Feasibility of renal perfusion imaging using velocity selective ASL

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Target audience: Researchers in the field of renal perfusion imaging

Purpose Perfusion imaging of the kidneys using CT or MRI contrast media is costly and potentially nephrotoxic. These limitations have sparked the desire to develop renal perfusion techniques that do not require contrast media injection. Arterial spin labeling (ASL) MRI is a candidate technique that employs the endogenous contrast of labeled protons in the blood to image renal perfusion. Previously, the feasibility of renal ASL has been investigated using pulsed (PASL) [1] and pseudo-continuous (pCASL) labeling strategies [2]. These labeling strategies require labeling of supplying arteries outside the region of interest (ROI) to avoid labeling of static tissue inside that region. PASL and pCASL necessitate careful planning of the labeling slab and a time delay for the labeled bolus to arrive at the target voxel distal to the labeling site. Velocity selective ASL (VS-ASL) may overcome these limitations of PASL and pCASL by globally labeling all spins that move above a certain velocity into a predefined direction. This effectively labels the entire blood supply of the organ of interest (i.e. the kidney), even into the large vasculature inside the organ. Consequently, there is only minimal delay before the label arrives at the target voxel, preserving the label's magnetization and thus improving SNR. As VS-ASL employs global labeling, it eliminates delicate planning aspects of PASL and pCASL. We investigated the feasibility of VS-ASL for whole kidney renal perfusion mapping in healthy volunteers, with a focus on abdominal organ motion in velocity selective labeling and imaging.

Table 1. Acquisition parameters

Parameter	Cor	Tra
TE (ms)	14.0	18.5
EPI factor	57	51
Flip angle (°)	90	90
Parallel im. factor	2.5	2
#Slices	21	17
Slice matrix	96x86	124x102
Thickness/gap (mm)	8.0/1.0	8.0/1.0
Resolution (mm)	3.9x4.0	3.0x3.0
Fat suppression	SPIR	SPIR

Methods *Imaging*. Six healthy volunteers (*mean age 55yo, range [48-62], 2 female*) were scanned twice with at least a week interval on a 1.5T MR system (Ingenia, Philips Healthcare, Best, Netherlands), equipped with a torso coil. Written informed consent was obtained. In each exam, two ASL scans were acquired; both with velocity selective labeling using a BIR-4 based tagging pulse [3], once with a readout in coronal and once in transversal direction, with 20 label and 20 control acquisitions each. The labeling employed a velocity threshold of 2.5 cm/s in the craniocaudal direction and a post labeling delay of 1500ms. Readout was performed with a multi-slice single shot spin-echo EPI (Table 1). Volunteers were instructed to shortly prolong their end-expiratory state to match the fixed TR of 6500ms, allowing for in- and expiration after the acoustically easily recognizable readout, such that labeling and readout were performed in exhaled position.
Analysis. In all VS-ASL scans, the kidneys were manually segmented using MeVisLab (v2.6, MeVis Medical Solutions AG, Bremen, Germany). 3D rigid motion correction (MoCo) [4] was applied between all label and control experiments, independently for the left and right kidney. Motion between the individual control and label images was quantified from the MoCo results, and displacement ranges over the 20 label-control pairs were derived. Intensity variabilities among the label and control images, averaged over the kidney ROIs, were expressed relative to the their respective means. After motion correction, pairwise subtractions were averaged and perfusion maps were expressed as signal percentage of the mean control image. We analyzed motion and intensity variability in relation to renal perfusion estimates.

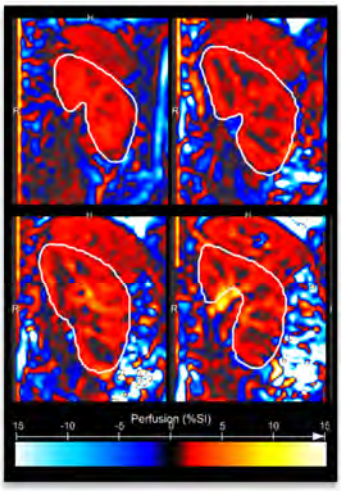

Figure 1*. Renal perfusion map expressed in relative signal difference for coronal VS-ASL.*

Results After rigid motion correction, coronal perfusion maps could be successfully computed in 50% of the cases without outlier rejection (Fig 1), resulting in perfusion maps that clearly depicted the expected corticomedullary perfusion gradient that is usually seen in the healthy kidney. The transversal perfusion maps did not show this clear contrast, possibly due to the large slice thickness of 8mm.
In some cases we noted overestimation of the renal perfusion. The high perfusion values could be explained by high intensity variability among the label images of these scans (Fig 2a) and not by variability in the control images (Fig 2b). These variabilities were correlated with the displacement range in the sequence (data not shown) and suggest that motion during labeling might have caused suboptimal labeling, possibly even labeling the moving kidney tissue itself.

Discussion This study on the use of renal VS-ASL in healthy volunteers demonstrates the feasibility of the technique. However, it also shows the sensitivity of the sequence to abdominal motion, during readout, but especially during velocity selective labeling. With the current imaging protocol, we could only speculate about breathing motion during labeling, as only indirect evidence could be seen in the readout images. Care should be taken in instructing the subjects to guide them in matching the acquisition cycle. Triggered labeling might relax these requirements. Future applications of abdominal VS-ASL would benefit from navigators or other imaging at the time of labeling to correct for motion. Future research will focus on rejection strategies and comparison of the resulting perfusion maps with DCE-MRI and arterial flow measurements.

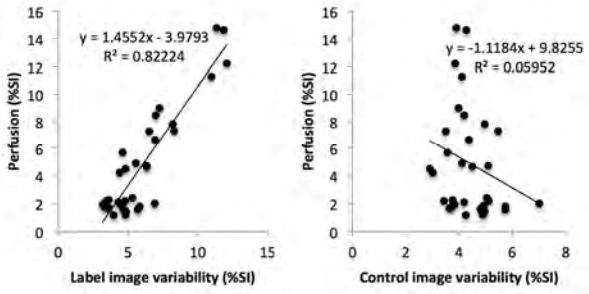

Figure 2*. Relation between variability among label images and perfusion (left), and the control images (right)*

Conclusions Renal perfusion imaging using velocity selective ASL is feasible. In order to improve the reproducibility of the technique, future research should be directed towards prospective and retrospective motion correction to suppress motion artifacts introduced during labeling and readout.

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References [1] Martirosian et al. MRM 2004, [2] Robson PM et al. MRM 2009 [3] Wong EC & Guo J ISMRM 2010 [4] Klein et al. IEEE TMI 2010.