Due to the repetitive nature of the data acquisition process in MRI, states of nuclear magnetization play an important role in the design of MR imaging protocols. In a standard Spin Echo protocol, the sequence repetition time is long enough that no transverse magnetization remains at the end of the cycle. As a result, the magnetization used to encode the image data is the same from view to view, which allows for straightforward encoding scheme.

When the acquisition process is accelerated to shorten the exam time, a residual transverse magnetization exists at the end of each repetition cycle and the magnetization used to encode the image data will vary from view to view. If the acquisition scheme is not specifically implemented to minimize the impact of this effect, large artifacts (severe ghosting or blurring) will occur in images.

Two practical approaches emerged to solve this problem. In one approach, known as a k-space reordering, nonstationary states of magnetization are used to encode the image data in a carefully crafted temporal order. As a result, the image is acquired quickly but a trade-off exists between the speed of acquisition that minimizes motion artifacts and the image blurring caused by k-space reordering of nonstationary magnetization states. This method is utilized in fast spin echo, turbo (magnetization prepared) gradient echo, mixed gradient- and spin- echo, and various implementations of echo planar imaging sequences.

In the other approach, a stationary state of magnetization is created by using a series of evenly spaced rf pulses. This stationary state is shown to be a sum of magnetic substates, each with unique contrast characteristics. When more than one substate contributes to an MR image, the substates interfere with each other, producing ghosts and other artifacts. However, appropriately designed gradient protocols can image single substates, producing ghost free, non-blurred images. The contrast of the image depends largely on the choice of the imaged substate. This method is utilized in fast gradient echo protocols that are used in MR angiography, dynamical contrast uptake studies, and functional MRI.

The needs of commercial MR market resulted in a wide range of proprietary protocols introduced to clinical use under a variety of trademark acronyms. Vendors claim that each protocol is unique and distinctly different from all others. However, when a detailed analysis of physical principles that govern the design of fast MR imaging protocols is performed, a simpler pattern emerges. Since the implementation details of an imaging protocol matter to imaging clinicians only to the extent to which these details affect the image contrast, it becomes possible to divide the large number of existing protocols into a few simple classes. Each protocol within a class, although possibly containing unique proprietary implementation elements, produces images with the same contrast when used with the same set of imaging parameters.

Educational Objectives

1. Review recent advances in fast MRI applications
2. Formulate conditions necessary and sufficient to produce artifact-free images using stationary and non-stationary states of magnetization.
3. Understand commercial implementations of fast MRI protocols.