Measurement of renal perfusion using 3D Pseudo-Continuous Arterial spin labeling

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INSTRUCTION: The damage of kidney vasculature plays a key role in many kidney disease progression and severity [1]. Therefore, the quantitative assessment of renal perfusion can provide valuable insight in the assessment of kidney diseases and in monitoring therapeutic interventions. Arterial spin labeling (ASL), as a non-contrast MRI technique, can be used to measure the kidney perfusion noninvasively while eliminating the risk of nephrogenic systemic fibrosis (NSF). 3D Pseudo-Continuous ASL (PCASL) is a recently developed ASL imaging sequence, incorporating pseudo-continuous labelling and a stack of spirals 3D fast spin echo imaging with background suppression [2]. This PCASL technique is a desirable approach for the capability of providing uniform perfusion measurements with good SNR and acceptable SAR [3]. However, the application of this new technique now is still limited in the neuro imaging. In this work, 3D PCASL sequence was used to measure the kidney perfusion and calculate the renal blood flow.

Method: MR scanning was performed on a 3-T whole-body MRI system (Discovery 750, GE Healthcare, Milwaukee, WI). The feasibility of kidney ASL was tested in healthy subjects with an 8-channels torso phase array coil. A 2D coronal breathe hold Single Shot FSE sequence was used to locate the kidney, with FOV 40x40cm, 22slices with 7mm slice thick and 1mm slice spacing, TE 80.9ms, TR 1800ms, Matrix 288x224. A 3D axial breathe hold LAVA-FLEX sequence was employed to exhibit the renal artery, with FOV 36x36 cm, 5mm slice thick and 2.5mm overlap, Matrix 320x180x36, TE 1.9ms, TR 4.1ms. The axial 3D PCASL sequence was scanned with following parameters: FOV 30x30 cm, 2mm slice thick with 60slices, Matrix 512x8. PostLabelDelay (PLD) was set to 1025ms, 1525ms and 2025ms separately. The tagging slice was manually set to 4cm above the imaging slab. The selection of imaging slab and tagging slice was illustrated in Fig.1. Renal blood flow was calculated with the following equation [2]:

$$rBF = \frac{\lambda(1-e^{\frac{-t_{sat}}{T_{1c}}})}{2\ \alpha T_{1b}(1-e^{\frac{-\tau}{T_{1b}}})}\frac{PW}{PD}e^{\frac{-PLD}{T_{1b}}}$$

where T_{1b} is the T_1 of blood (1600ms)[4], T_{1c} is the T_1 of renal cortex (1545ms) [5], α is the labelling efficiency (0.95)[2], λ is the cortex–blood partition coefficient(1)[6], t_{sat} is the time the saturation performed before imaging (2,000 ms), τ is the labelling duration (1,500 ms) and PLD is the post-labelling delay time.

Result: Both 1525ms and 2025ms PLD could get renal perfusion images. Perfusion weighted images, the difference between tagging images and control images, with 2025ms PLD (Fig.2b) exhibit better CNR and better background suppression, as showed in Fig.2. Fig.3 demonstrates the renal blood flow (ml/min/g). Mean renal blood flow of the kidney cortex is about 0.5015, similar to prior PET results [7].

Discussion: In this work, the abdominal aorta was tagged rather than the renal artery because renal arteries were pretty short and located in the imaging slab. Then perfusion images of two kidneys had different transit time effects because of the asymmetry of two renal arteries. The tagging slice couldn't be too close to the imaging slab for the interference between tagging RF pulses and imaging RF pulses. Therefore, the chosen of PLD was critical. PLD should be a little longer than the transit time to reduce the transit time effect while too long PLD would reduce the CNR and bring pollution from veins [8]. In our experience, 2025ms PLD showed sufficient renal cortex perfusion and good background suppression. However, this value may vary with patients, especially with patients with angiostenosis. The T_1 of renal cortex was used in the calculation of renal blood flow for the correction of incomplete recovery. As showed in the equation, the effect of tissue T1 is relatively small so that tissue T1 differences should not have a major effect on quantification. With the long PLD time, one fragment of the sequence for each tagging and imaging was about 4-5s. It was too long to use the respiration gating. So respiration artifacts could be seen in images. Single shot approach may help to implement the scan in one breathe hold.

Conclusion: 3D PCASL technique was successfully implemented in the measurement of kidney perfusion and renal blood flow was calculated.

Reference:[1] JMRI 34:608–615 (2011); [2] Neuroradiology 52:307–317(2010);[3] Magn Reson Med 66:768–776 (2011);[4] Magn Reson Med 52:679–682(2004);[5] Radiology. 2004 Mar;230(3):652-9. [6] Kidney International, Vol. 57 (2000), 2511–2518; [7] Eur J Nucl Med Mol Imaging (2009) 36:683–691; [8] J Cereb Blood Flow Metab. 16:1236-1249 Vol. 16, No.6, 1996

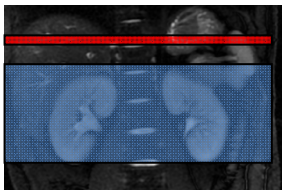

Fig.1: Tagging slice(red) is axial and 4cm above the imaging slab(blue).

Fig.2: (a) PW images with 1525 ms PLD; (b) PW images with 2025ms PLD; (c) PD images used for rBF quantification.

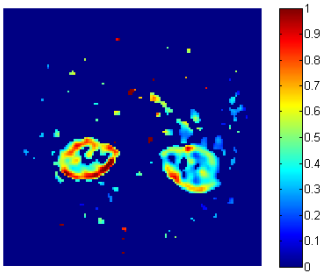

Fig.3: Renal blood flow (ml/min/g)