Stress MRI for Evaluation of CAD – Acquisition Issues

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Background

There are a wide range of sequence designs and parameters to consider when optimizing an acquisition protocol for myocardial stress perfusion imaging. This presentation will describe the technical issues, interdependence between acquisition parameters, and provide insights into the various performance tradeoffs. It will review the basic design for T1-weighted first pass myocardial perfusion imaging, and go on to discuss the tradeoffs associated with various schemes to provide multi-slice coverage. Artifact mechanisms will be discussed and related to sequence design and parameters. Additionally, the selection of quantitative versus qualitative analysis affects various performance requirements, such as spatial and temporal resolution and linearity of enhancement. Understanding the interaction between the pulse sequence parameters and resulting image quality is important for improving myocardial perfusion imaging.

Imaging requirements

Successful myocardial perfusion imaging requires optimizing sequence and parameters to meet often contradictory requirements. The basic requirements are:

1. Temporal Resolution.

Several distinct measures of temporal resolution are important for perfusion imaging. The time between two images of the same slice location affects the ability to sample the dynamic signal intensity changes during the first pass to allow modeling the kinetics of blood flow to the myocardium. Typically, images are acquired every 1-2 heartbeats to adequately sample myocardial blood flow. For quantitative perfusion, an accurate estimate of the arterial input function may require sampling the LV blood signal every heartbeat. Also of importance is the time per slice (T_{slice}) within the cardiac cycle, and the actual duration of imaging readout ($T_{imaging}$) which determines the sensitivity to cardiac motion.

2. Spatial Resolution

The spatial resolution must be adequate to distinguish sub-endocardial ischemia (< 3 mm in-plane) and to assess transmural extent of defects. Improved spatial resolution is also beneficial in order to reduce “dark rim” artifacts.

3. Spatial Coverage

It is desirable to have full coverage of the heart. A minimum of 3 slices is generally considered adequate to cover at least 16 segments of the heart. A greater number of slices is desirable.

4. Linearity

A linear or quantifiable relationship between signal intensity and contrast agent concentration is desirable in order to quantify perfusion.

5. Image Quality

Image quality must be sufficient to provide contrast between normal and ischemic regions and must be free of artifacts.

The desire to quantify myocardial perfusion imposes additional requirements regarding accurate knowledge of the arterial input function, which represents the delivery of contrast to the

heart and is commonly estimated from the blood signal. Therefore, quantitative myocardial perfusion imaging requires measuring both the blood and myocardial signals. The blood and myocardium have different contrast agent concentrations as well as T1, T2, and T2* relaxation parameters leading to significantly different imaging characteristics and signal intensities.

Acquisition Issues:

A number of acquisition issues must be considered:

1. Type of sequence, e.g., SR-SSFP, SR-FLASH, SR-hybrid GRE EPI and how this choice affects SNR, CNR, and artifacts.
2. Linearity of signal vs contrast agent concentration and dependence on TI, excitation flip angle, and readout type
3. Saturation performance of SR preparation pulse
4. Artifacts mechanisms such as transient approach to steady state, fat, Gibb's ringing
5. Parallel imaging and temporal fidelity
6. Method for acquiring arterial input function from blood pool signal
7. Heart rate variability and ECG gating
8. Respiratory motion and breath-holding

There are numerous publications that describe individual sequences or comparisons. The reader is directed to the 2 reviews cited below and the references contained within.

References

1. Kellman P, Arai AE. Imaging sequences for first pass perfusion – a review. J Cardiovasc Magn Reson 2007. 9(3):525-537.
2. Gerber BL, Raman SV, Nayak K, Epstein FH, Ferreira P, Axel L, Kraitchman DL. Myocardial first-pass perfusion cardiovascular magnetic resonance: history, theory, and current state of the art. J Cardiovasc Magn Reson. 2008. Apr 28;10:18.