MR Physics & Techniques for Clinicians: Ultrafast Imaging

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Introduction

The purpose of this lecture is to introduce various methods used in MRI to reduce acquisition times, and the ensuing pitfalls of these fast methods. An excellent, detailed overview of the topic is given by Jeffrey Tsao [1]. To start, the main advantages of ultrafast imaging are: (1) reduced sensitivity to motion, and (2) allowing clinically feasible acquisition times for scans that have limited imaging windows (e.g., ECG/respiratory-gated schemes, dynamic imaging or magnetization-prepared sequences). Example applications are discussed throughout the lecture.

Strategies

There are several strategies to reduce acquisition time or increase temporal sampling and they can be categorized by complexity. We assume that the desired image parameters (such as FOV, resolution) do not change.

<u>Simple:</u> Increase readout bandwidth (a.k.a. data sampling rate) which reduces the readout period. Reduce TR although the image contrast might change.

<u>Intermediate:</u> Use echo-train imaging (RARE, EPI) so that fewer excitations are required. Use rapid gradient echo methods such as balanced/fully-refocused SSFP. If magnetization preparation schemes (e.g., IR, fat sat, T2-prep) are used, "fast" imaging / k-space segmentation is used to the reduce number of magnetization preparation modules required.

<u>Advanced:</u> Use non-Cartesian trajectories (spiral, rings or cones) to increase readout length per excitation; these methods require a re-gridding process in order to use Fourier reconstruction. Use parallel imaging or compressed sensing to reconstruct under-sampled data (not discussed in this lecture).

Disadvantages

Two main disadvantages arise from increasing imaging speed:

(1) Decreased signal-to-noise (SNR). Without any sophisticated reconstruction process, the MR image SNR is directly proportional to the square root of the time spent acquiring data.

(2) Increased image artifacts. Generally, echo-train imaging and longer readouts (EPI and non-Cartesian) are more sensitive to hardware imperfections (e.g., eddy currents, static magnetic field or B_0 inhomogeneity). Under-sampling beyond the capability of the phased-array receive coils leads to increased noise and ghosting.

Solutions

The chart (Fig. 9 from [1]) on the right summarizes several solutions to mitigate SNR loss and image artifacts. In general, we can improve image quality by careful consideration of hardware settings and pulse sequence design, combined with clever reconstruction methods.
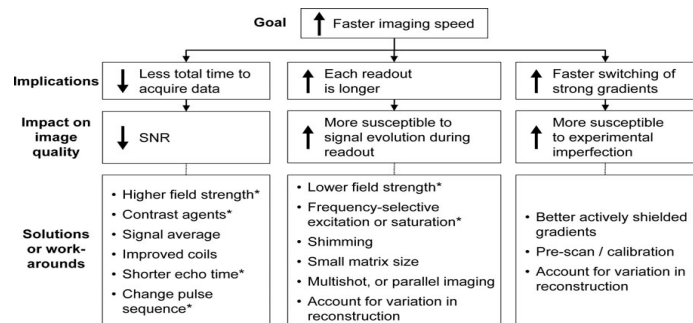
Summary

Imaging speed of MRI has significantly improved over the past few decades and several methods now allow robust and fast acquisition of images in the clinical setting.

References

1. Tsao. Ultrafast imaging: principles, pitfalls, solutions, and applications. J Magn Reson Imaging (2010) vol. 32 (2) pp. 252-66.