ISMRM 2013 Weekend Education Course
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Title: Gradients: What Can They Do? (ID: 7321)
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A key component of MR imaging systems, called gradients, introduces a well-controlled spatial variation in the otherwise uniform magnetic field inside the imaging volume for a specific time period. Such gradients, independent in all three orthogonal spatial directions, are used extensively in modern MRI techniques for 1) spatial localization and spatial encoding; 2) artifact suppression and 3) motion sensitization and quantification and are responsible for the sounds many of us grew familiar with.

In the case of spatial localization, a gradient is imposed at the same time as an RF pulse. Only the spins with resonance frequency within the bandwidth of the RF pulse will experience its effect. Such conditions allow for selective manipulation of magnetization within certain regions, typically a slice or slab perpendicular to the direction of the gradient, so that only the selected magnetization contributes to the final images or experiences saturation. In case of spatial encoding, the gradients are used to produce spatial dependent frequency differences or phase shifts in the magnetization. Such frequencies and phase differences embedded in the received signal can be decoded by the reconstruction algorithm to sort out their spatial origins. Gradient based spatial localization and encoding can be applied either independently or in conjunction to produce multi-dimensional MR images with high spatial resolution.

Another kind of use of gradients is to eliminate the undesired magnetization which would otherwise cause image artifacts and reduce image contrast. If the dispersion of accumulated phases within a voxel is large enough as the result of gradients, the net magnetization approaches zero. Examples for such application of gradients are crushers, which suppress the magnetization arising from the imperfection of the refocusing RF pulse, and spoilers, which suppress the magnetization remaining from previous excitations.

While a gradient pulse generates different amounts of phase accumulation along the direction of the gradient, a second gradient pulse with opposite polarity can cancel out such phase accumulation if the spins remain stationary. If not, a net phase shift remains after such bipolar gradients. Such phenomena allow motion-sensitizing gradients to be incorporated into various pulse sequences to quantify diffusion, flow or other types of motion and leads to many advanced and quantitative MRI applications such as DWI/DTI, Phase contrast MR Angiography/Flow Quantification and more recently MR Elastography.

The purpose of this lecture is to illustrate these fundamental concepts in detail and therefore provide the basis for understanding MR image formation and advanced techniques. Such knowledge is essential for anyone involved in the clinical applications such as radiologists and MR technologies in order to select appropriate techniques and imaging parameters and is critical for those involved in the technical developments such as engineers and scientists in order to implement them correctly to achieve desired results.

1. Bernstein MA, King KF, Zhou XJ. Handbook of MRI Pulse Sequences, Chapter 7-10. Academic Press 2004