

SPIN LABELING MRI WITH LOOK-LOCKER READOUT FOR IMPROVED PORTAL VENOUS PERfusion QUANTIFICATION

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PURPOSE: Spin labeling (SL) MRI is a non-invasive technique for perfusion evaluation. A few studies address SL-MRI of the liver with promising results. Both pulsed [1-4] and continuous [5] labeling techniques have been applied using single time point readout [1-3,5]. With single time point readout the bolus arrival time needs to be estimated for perfusion quantification and is therefore assumed equal over the liver. Multiple time point Look-Locker (LL) readout has only been explored in mice [4]. The advantage of the LL readout is determination of local bolus arrival time and consequently potential improvement of the perfusion quantification. We evaluated differences in bolus arrival times throughout the liver using SL-MRI with LL readout. We investigated the feasibility of portal venous perfusion quantification and compared pulsed and pseudo-continuous labeling strategies.

METHODS, Image acquisition: Imaging was performed on a 1.5T MR Ingenia scanner (Philips Healthcare, Best, The Netherlands) equipped with an anterior and posterior 28-channel coil in healthy volunteers. Written informed consent was obtained. For bolus arrival time evaluation, SL-MRI with high temporal resolution (single shot gradient-echo EPI, two 8mm slices, 0.8mm gap, TE=18.4ms, EPI factor 53, flip angle 25°, matrix 128x128, voxel size 2.9x2.9mm, parallel imaging factor 2) was performed in 2 healthy volunteers (1 female, 27-33) with pseudo-continuous (pCPSL, [6], 1250ms duration) and pulsed portal venous techniques (PPSL, EPISTAR [7], 150mm). The LL readout was performed with 100ms spacing (pCPSL: min post labeling delay (PLD) 50ms, 24 images; PPSL: min PLD 50ms, 36 images). Label slabs were planned oblique covering the portal vein. For perfusion assessment, pCPSL and PPSL were performed in 11 healthy volunteers (6 female, mean 27 yrs, range 24-33) after \geq 5 hours fasting to support comparison. A similar LL readout was used, with 9 slices and 400ms spacing (pCPSL: 1250 duration, PLD 50ms, 6 images; PPSL: PLD 900ms, 7 images). Volunteers were instructed to in- and exhale after each readout, easily audible, and kept expiratory breath-hold during label and readout. A spoiled gradient echo based flow sequence (Philips Q-flow) of the portal vein was performed thrice for reference perfusion values.

Data analysis: All SL experiments were averaged over 20 subtractions of label/control pairs, after manual outlier rejection of pairs with major motion artifacts (range 0-6 pairs, mean 1.5). We adapted the standard ASL kinetic model [8] to match our labeling and readout strategies, similar to [9]. Both the delivery function $c(t)$ and the magnetization relaxation function $m(t,t')$ were adjusted to account for a PLD > 0 and multi time point LL readout. Perfusion rates and bolus arrival times were evaluated quantitatively for the whole liver, excluding the large vessels. SL-based perfusion was compared to measurements based on portal flow by $(\text{mean portal velocity} \times \text{cross-sectional area}) / (\text{liver volume})$.

RESULTS AND DISCUSSION: The LL readout revealed intersubject and regional bolus arrival time differences (see figure 1). The adjusted perfusion models were successfully fitted to the data. See figure 2 for example perfusion and bolus arrival time maps. The SL-based quantification by PPSL and pCPSL agreed well with 49 ± 17 and 47 ± 31 ml/100ml/min, respectively. SL-based perfusion also corresponded well to the reference perfusion based on portal venous flow measurements (56 ± 12 ml/100ml/min). Bolus arrival times were successfully measured using the adapted models for the PPSL data (0.88 ± 0.28 s). However, pCPSL analysis showed non-physiological negative bolus arrival times in two cases with low portal perfusion. Compared to pulsed labeling, pseudo-continuous labeling strategies have the drawback that the bolus often has arrived before the first readout, hindering quantification.

CONCLUSION: Hepatic spin labeling MRI with LL readout can be used for successful perfusion quantification and reveals local differences in bolus arrival time. Although pulsed and pseudo-continuous SL resulted in similar perfusion as flow-based perfusion, estimating bolus arrival time using pulsed SL was favorable.

References: [1] Hoad et al. ISMRM 2011, [2] Cox et al. ISMRM 2013, [3] Katada et al. Jpn J Radiol 2012;30(10):p863, [4] Ramasawmy et al. ISMRM 2012, [5] Gach et al. ISMRM 2002, [6] Silva et al. MRM 1999;42(3):p425, [7] Patel et al. MRI clin of N Am 1995;3(3):p425, [8] Buxton et al. MRM 1998 Sep;40(3):p383, [9] Günther et al. MRM 2001 Nov;46(5):p974

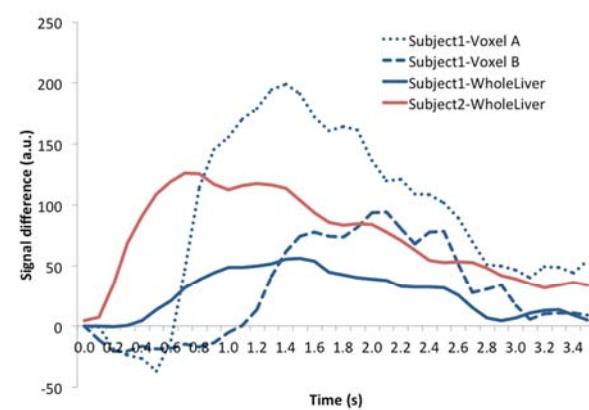


Figure 1. Perfusion time curves revealing bolus arrival time differences within and among subjects.

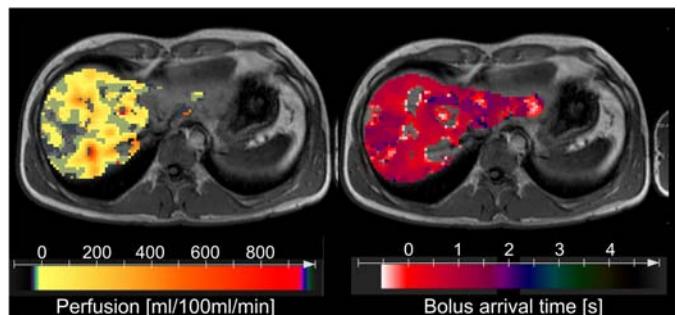


Figure 2. Perfusion and bolus arrival time maps for a representative volunteer.