

Coronary Artery Wall Imaging and Assessment of Flow

Jennifer Keegan PhD, Royal Brompton Hospital, London

Who will benefit from this information?

Like X-Ray contrast angiography, MR coronary angiograms show the vessel lumens, rather than the vessels themselves and consequently, outward remodeling of the vessel wall - which occurs in subclinical coronary disease prior to luminal narrowing - cannot be seen. The current gold standard for assessing the coronary vessel wall is intravascular ultrasound, and more recently, optical coherence tomography, both of which are invasive and use ionizing radiation. A non invasive, low risk technique for assessing the vessel wall would be beneficial to cardiologists interested in the early detection of preclinical disease and for the safe monitoring of the progression or regression of disease in longitudinal studies.

In later stages of coronary disease, the vessel lumen becomes compromised and while this can be observed on MR coronary angiograms, and the diameter reduction estimated, this does not tell us about the functional significance of the stenosis. However, both phasic coronary artery blood flow and flow velocity may be affected and the ratio of coronary artery flow under maximal vasodilation to that at rest (the coronary flow reserve) is a good indicator of the physiological significance to the myocardium. MR measurement of coronary flow and velocity would therefore be beneficial for the non-invasive assessment of the physiological significance of coronary artery disease.

How was a problem determined?

For both vessel wall imaging and flow assessment, spatial and temporal resolutions are key issues. High spatial resolution is required to increase the number of pixels across the vessel and vessel wall and in addition, for flow studies, to reduce partial volume flow effects. For vessel wall studies, short and accurately-timed subject-specific acquisition windows are crucial to avoid motion blurring and artefact. Short acquisition windows (and high temporal resolution) are also

required for coronary flow studies, both to minimize motion blurring and to be able to accurately resolve peaks in the bi-phasic coronary temporal flow profiles.

While coronary flow studies have generally been performed during breath-holding, the higher spatial resolution required for vessel wall imaging has generally tended to favour free-breathing navigator gated studies. Issues relating to respiratory motion are therefore particularly relevant and scan times can be long without good image quality being assured.

Examples of how this issue has been addressed

The most common sequence applied to coronary vessel wall imaging is double inversion dark-blood prepared turbo spin echo (TSE). This can be performed in 2D with limited resolution in a breath-hold, and with improved resolution and 3D coverage with navigator-gated free-breathing. Navigator-gated dark-blood prepared 3D spiral imaging has also been used and has the advantages of inherently efficient k-space coverage and short acquisition windows which minimize the detrimental effects of cardiac motion. Radial k-space coverage has also been used with good results. Regardless of the method of k-space coverage, dark-blood prepared techniques require careful adjustment of the inversion time to minimize coronary blood signal and to maximize blood-wall contrast and a phase-sensitive approach has been shown to be useful. Three-D coverage is preferable as it has the potential for detailed assessment over multiple thin contiguous slices with higher SNR per unit acquisition time. However, navigator-gating is an inherently inefficient technique and acquisition durations may be prolonged, particularly with irregular breathing patterns and/or respiratory drift. More complex respiratory motion correction techniques may be of use – for example, a recent retrospective beat-to-beat image-based respiratory motion correction approach has resulted in highly efficient data collection with good reproducibility, albeit with retrospective (and time consuming) reconstruction.

For coronary flow, most early work was based on the segmented FLASH sequence with through-plane velocity encoding of ± 25 cm/s. However, the long acquisition windows resulted in limited temporal resolution (improved with view-sharing) and most recent work has been performed with short spiral readouts which result in high temporal resolution and limited motion blurring. Recent work at 3T has also shown significant improvements in signal-to-noise ratio. Due to the limited number of pixels across the vessel – and consequent inaccuracies in determining the vessel cross-sectional area – most groups have focused on measuring

coronary flow velocity, rather than coronary flow. Alternatively, some groups have measured flow in the larger and less mobile coronary sinus as this is a marker of total coronary flow (96% of ventricular drainage enters the right atrium through the coronary sinus).

What learners will be able to do differently because of this information

Coronary vessel wall imaging is difficult and requires very careful attention to detail - correct setting of the dark-blood inversion time, meticulous setting up of the navigator, and tailoring of the sequence parameters to the individual patient. In particular, motion blurring and artifact should be minimized by careful adjustment of the acquisition window to the patient's own cardiac rest period. Heart rate lowering medications may be helpful.

Coronary flow assessment isn't easy either! To date, it would seem that the best technique is spiral imaging as this gives high signal to noise ratio with short readouts and consequently high temporal resolution. Off resonance blurring of fat can be much reduced by using water-excitation RF pulses which also results in good contrast between the vessel and its surroundings. If conventional k-space coverage is the only available option, it may be more realistic to aim to measure coronary sinus flow as a surrogate for total coronary flow.