Myocardial perfusion assessment in humans using steady-pulsed arterial spin labeling

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Target audience: Cardiac magnetic resonance in clinical research.

Purpose: Arterial Spin Labeling (ASL) appears as a powerful, fully non-invasive alternative to contrast agent injection for assessing myocardial perfusion in humans (1,2). Although it has become a routinely performed method in the rodent heart, its application remains challenging (1,2) in humans. Comparatively low tissue blood flow, motion constraints and physiological noise are major difficulties in a reliable assessment of human myocardial perfusion by ASL. Specifically addressing sensitivity improvements, an alternative steady-pulsed labeling strategy has recently been proposed, which drives the tissue magnetization into a perfusion-dependent steady-state (3,4). This approach was earlier validated in the mouse heart as cine-ASL, but it also promises significant increase in acquisition efficiency for human application. This work aimed at evaluating the feasibility and potential of the steady-pulsed labeling technique in the human heart.

Methods: The steady-pulsed labeling principle was implemented on a Siemens Verio 3T human scanner. A triggered single-shot SSFP acquisition during diastole (TR/TE=334/1.61 ms) was combined with RF-pulsed labeling applied in end-systole (Sech 10 ms), yielding one image at each cardiac cycle. The labeling slab of 60 mm thickness was placed in the basal heart for the Tag scans. Control scans were acquired with the inversion slab positioned symmetrically to the imaging slice in order to compensate for MT effects (figure 1). 128 Tag and Control short-axis images (FoV 244 x 300 mm², matrix size 104 x 128) were acquired sequentially while the subject was freely breathing for a total duration of about 4 minutes. To account for respiratory motion, the images were retrospectively sorted using a cross-correlation algorithm, in such a way that Control-Tag difference images were averaged when myocardium was at equal positions. In order to confirm that the signal indeed results from blood flow itself and not from residual motion of any kind (respiratory, cardiac) during acquisition, an additional experiment was performed with a tag slab thickness reduced to its minimum (3 mm), so that blood was not labeled. For comparison, a FAIR-ASL method was also applied in the myocardium as published by Zun *et al.* (1) with two breath-holds. Myocardial blood flow (MBF) quantification in the steady-pulsed scheme was adapted from (4) to SSFP acquisitions and was evaluated in four myocardial regions and in the chest muscle. The protocol was performed on 9 healthy volunteers.

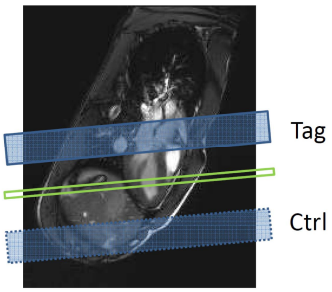

Figure 1: Schematic of the labeling slabs and imaging slice positions.

Results: Figure 2 shows a typical signal difference map obtained in one subject. As shown in figure 3, the signal difference was significant in the myocardium whereas it was not different from zero in the chest muscle, which is presumably not perfused with labeled blood. In addition, myocardial signal difference was absent in the "No Tag" experiment where a minimum labeling slab thickness was used (p=0.0031). In the chest muscle, which is prone to motion artifacts, no signal difference was found either. In comparison, the FAIR signal difference was lower and had a larger group variance than the steady-pulsed approach, though acquisition durations were different. Figure 4 shows regional MBF values found in the group. Intra-subject repeatability was evaluated in 5 subjects (2 repetitions), giving an intra-class correlation of 0.97. The average group blood flow obtained was MBF = 1.13 ± 0.34 mL min^{-1} g^{-1}.

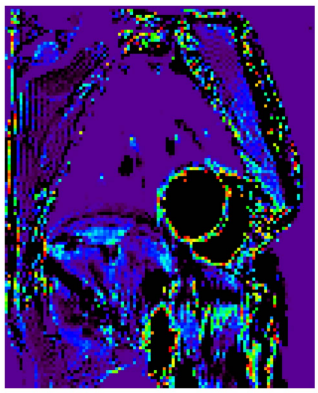

Figure 2: Typical signal map obtained in a representative subject.

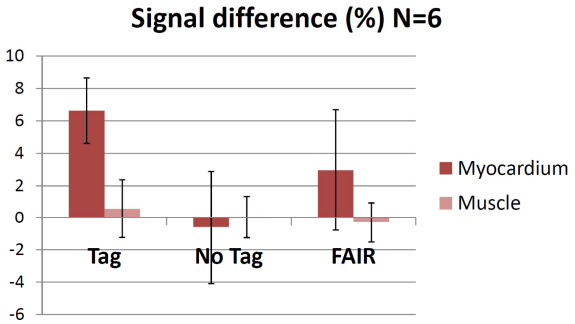

Figure 3: Signal difference (mean ± group SD) measured in myocardium and chest muscle with "Tag", "No Tag" and FAIR acquisition schemes.(N=6 subjects)

Discussion/Conclusion: A recently proposed steady-pulsed labeling approach designed to improve acquisition efficiency in myocardial ASL was implemented to measure blood flow in humans under free breathing. Combined with retrospective breath-gating, this new method provided higher ASL signal with respect to an existing FAIR method which was performed under breath-hold but consequently with a shorter acquisition time. Human myocardial perfusion values were found with good repeatability and in agreement with previously reported studies. This method, as all ASL techniques, remains less sensitive than first-pass perfusion MRI. However since quantification in ASL is easier, it appears particularly interesting for studying pathologies with diffuse microvascular alterations. This work was supported by Agence Nationale de la Recherche QASAREM (08-BLAN-0058).

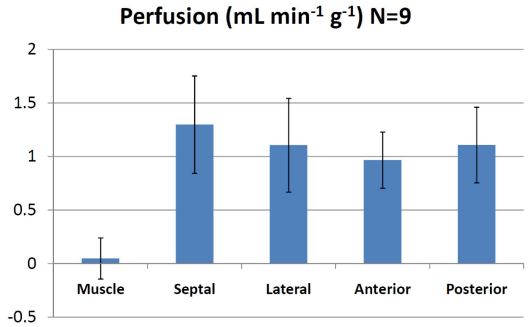

Figure 4: Perfusion values (mean ± group SD) obtained in different regions.(N=9 subjects)

References:

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(2) Wang DJ *et al.*, Magn Reson Med 2010; 64(5):1289-1295.
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(4) Capron T *et al.*, Proc. Intl. Soc. Mag. Reson. Med. 20, 2012; Capron T *et al.*, Magn Reson Med, submitted