Stress MRI for Evaluation of CAD

Post-Processing Issues

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Introduction: A wide range of post-acquisition approaches is used to assess myocardial perfusion, ranging from visual evaluation and scoring, to full quantification of myocardial blood flow using tracer-kinetic modeling, or model-independent approaches. Common to all of them is the goal of achieving diagnostic and/or quantitative accuracy. The approaches for post-processing are divided for this presentation into three categories: qualitative evaluation, semi-quantitative analysis, and absolute quantification of perfusion. The technical requirements, time-demands, and complexity of the analysis increase in the same order. The added effort required for a quantitative approach is partially justified by the improved accuracy in the detection of coronary artery disease, as demonstrated in a recently published study. [1]

Qualitative Analysis: For a qualitative analysis the presence of perfusion defects is evaluated during review of the "first-pass" images in cine mode. The conspicuity of a perfusion defect depends not only on the severity of the blood flow deficit, relative to other areas of the LV wall in the same heart, but also on contrast dosage, image quality (contrast-to-noise), and last but not least, the experience of the observer. Rest and stress studies are compared to distinguish artifacts (e.g. "dark rim" artifact) and true perfusion defects.[2]

Semi-Quantitative Analysis: A less observer-dependent approach consists in segmenting the perfusion images along the endo- and epicardial borders to generate signal intensity versus time curves, which depict the contrast-enhancement in a user-defined region, or a myocardial segment, during transit of the contrast bolus. The slope of a signal-intensity curve during the early phase of contrast enhancement, often referred to as "up-slope" in the cardiac MRI perfusion literature, is the most commonly used parameter for a semi-quantitative evaluation of perfusion.[3] The up-slope parameter has an approximately linear dependence on blood flow, and it can be used to gauge the relative variation of blood flow within the LV wall during a given hemodynamic state. But like most parameters derived from signal intensity curves, it depends on the shape of the arterial input, and therefore also on the hemodynamic conditions. [4] More recently the area under the myocardial signal curve, up to the time where the first pass peak is observed in the blood, was used to estimate the perfusion reserve, and validated against microsphere measurements[5].

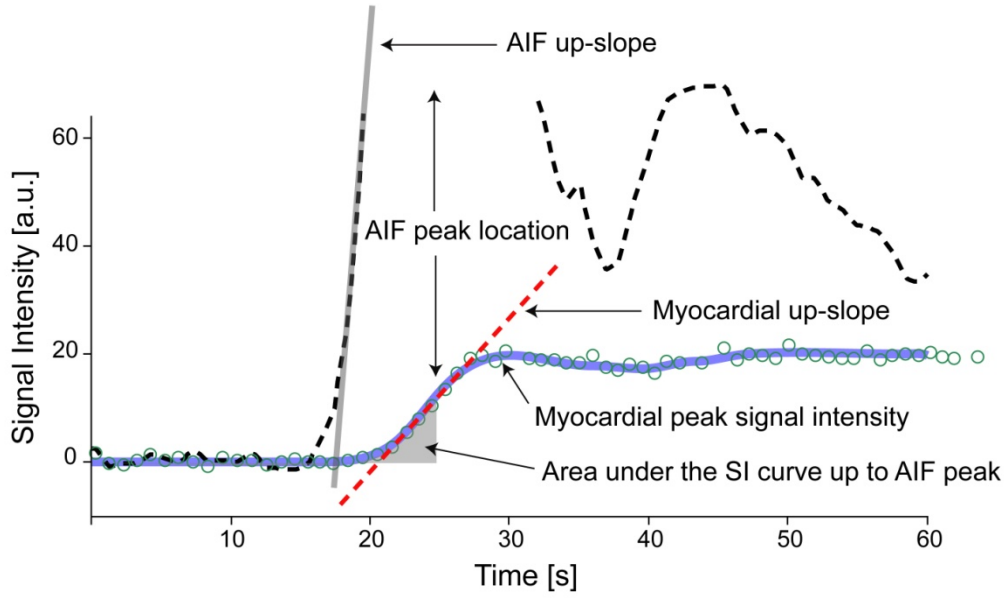

Figure 1: The characteristics of myocardial contrast enhancement have been assessed in the literature using several semi-quantitative parameters, as illustrated in this example, showing the signal intensity changes in the LV blood pool (arterial input function – AIF), and in an anterior segment of the left ventricle (green circles). The dashed red line is commonly referred to as the up-slope parameter, and gives the initial rate of contrast enhancement. It is often normalized by the up-slope of the AIF, as an empirical correction factor to account for hemodynamic changes between rest and stress. The area under the tissue curve (gray shaded area) up to the location in time where the peak of the AIF is observed has been proposed as an alternative parameter to assess perfusion and the perfusion reserve. The myocardial peak signal intensity during the first pass of the contrast bolus in the LV is arguably the least flow-sensitive parameter, and therefore only used to assess contrast-to-noise, but not changes or differences in myocardial perfusion.

Absolute Perfusion Quantification: Model-based perfusion analysis describes the myocardial tissue as a set of compartments and spaces, combined with numeric models of the transport of contrast through the vascular compartments/spaces, and of the exchange of contrast between compartments/spaces. The parameters of the model, like blood flow, are determined, by sensitivity analysis, and by adjustment of the paramater values to achieve optimal agreement of the model outputs (e.g. concentration vs. time curves) with the measured contrast enhancement.[6] Model-independent analysis [7] is based on the central volume principle of Zierler.[8] Briefly, it states that the response of the tissue to an arterial impulse response equals the rate of flow through the tissue region of interest. Examples of both types of analysis for quantification of blood flow will be shown in the presentation.

Representation of Results: An important aspect of semi-quantitative or quantitative post-processing is the representation of the results, which depends on whether the analysis is myocardial segment-based, or pixel based. Segment based analysis gives rise to displays of perfusion in a so-called bull's eye format. Pixel based analysis lends itself to the superimposition of parametric maps on MRI source images.

References

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