Complementary Techniques for Accelerated Imaging

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7.1 Introduction

In many MR imaging applications, a short scan time is required to observe dynamic processes such as the beating heart, the passage of a contrast bolus, guidance of an interventional procedure, or to reduce artefacts from physiological motion. The previous chapters explored the design of rapid sequences, the use of alternative k-space trajectories, and parallel-imaging techniques to achieve faster acquisitions. This chapter discusses techniques that reduce imaging time for a desired spatial resolution by exploiting assumptions of redundancies in the sampling of static images or dynamic time series that allow minimal errors in the reconstruction. For all of these approaches, a single receiver coil is sufficient, and most of them can be combined with parallel imaging techniques when multi-channel receiver coils are used as described in Chap. 11.

7.2 Partial Fourier Acquisitions

Partial Fourier imaging refers to MR acquisitions in which Fourier space is not sampled symmetrically around its origin. The missing data are either simply replaced by zeros, or they are calculated during the reconstruction process from the acquired data. Most commonly, data sampling in MR imaging occurs on a rectilinear grid in Fourier space, also referred to as k-space. Figure 7.1 illustrates strategies to save imaging time for a given field of view by purposefully leaving areas of the 2D Fourier space grid unsampled. The total imaging time is determined by the product of the number of phase-encoding steps and the repetition time, TR. The imaging time required to sample a 2D image (a) fully can be reduced by partial phase encoding, where some phase-encoding steps are not acquired (b). Alternatively, the minimum TR can be reduced by the acquisition of a partial echo (c), also referred to as an asymmetric or fractional echo, which also reduces flow-induced artefacts. It is possible to combine both partial phase encoding and partial echo acquisition to further minimize imaging time (d).

Even though most diagnostic images are shown as magnitude images, all MR images are completely characterized in a complex notation only. In other words, two matrices showing either the real and imaginary components or the magnitude and phase of the image data are required to represent uniquely such a data set. Figure 7.2 demonstrates the complex data sets of a head scan in k-space and in image space.
Fig. 7.1a–d. The Fourier space grid can be sampled more rapidly if areas are purposefully left out with a partial Fourier acquisition. In comparison to a fully sampled data set a, the imaging time can be shortened by reducing the number of phase-encoding steps for asymmetric coverage of k-space b. Alternatively, the echo time and repetition time can be reduced by the acquisition of a fractional echo along the readout direction c. These two techniques can be combined to further reduce total imaging time by sampling slightly more than one quadrant of k-space d. For proper image reconstruction, a certain region of k-space has to be sampled symmetrically around the origin to provide a reasonable low resolution phase estimate of the image (solid rectangles in b and c).

Fig. 7.2a–d. The magnitude a and phase b of the raw k-space signal acquired during a head scan. The magnitude c and phase d of the corresponding representation in image space is obtained by an inverse 2D Fourier transform. In this example, the image phase varies slowly in the diagonal of the sagittal slice, more rapidly at some tissue interfaces, and is random in the surrounding air.