Measuring Blood Flow with MRI
Tuesday, August 11, 8:35 to 9:30 am

This presentation focuses on the phase-contrast magnetic resonance imaging (MRI) quantitative flow (Q-flow) method and its variants (i.e. complex difference). The accuracy and utility of MRI Q-flow measurements versus other approaches such as the indicator dilution method, flow meters, and Doppler ultrasound shall be examined. The MRI methods demonstrate several benefits when compared to more conventional clinical methods for measuring blood flow.

The motion of nuclear spins easily modifies the phase of the MRI signal. Although this phenomenon can lead to image artifacts, when it is properly managed MRI can be used to measure *in vivo* physiological flow non-invasively. The concepts of gradient moment nulling and velocity-encoded gradient waveforms are used in the phase-contrast MRI method. To process the velocity image a threshold must be set, which is determined by considering the different influences of noise on the MRI phase and magnitude MR images.

Proper application of MRI to the measurement of physiological flow requires consideration of the classical physics of flow, including the work of Reynolds and Bernoulli, with particular attention to flow in the human cardiovascular system. An understanding of laminar flow characteristics and the properties of turbulence and flow structure at vessel branches and stenoses is important for the proper design of MRI Q-flow pulse sequences. The principles and history of MR flow measurements, including phase-contrast and time-of-flight approaches, should be contemplated in this context.

Specific sources of MRI Q-flow errors that the MRI physicist should understand include intravoxel phase dispersion, improper setting of the velocity sensitivity, and the misalignment of the flow-encoding gradient with the axis of blood flow. When determining flow in small vessels the partial volume effects on the accuracy of the velocity measurement must be taken into account. Fast imaging methods, such as k-space segmented breath-hold gradient reversal MRI and echo-planar MRI, offer significant advantages for the accurate measurement of pulsatile flow in difficult clinical situations. Based on these considerations, strategies for the design of effective MRI Q-flow studies are developed.

MRI Q-flow has been shown to be effective for assessing various pathological conditions such as cerebrovascular abnormalities, renal hypertension, intracardiac shunting and coronary artery disease. MRI Q-flow data from measurements performed on patients with these conditions, compared to data from conventional clinical flow measurement methods, demonstrate the potential utility of Q-flow MRI. Despite these promising results, educational and technological difficulties have limited the routine use of MRI Q-flow measurements to the academic MRI clinic.

Educational Objectives:

1. Understand the basic principles of MRI Q-flow measurements.
2. Identify clinical conditions for which MRI Q-flow would have potential benefits.
3. Be able to plan an MRI Q-flow study to minimize artifacts and maximize accuracy of the measurement.

This work has been done during the tenure of an Established Investigatorship from the American Heart Association.