

# Intrinsic Phase Sensitive Dual Inversion Recovery for Carotid Vessel Wall Imaging

Gabriele Bonanno<sup>12</sup>, David Brotman<sup>12\*</sup> and Matthias Stuber<sup>12</sup>

<sup>1</sup>Department of Radiology, University Hospital (CHUV) and University of Lausanne (UNIL), Switzerland,

<sup>2</sup>Center for Biomedical Imaging (CIBM), Lausanne, Switzerland, \*The first two authors contributed equally

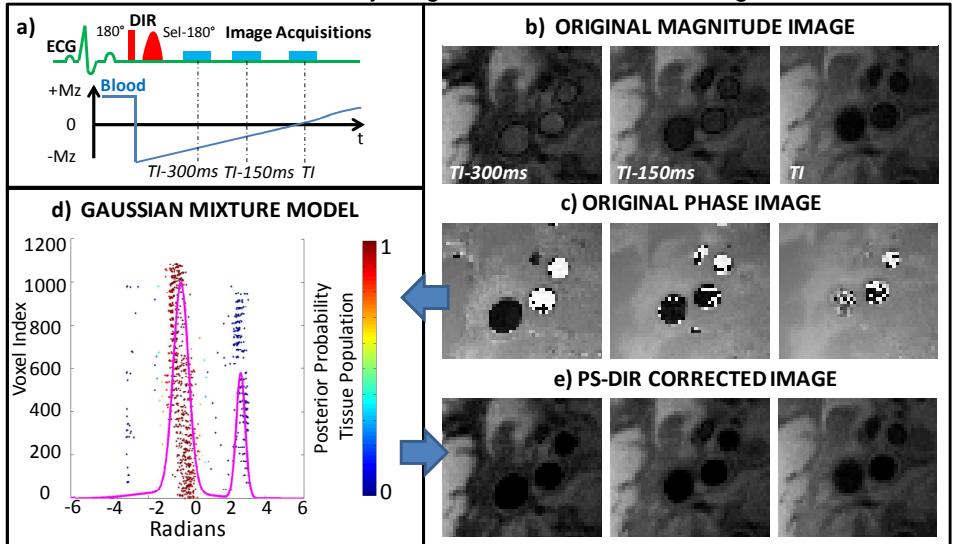
**Introduction:** Dual Inversion Recovery (DIR) [1] is a current standard of reference for MR dark-blood vessel wall imaging. However, for ECG triggered DIR imaging, optimal lumen-to vessel-wall contrast is difficult to obtain since the blood-signal nulling time (TI) depends on both T1 and the subject's heart rate [2]. Moreover, imaging at TI limits the window of opportunity during which black-blood images can be acquired. This makes DIR imaging rather time-inefficient and multi slice acquisition, which may be necessary for sufficient volumetric coverage, results in prolonged scanning times. The phase sensitive (PS) technique addresses these issues by exploiting information from the phase images [3]. In coronary imaging, not only an improved lumen-to-vessel wall contrast was reported using PS, but constraints related to the choice of TI could be removed and time-efficient multi-slice imaging was enabled [4]. Hence, we propose an innovative extension of PS-DIR for carotid vessel wall imaging. By probing the statistical distribution of values in the phase image [5], carotid lumens are automatically segmented and residual signal in the lumen suppressed.

**Methods:** When imaging before TI (Fig.1a), moving spins flow through the slice with a negative magnetization that produces phase values around 180° in voxels inside the vessel lumens (or -180° in the case of phase-wrapping). However, in the magnitude image, this is typically recognized as bright lumen surrounded by a dark ring (Fig.1b). For our algorithm, a region of interest (ROI) that includes lateral carotid lumens and the surrounding parenchyma is drawn by the user on the magnitude image (Fig.1b) and the relative phase histogram is obtained. A Gaussian Mixture Model (GMM) is then used to fit the populations of the phase values for lumen and parenchyma (Fig.1d). By thresholding the posterior probability of the Gaussians, only voxels inside the lumens are segmented and set to zero on the magnitude image obtaining artifact-free PS-corrected black blood images (Fig.1e). MR imaging was performed at 3T (Siemens Trio, Erlangen, Germany), with a dedicated 4ch carotid coil in four healthy volunteers with a Cartesian DIR-prepared gradient-echo sequence (216x240matrix, 135x150mm FoV, 0.6x0.6x3mm resolution, TR/TE=7.4/3.6ms, α=30°). In each subject, images were acquired axially above the carotid bifurcations and at 7 different time points after the R-wave of the ECG (including TI), with a 50ms increment. Quantitative image analysis was then performed for vessel wall/lumen contrast-to-noise ratio (CNR<sub>wall/lumen</sub>) and vessel wall sharpness (%VWS) for all the PS-corrected and original magnitude images using Soap-Bubble [6].

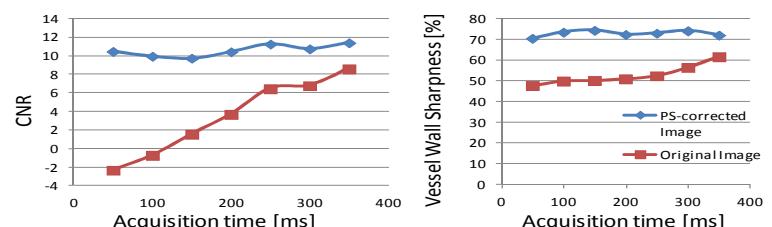
**Results:** Original and PS-corrected images of the right carotid system obtained in a healthy volunteer are shown in Fig.1b,c and e. Two images acquired 300ms and 150ms prior to TI and one obtained exactly at TI are displayed. In contrast to the results shown in Fig.1a, effective suppression of the blood signal can be observed for all the utilized inversion times as shown in Fig.1e. Accordingly, CNR and %VWS evaluation of all the images acquired at 7 time points after the R-wave shows improved performance for the PS method.

**Discussion:** The presented technique enables black-blood imaging at multiple time points after inversion. However, its effectiveness is limited to time points prior to (and including) TI, since the polarity of the blood signal after TI will be positive and the signal phase in the blood-pool no longer discernible from that of its surroundings. **In conclusion**, we have developed and tested a new PS-DIR method for *in vivo* carotid vessel wall imaging at 3T that removes the constraint of obtaining effective black-blood suppression at TI only. This technique will be enabling for interleaved multi-slice black-blood imaging and a larger volumetric coverage per unit time.

**References:** [1] Edelman RR et al. Radiol.1991; [2] Fleckenstein JL et al. Radiol.1991; [3] Huber A et al. Invest.Radiol.2006; [4] Elmoniem K et. al. MRM 2010; [5] Ahn CB et al. IEEE1987; [6] Etienne et al. MRM 2002.



**Figure 1 – DIR acquisitions and blood magnetization recovery:** (a) PS correction enables imaging before TI. **PS-DIR technique:** (b, c) Original magnitude and phase image acquisition at TI and 2 prior time points from a healthy volunteer. (d) A Gaussian model (pink envelope) fits the phase values of the ROI (scatter plot) and its posterior probability is used to segment tissue and lumen voxels. **PS corrected images:** (e) bright blood artifact-free results show enhanced lumen to vessel wall contrast.



**Figure 2 – Quantitative image analysis.** Right internal carotid data from images acquired at 7 different time points including TI, in a healthy volunteer. CNR<sub>wall/lumen</sub> and %VWS remain constant for the PS technique showing improved performance relative to the conventional DIR method even at TI (350ms).

**1. My preferred presentation type is:**

Oral / Traditional Poster / Electronic Poster

**2. Keywords:**

Phase Sensitive - Dual Inversion Recovery, Carotid, Black-blood imaging

**3. I am eligible for the Potchen Award**

YES

(\* please delete as appropriate. Note: only new investigators who have entered the field within the last 5 years are eligible for consideration).