Renal Perfusion Imaging using Continuous Arterial Spin Labeling with Separate Labeling and Imaging Coils

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Introduction: Assessment of renal perfusion rates can provide important information about kidney function, but also about diseases with pathological perfusion changes, e.g. nephrocalcinosis and renal infarction. To minimize potential risks of nephrotoxicity associated with Gd-based MR perfusion techniques, arterial spin labeling (ASL) is currently being adapted to the kidneys [1-3]. ASL, a method originally developed for application in the brain, utilizes arterial water as an endogenous contrast agent in order to measure microcirculatory blood flow. However, the method suffers from a lower signal to noise ratio (SNR) compared to conventional Gd-based perfusion methods, and its application for renal imaging is further compromised by physiological/respiratory motion and irregular, complex blood flow patterns. Therefore, only single slice ASL techniques are currently used. In this study we investigate whether another approach first introduced in brain imaging can be eventually translated to renal ASL: Continuous ASL (CASL) using a separate RF coil for labeling and imaging [4,5]. The potential advantage of CASL over existing FAIR based renal ASL methods is improved SNR and multi-slice capability.

Methods: CASL usually requires the use of an independent labeling and imaging coil. In our approach, a labeling coil (20cmx15cm) was placed directly dorsal to the aorta and superior to the kidneys to avoid saturation of kidney tissue. The labeling coil was attached to an external transmit channel [4]. The sequence sends an optical signal to the external transmit channel to direct time and duration of the labeling. Measurements were performed on healthy volunteers after informed consent has been obtained using a 3T MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany). The free breathing measurements were performed using a spin echo EPI sequence (128x128 matrix, FOV=380 to 420mm, TE=22ms, TR=2s, labeling time (TL)=2.7s, post-labeling delay (TD)=700ms, imaging gradient=1.5mT/m) acquiring a single slice for a total 40 labeled-unlabeled pairs. The RF power output and LT were set as to not compromise clinical SAR limits mandated by the FDA. Motion correction was applied offline using a homemade MATLAB (Mathworks, Natick, MA) program using a separate two region weighted method around each kidney. The motion corrected labeled and non-labeled images were averaged and subtracted. Regions of interest (ROIs) placed manually were used to selectively remove the kidney perfusion signal. A color map was applied to the signal intensities in the ROI and overlaid on the mean non-labeled image.

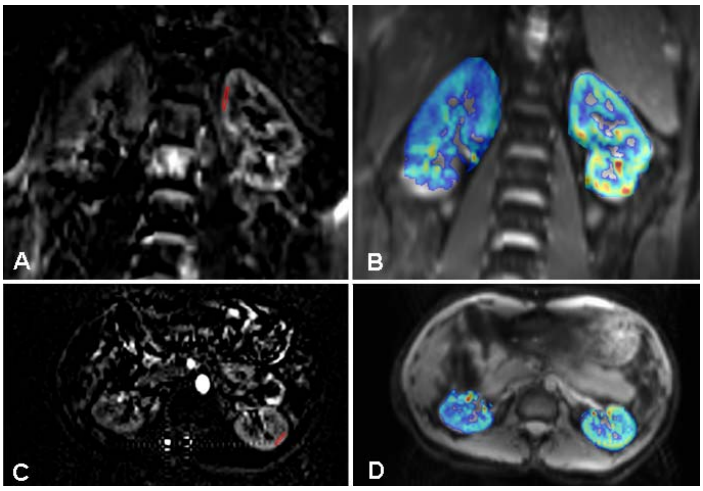

Figure 1 Composite image of renal perfusion in the coronal (A) and transverse (C) slice orientation. Regions of interest measure the percent change between labeled and non-labeled images. B and D have perfusion intensities displayed using a color map and are overlaid on the mean non-labeled image.

Results: Figure 1 depicts the result of a volunteer measurement in the coronal and transverse plane. Perfusion is clearly visible within the parenchyma of both kidneys. A higher perfusion signal is seen in the cortex of the kidneys where perfusion values are known to be larger then in the medulla. Small ROIs, as depicted in image A and C, were used to measure the mean difference signal and were divided by the mean non-labeled image signal. The ROIs in image A and C depict a 3.4% and 2.8% change in signal intensity between label and non-labeled images, respectively. The small area of high intensity perfusion signal visible in image A and B is most likely due to a folding artifact as seen in image A.

Discussion: Volunteer measurements performed in this study represent a first proof of principle that the CASL technique can be used with an external coil for adiabatically inversion of the aortic water flowing to the kidney in order to acquire a perfusion weighted image. Additionally, our technique can be performed as a multi-slice acquisition allowing for whole-kidney perfusion mapping, which is unavailable in the established FAIR True-FISP approach. With our current experimental methods, we are limited by a low SNR due to poor labeling efficiency in the aorta. Therefore, further optimizations are needed to increase labeling efficiency and consequently the overall SNR of the images. The CASL technique can be further enhanced by applying background suppression to remove the stationary (i.e. non-labeled) tissue. Timed breathing strategies have also been shown to increase SNR and reduce strong variation in kidney position. The principle advantage of a CASL approach versus a FAIR True-FISP technique is its insensitivity to non-inverted tissue moving into the imaging plane due to organ motion, therefore eliminating the need for a navigator-triggered technique. However, the key advantage of CASL with an external labeling coil for adiabatic inversion is its compatibility to other techniques such as True-FISP for measuring kidney perfusion.

Conclusion: We were able to demonstrate with volunteer measurements that CASL in conjunction with a separate labeling coil is a useful tool in the quantitative assessment of kidney perfusion. CASL can be easily implemented and combined with a wide range of techniques and therefore holds great promise for the noninvasive assessment of renal perfusion

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