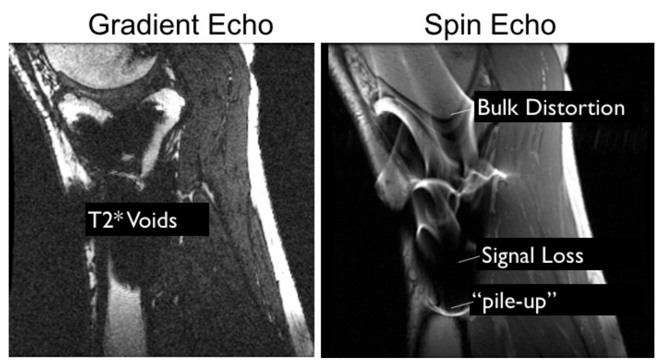

Figure 2: *Examples of metal artifacts from tibial screws. In high-bandwidth gradient-echo images, the T2* voids dominate. In spin-echo images, T2* loss is corrected, but through-slice and in-plane distortions cause bulk distortion, signal loss, and "pile-up" effects.*

Through-Slice Artifact Reduction: Increasing excitation bandwidth will reduce slice distortion, at a cost of increased RF amplitude, power and heating. The use of field mapping can further correct small slice distortions [5]. Non-selective excitations avoid distortions, but may not excite a sufficiently high bandwidth, or may not be compatible with in-plane correction methods [2,6]. Arbitrary slice distortions may be corrected by the use of through-slice phase encoding with frequency-selective [7] or slice-selective [8] excitation. Both of these methods correct most artifacts to within a pixel, but require greater scan times and ultimately trade some SNR for artifact correction.

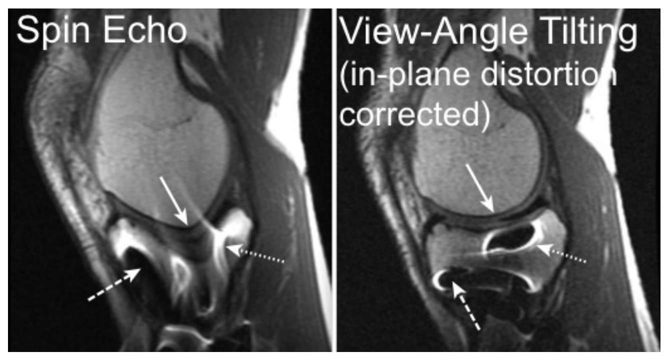

Figure 3: *Comparison of standard spin echo to view-angle-tilting (VAT). VAT corrects in-plane bulk distortion, showing the correct shape of the femur (solid arrow), and restricting the location of through-plane signal loss (dashed arrow) and pile-up (solid arrow) to the correct in-plane location. However, VAT does not correct through-plane artifacts.*

Summary: The susceptibility shifts from metal cause challenges in MRI due to T2* signal loss, and frequency shifts that cause artifacts and may require a broader excitation bandwidth. The tradeoffs involved in artifact reduction are important for general protocol optimization imaging and further research.

References: [1] Schenck JF. Med Phys, 23(6):815–850, 1996. [2] Du J, et al. ISMRM 2010, p.132. [3] Cho ZH, et al. 6th SMRM 1987, p.912. [4] Olsen RV, et al. Radiographics, 20(3):699–712, 2000. [5] Butts K et al. ISMRM 2006, p.2380. [6] Hoff MN, et al. ISMRM 2010, p.3081. [7] Koch KM, et al. MRM 2009; 61:381–390. [8] Lu W, et al. MRM 2009; 62:66–76.

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