Artifacts to Artefacts: Causes & Cures from Clinical Perspective

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Introduction: The ability of MRI to obtain data largely in a different domain, the spatial frequency domain, is both its greatest strength and weakness. As a strength, MRI non-invasively uses RF wavelengths on the orders of tens of centimeters to meters to perturb the body, yet can image at resolutions well under a millimeter without any moving parts. However, MRI does not have the same freedom to speed acquisition by adding more sensors as relatively simply as ultrasound or computed tomography can. As a weakness, the requirement that MR spatially encode its signal in another domain makes it inherently slow and prone to artifacts.

This presentation will categorize MR artifacts with two schemes, the first clinically based and the second based on the k-space acquisition.

Identifiable vs. Mimicking Pathology

As a clinician using conventional MRI and assessing new developments in the field, MR artifacts can be categorized conveniently into two categories: 1) easily identifiable and 2) mimicking pathology. Easily identifiable artifacts do not create a risk of an errant diagnosis. Rather, they create a nuisance in that regions of the body that may need to be characterized are altered by artifactual signal. Parallel imaging with too high acceleration factors cause aliasing errors that fit in this category. Here understanding of the sources of the artifact lead to changes in imaging protocol that minimize these artifacts and generally improve image quality.

Understanding artifacts that mimic pathology are obviously much more important and require more attention from physicians. While a noise-like artifact across the knee may not be bothersome to physicists, mottling the meniscus will make it much more difficult to detect meniscal tears that can be fixed with surgery. In the worst case, these mottling artifacts could mimic a meniscal tear.

Often these mimicking artifacts may not be appreciated by the physicists and imaging scientists who often develop new MR technology. Physicians who take part in clinical evaluation of new technology thus play key roles in diligently identifying mimicking artifacts before the technology is adopted on a wider scale.

Amplitude vs Phase Errors

Some knowledge of MR physics is also useful in categorizing and understanding MR artifacts. It is useful to think first of an image of the body having a perfect acquisition in k-space, which then undergoes some type of error. One can categorize those k-space errors as amplitude errors or phase errors. Having some appreciation for the relation between k-space and image space can simplify your understanding of how errors in k-space are likely to appear in the image. However, the maturity of MRI is allowing physicians to thrive without forcing an understanding of k-space by providing more image-based discussions of artifacts[1]
In general, more sources of image degradation are caused by phase errors than amplitude errors. Phase errors are somewhat harder to conceptualize than amplitude errors for many. Phase errors typically cause blurring and eventually cause signal in localized regions to dropout completely, leaving no way to assess tissue in those localized regions.

MR imaging is more resilient to amplitude errors, though amplitude errors can be significant. For example, the slow acquisition speed of MR causes it to sample signal from arteries at numerous points in the cardiac cycle and thus under different velocities and thus different amounts of RF saturation. Differing amounts of RF saturation thus lead to different signal levels for blood vessels in differing regions of k-space. These amplitude errors manifest themselves as ghosted replicas of the vessel in the phase encoding direction. The significance of these ghosts will depend on where they reside. If the flow in the vessel is turbulent enough, loss of signal can also occur due to dephasing of flowing spins within a voxel (a phase error).

**Tradeoffs**

In general, techniques that minimize artifacts often take more imaging time than those that don’t. For example, spin echo imaging removes chemical shift and signal loss due to B0 inhomogeneity, but often at a significant increase in imaging time compared to gradient recalled echo imaging. The physician must balance the drivers for speed, such as capturing physiological motion, imaging uncooperative patients, and economics vs the downside of creating imaging artifacts.

Discussion of artifacts will be provided in this context, with efforts to relate them to topics discussed earlier in the week including spin vs gradient echo, Fast Spin Echo or Turbo Spin Echo, high field diffusion imaging, and contrast agents.