Magnetic resonance angiographic imaging techniques can be categorized as *phase contrast*, *time-of-flight*, or *contrast-enhanced* methods. When properly implemented, all of the MR angiographic methods can yield diagnostic-quality images.

Phase contrast techniques derive contrast between flowing blood and stationary tissues by manipulating the phase of the magnetization. Data acquired using phase contrast methods can be used to produce phase-difference, complex-difference, or magnitude images. The phase difference images can be used to determine quantitative information regarding the velocity and volume flow rate of the blood.

Phase contrast methods can be implemented using two-dimensional or three-dimensional acquisition. Two-dimension acquisition can be completed rapidly and is effective for localizing. It also can be cardiac gated to provide velocity or volume flow rate information throughout the cardiac cycle.

Time-of-flight techniques derive contrast between flowing blood and stationary tissues by manipulating the magnitude of the magnetization. With these methods, the contrast between blood and stationary tissues is strongly dependent on several imaging parameters, including TR, slice thickness, tip angle, slice orientation, etc., which must be carefully chosen when designing imaging protocols.

Time-of-flight methods can be implemented using two-dimensional or three-dimensional acquisition. When three-dimensional acquisition is employed, additional mechanisms must be implemented in order to reduce the signal from stationary tissues, including the use of magnetization transfer, the appropriate echo time, and a ramped tip angle. With both two-dimensional and three-dimensional acquisition methods, a spatial

saturation pulse can be applied outside the imaging volume to eliminate signal from unwanted venous blood that is going to flow into the imaging volume.

Contrast-enhanced techniques derive signal differences between blood and stationary tissues by manipulating the magnitude of the magnetization. These signal differences are achieved by using the appropriate acquisition parameters and an intravenous injection of a contrast agent into the vascular system, which selectively, and dramatically, shortens the T1 of the blood. By implementing a T1-weighted imaging sequence during the first pass of the contrast agent, images can be produced that show arteries with striking contrast relative to surrounding stationary tissues and veins. Synchronizing the acquisition with the arrival of the contrast agent is critical to image quality. Several methods have been developed to ensure proper timing of the acquisition relative to the passage of the contrast agent. Contrast enhanced methods provide high quality images with fewer artifacts than the non-contrast-enhanced methods. Large fields-of-view can be imaged to demonstrate large vascular areas in a short acquisition time. The short imaging time permits acquisition in a single breath-hold interval, providing high quality images even in areas affected by respiratory motion.

After attending this Refresher course, the participant will be able to:

1. Describe the characteristics of each of the MRA techniques, and the mechanisms that are employed to achieve contrast in each of the three classes of MRA techniques.
2. Identify artifacts associated with each of the MRA techniques, and suggest modifications to diminish or eliminate the artifacts.

3. Determine which MRA techniques are best suited for given applications.