

"Pitfalls in Diffusion: What Artifacts Should I Worry About?"

Pratik Mukherjee, MD PhD

SYLLABUS

This presentation covers the sources of many common diffusion image artifacts. Some of these arise from the limitations of single-shot echoplanar imaging (EPI), including *low spatial resolution, blurring effects of T2* decay and T2 decay* occurring during image readout, and sensitivity to artifacts due to *Nyquist ghosting, chemical shift, magnetic field inhomogeneity, and local susceptibility effects*. The very rapid acquisition times of single-shot EPI is helpful because even minimal bulk patient motion during acquisition of diffusion-weighted images can obscure the effects of the much smaller microscopic water motion due to diffusion. Furthermore, the motion insensitivity of single-shot EPI means that DWI can often produce diagnostic results in ill, uncooperative patients where most other sequences are too motion-degraded to be useful.

As diffusion gradients become more powerful, they may exacerbate problems such as *eddy currents and mechanical vibration*. All MR gradient coils are self-shielded to prevent eddy currents, which are residual magnetic fields induced by gradient switching that persist after the gradients are turned off. However, self-shielding is inadequate for the large amplitude and rapid onset and offset of diffusion-sensitizing gradients at high *b* values. Eddy currents cause three different types of image artifacts in DWI: *scaling, shift, and shear*. Scaling refers to expansion or contraction of the diffusion-weighted

image. Shift describes displacement of the image along the phase-encoding direction. Shear denotes shifting of the image in opposite directions on the left and right sides. Diffusion gradients are powerful enough to shake the entire MR scanner and its platform, too. These mechanical vibrations may be transmitted to the patient and cause characteristic artifacts in the diffusion-weighted images. Vibrations induced by diffusion-encoding gradients increase strongly with b value.

New multi-channel phased array head radiofrequency (RF) coils with better SNR characteristics than the standard birdcage head RF coils have improved DWI, which is an SNR-limited modality. Another advantage of phased array head coils is their multiple independent receiver channels, which enable parallel imaging on modern MR systems. Parallel imaging techniques such as sensitivity encoding (SENSE), array spatial sensitivity encoding technique (ASSET), and generalized autocalibrating partially parallel acquisition (GRAPPA) can all be used to shorten the echo train length of EPI, thereby mitigating *susceptibility-induced geometric warping artifacts* and reducing the *blurring of T2 and T2* image contrast* that occurs with extended EPI echo trains. Moreover, due to the shorter readout, the TE may be decreased, which has the effect of improving SNR and further reducing susceptibility and *off-resonance artifacts* as well as *T2 shine-through*. These substantial improvements increase with the acceleration factor used in parallel imaging, but must be balanced against the greater loss of SNR at higher acceleration. However, parallel imaging can also introduce new types of artifacts into DWI, such as the *unfolding artifact*. Image domain parallel imaging techniques work by unfolding and combining small field of view (FOV) images from each receiver channel

to form the full FOV image. SENSE and ASSET both require a calibration scan performed prior to DWI to estimate the sensitivity profiles of each of the coil elements. The calibration may be inaccurate in areas of warping on DWI, especially at high field where the geometric distortions are more pronounced, leading to unfolding errors in the parallel imaging reconstruction that appear as ghosting along the phase encoding direction.