

MRA: Contrast-Enhanced Techniques Stephen J. Riederer, Ph.D.

Contrast-enhanced MR angiography (CE-MRA) was first discussed in the mid-1990s. Since that time the technique has evolved in that image quality has improved markedly, the extent of applications has expanded widely, and some kind of CE-MRA package is now offered on virtually all commercial MRI scanners. The purpose of this presentation is to provide an overview of contrast-enhanced MRA, including a review of how this technique has developed since its initial description in the mid-1990s, how it is used today, and what emerging methods may provide further advances in the future.

Although it is possible to perform MR angiography without the administration of contrast agents, such methods are prone to certain limitations which can adversely affect image quality. These include undesirable spin dephasing due to motion, limited signal enhancement if the flow in the target vessel is not adequately fast or pulsatile, and relatively long acquisition times. These can lead to artifactual signal reduction, diminished vascular signal, and increased sensitivity to motion. Thus, a major driver for contrast-enhanced methods is to avoid these limitations.

The effective implementation of contrast-enhanced techniques brings about its own challenges. Central in these is the limited duration over which contrast-enhanced blood fills the target vessels, generally on the order ten seconds for the first pass. This is a driver for high speed. A variety of methods have been developed and are continuing to be developed to address this, including high performance gradients to allow short TR times, and various means for allowing undersampling of k-space such as partial Fourier, acceleration techniques such as SENSE and GRAPPA, and more recently compressed sensing. Another challenge is to accommodate the broad patient-to-patient range of transit times of the contrast agent from the injection site to the targeted vasculature. This has been addressed historically by use of a test bolus or fluoroscopic triggering, but contemporary methods such as highly accelerated time-resolved techniques may also be applicable.

Ongoing research is directed toward improved performance and expanded applications. As acceleration methods have become more integral to CE-MRA studies it is of interest to determine what the limit is in their implementation, and “acceleration optimization” is an area of interest. For many anatomic regions it is desirable to suppress the unwanted fat signal, and this is typically performed by acquiring a pre-contrast data set and subtracting it from the post-contrast images. However, this is prone to artifact from subject motion, such as in the abdomen. To address this, investigators are turning to alternative methods for performing fat-suppressed CE-MRA such as with variants of the Dixon technique. Yet another area of expanding application is that of aiding in the planning of reconstructive surgery and providing delineation of arteries and veins of tissue flaps.

CE-MRA is accepted clinically and recognized as a very valuable application of MRI. Its unique requirements have contributed to the impetus for improved technical performance on clinical MRI scanners, such as in faster gradients, high count multi-coil receiver arrays, real-time signal processing capabilities, and sophisticated image reconstruction methods. This trend is expected to continue with further advances.