Qualitative and quantitative myocardial perfusion with arterial spin labeling

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Introduction

A reduction of myocardial blood perfusion is the main physio-pathologic mechanism determining ischemic heart disease. Whilst SPECT and echocardiography are considered the reference standards for imaging perfusion defects, MRI techniques are emerging. Dynamic imaging of the first-pass of a contrast agent is currently the most frequently used of these techniques, however, guidelines on the dose of contrast agent that a patient can receive imposes limitations on the MR protocol. Arterial spin labelling (ASL) in contrast is an alternative to first pass imaging and can be performed without the need for contrast agent. Perfusion imaging using ASL can therefore be repeated several times and requires no timing of a bolus of contrast agent. With standard ASL techniques such as flow-sensitive alternating inversion recovery (FAIR) the signal from arterial blood is measured only at one inversion time and is therefore inefficient and time-consuming. A new ASL method for brain imaging has been previously proposed which combines the FAIR preparation with Look-Locker (LL) readout [1] to allow time resolved perfusion studies by the acquisition at multiple inversion times (TI) with high temporal resolution. In this study, this technique has been modified and implemented for myocardial perfusion in a single breath hold. Furthermore, the combination of T_1 mapping and ASL allows quantification of myocardial blood flow [2-4]. Quantification of myocardial blood flow can be used as an indicator of microvascular function and can provide sensitive information about heart function. In this study, the combination of qualitative and quantitative assessment of myocardial perfusion is presented in only two breath holds. First results are shown in 6 healthy volunteers.

Methods

Imaging was performed on a clinical 3T scanner (Achieva, Philips Medical Systems) using a 6 channel cardiac coil. The new sequence for a qualitative assessment of myocardial perfusion is shown in Figure 1. A FAIR ASL scheme was combined with a LL sampling principle [1]. Using this, a 2D single breath hold imaging sequence was created with retrospective gated cine acquisition with a high temporal resolution (20 ms) and a segmented k-space combined turbo field echo and echo planar imaging (TFE-EPI) readout (TFE factor: 2, EPI factor: 5, $\alpha = 6°$, TR/TE = 10/3.1, SENSE factor of 2, resolution: 1.5/1.5/10 mm^2). Total scan time was 14-22 seconds. At the beginning of each cardiac cycle, an ECG-triggered inversion pulse (either slice-selective or non-slice selective) was performed resulting in a slice selective and non-selective LL image series. The difference of these two image series showed the signal of inflowing blood into the myocardium.

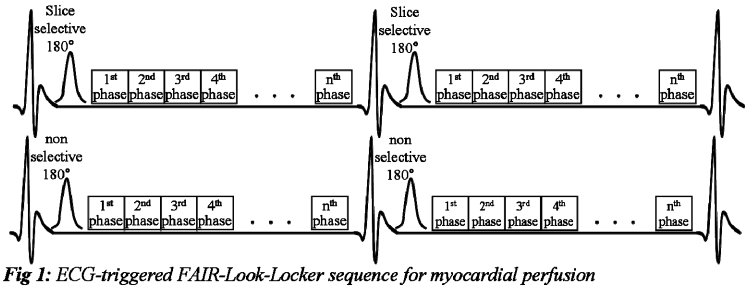

***Fig 1:** ECG-triggered FAIR-Look-Locker sequence for myocardial perfusion*

For the quantitative assessment of myocardial perfusion, T_1-mapping after non-selective and slice-selective IR preparation was performed [3]. For the accurate and reproducible measurement of T_1, modifications were made to the MOLLI [5] sequence. An ECG-triggered single-shot SSFP sequence was used to reduce the influence of the imaging readout on the T_1-relaxation [6]. Furthermore, to reduce the acquisition window, the quantitative ASL sequence was combined with k-t SENSE with an acceleration factor of 4 using the simultaneous measurement of training data [7]. This scan used the following imaging parameters: $\alpha = 30°$, TR/TE = 2.4/1.2, half Fourier, resolution: 1.5/1.5/10 mm^2 with an acquisition window of 110ms. Two successive IR experiments with two different initial inversion times (TIs) (TI_1 = 110ms, TI_2 = 400ms) were conducted. To optimize the measurement of the long T_1 relaxation times at 3T, six single-shot readouts were applied successively at the same cardiac phase after the inversion pulse resulting in 24 images per breath hold. Undisturbed magnetization recovery was allowed for two to three cardiac cycles between each IR experiment.

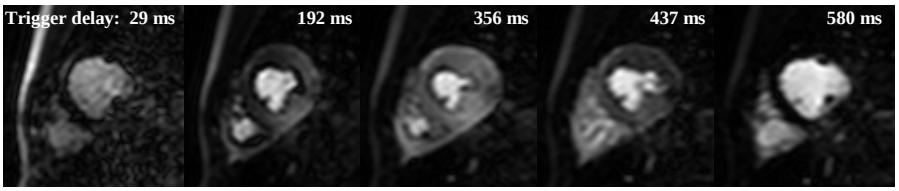

***Fig 2:** Selection of qualitative ASL-images of a healthy volunteer shows myocardial perfusion in one cardiac cycle.*

Results

Figure 2 shows a selection of 5 of the 37 ASL-LL difference images between slice-selective and non-selective spin preparation in a healthy volunteer. The inflow of the labelled blood into the myocardium is clearly visible as well as the intramyocardial perfusion gradient from the epicardial layer of the myocardium radial towards the endocardial layer. The average myocardial T_1 measurements in all healthy volunteers were 1004±58ms for T_{1S} and 1095±58ms for T_{1NS} with an overall perfusion value of 2.9±0.7ml/g/minute. Figure 3 shows the results of one healthy volunteer.

Discussions and Conclusions

In this preliminary study, we tested time-resolved ASL as a qualitative approach to study myocardial perfusion with high temporal resolution in a single breath hold without the need for contrast agent. Therefore this technique can be applied multiple times at different positions to fully assess the whole myocardium. The quantitative assessment can then be planned on these images and the absolute quantification of myocardial perfusion with the use of k-t SENSE with an acceleration factor of 4 allows acquisition of high resolution T_1- and perfusion-maps in a single breath hold.

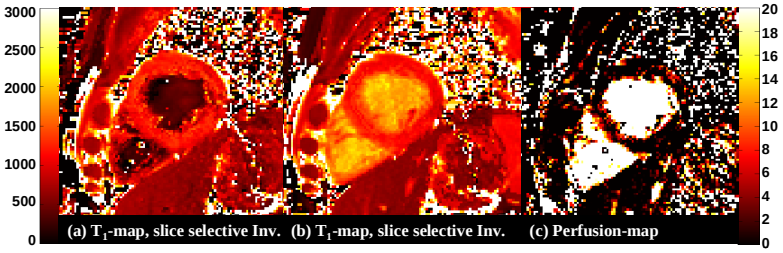

***Fig 3:** Results of quantitative ASL methods of a healthy volunteer*

References

[1] Guenther M et al, MRM 2001; 46:974; [2] Belle V et al, JMRI 1998; 8:1240; [3] Zhang H et al, MRM 2005; 53:1135; [4] Wacker CM et al, JMRI 2003; 18:555; [5] Messroghli DR et al, MRM 2004; 52 :141; [6] Scheffler K et al, MRM 2001; 45:720; [7] Plein S et al Radiology 2008; 249:493