Improved Spatial Resolution and Post-Processing for Myocardial Blood Flow Quantification in Humans using Steady-Pulsed Arterial Spin Labeling

Thomas Troalen[1], Julien Pugnaire[1], Thibaut Capron[1], Benjamin Robert[2], Monique Bernard[1], and Frank Kober[1]

[1]Aix-Marseille Université, CNRS, CRMBM (Centre de Résonance Magnétique Biologique et Médiacle) UMR 7339, Marseille, France, [2]Siemens Healthcare France SAS, Saint-Denis, France

Target audience: Cardiovascular magnetic resonance in clinical research.

Purpose: Arterial spin labeling (ASL) appears as a powerful, direct and fully non-invasive alternative to first-pass MRI to assess absolute quantification of myocardial blood flow (MBF). Although ASL has become a method of choice to quantitatively map rodent MBF, its application to the human heart remains challenged by low tissue blood flow and strong physiological noise[1-3]. To improve sensitivity, an alternative free-breathing steady-pulsed ASL (spASL) strategy had been proposed earlier[4-6]. Respiratory motion had been addressed by retrospectively selecting images using a cross-correlation (CC) algorithm and a Canny-Deriche edge-enhancement filter. Tag/Control pairs were averaged only when myocardium was at equal positions, yielding to a suboptimal acceptance rate of about 30% of the acquired data. In this work, robustness under free breathing and efficiency of spASL were further improved by way of a dedicated motion correction algorithm (Moco). Higher spatial resolutions were also shown feasible using GRAPPA acceleration.

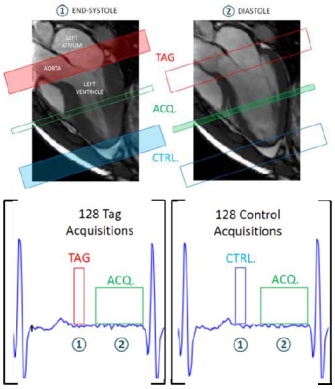

Fig 1: *Schematic of the spASL sequence. Temporal and spatial placement of the Tag (red), Control (blue) and Readout (green) slabs.*

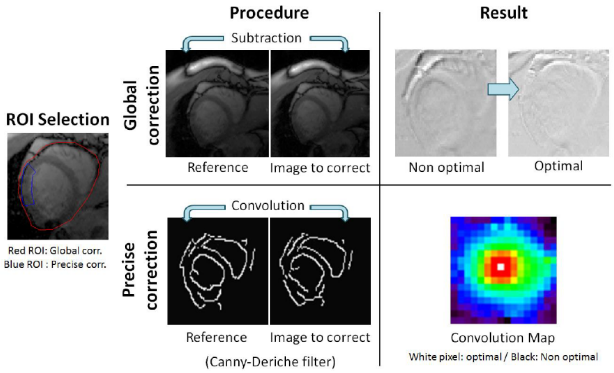

Fig 2: *Moco post-processing with the use of subtraction algorithm (top) (red ROI) and contour- based algorithm (bottom).*

Methods: The spASL sequence was implemented on a Siemens 3T Verio system, based on an ECG-triggered bSSFP acquisition combined with a slice-selective labeling module. Arterial blood labeling was performed at each cardiac cycle to drive tissue magnetization into a perfusion-dependent steady-state (Fig 1). After labeling, a short-axis view was acquired in end-diastole using high resolution bSSFP readout of 334 ms (matrix size 192*156; GRAPPA 3). The spASL acquisition was repeated 128 times for both Tag and Control scans (Acq. time ~3.5min). In addition to the previously employed Tag/Control pair selection, a customized three-step Moco for spASL perfusion imaging was carried out beforehand. First, overlaid Tag and Control reference images were chosen allowing independent Moco for each Tag and Control series. Second, global correction in a large ROI was performed by spatially shifting every image and minimizing signal difference with the reference. Third, a more precise regional correction based on contour correlation was used (Fig 2). This third step used a Canny-Deriche filter on both images (reference and image to correct) to detect contour and to calculate the highest possible correlation between them.

Results: When performing global correction on the whole heart (1st and 2nd step of the algorithm), MBF mapping was possible. Figure 3 shows a comparison between two maps in a volunteer without and with Moco after keeping 50% of the acquired data. Better homogeneity and delineation of the myocardium can be seen. Using the 3rd described step before carrying out the quantification in myocardial regions led to improved signal stability. Figure 4 shows the standard deviations between 6 subjects of regional signal difference values as a function of the fraction of included images after contour based selection. Without Moco, the lowest SD was found when including between 10 to 30% of all images. With Moco, the signal reached a plateau around 50% but remained stable between 10 up to 80% of included images. Using both steps, intra-pixel relative standard deviation was reduced, and more data could be retained for signal averaging.

Discussion/Conclusion: The use of semi-automated Moco led to a significant decrease of intra-subject SD with spASL myocardial perfusion imaging. The measured signal was found stable within a wider range of included images (Fig 4). In this work, we only used rigid Moco in order to guarantee unchanged signal quantification. Nevertheless, the improvement of spASL by Moco is twofold. On the one hand, it allows inclusion of a much higher number of acquired images in the quantification procedure making the post-processing chain more robust. On the other hand, it is a step towards calculation of perfusion maps with higher spatial resolution (Fig 3). Moco might in the future also allow for reducing acquisition time.

References: [1]Northrup, *et al.* JCMR 2008. [2]Zun, *et al.* MRM 2009. [3]Wang, *et al.* MRM 2010. [4]Capron, *et al.* MRM 2013. [5]Troalen, *et al.* MRM 2013. [6]Capron, *et al*. Proc. 21st ISMRM, 2013.

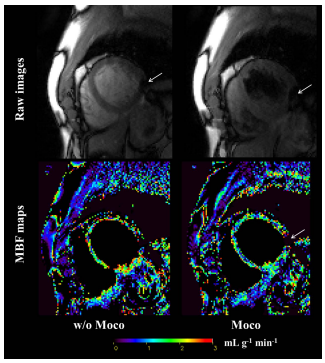

Fig 3: *MBF maps without (left) and with (right) Moco applied on the whole heart. Drop in signal (white arrows) was only due to artifact.*

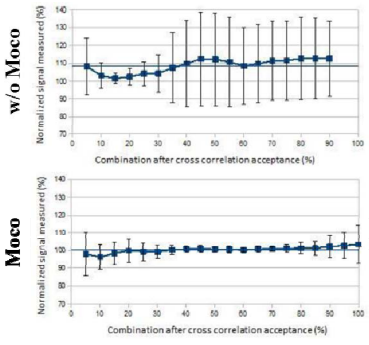

Fig 4: *Stability of the myocardial signal in 6 subjects as a function of the fraction of included images.*