Subtraction errors in regional perfusion imaging using a single control aquisition

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INTRODUCTION: Regional Perfusion Imaging (RPI) allows non-invasive visualization of perfusion territories of the major feeding cerebral arteries [1,2]. In the original RPI method, three territories supplied by the left internal carotid artery (ICA), right ICA and both vertebral arteries (POST) were obtained using pulsed ASL and angulated labeling slabs in three consecutive scans. Separate acquisitions and relatively long total acquisition time (10-15 min) increase the sensitivity to motion artifacts which may lead to mislabeling of different arteries and result in incorrect perfusion territories. However, shorter scan time and lower sensitivity to motion are necessary for clinical applications. Several strategies, such as dual-vessel labeling and cycling through the labeling slabs in a single acquisition, have been proposed to address these issues [3,4]. The later approach [4] is particularly interesting for its efficient encoding, based on a single "control" and three "labeling" conditions, for separation of all three vascular territories in only 2 min. This approach could also be used to improve the efficiency of the original RPI method (fig.1). However, with a single control, errors in subtraction between control and label experiments could arise either due to direct tissue saturation in each slab or due to imperfect cancellation of the magnetization transfer (MT) effects. In general, RF pulses used during inversion and control experiments will be at different offset frequencies since planning of the slabs depends on individual anatomy. The aim of this work was to investigate the magnitude of subtraction errors using different control acquisitions.

METHODS: Experiments were performed in healthy volunteers under the general sequence development protocol approved by the local ethics committee. RPI data was acquired on a 3T clinical scanner (Philips Medical, Best, Netherlands) using the QUASAR sequence [5] with the following parameters: FOV=240 mm, matrix=64x64, 7 slices (8mm, 1mm gap), TR/TE=3000/20 ms, flip=35°, $TI_1/\Delta TI$=40/300 ms (9 time points, Look-Locker readout), vascular crushing V_{enc}=6 cm/s, SENSE=2.5. Adiabatic 180° and 0° pulses with equal RF power were used for the labeling and control acquisitions [6]. For the purpose of the study, the sequence was modified to include 4 slabs for label and control pulses (LICA, RICA, POST and an extra control (CT) slab). The actual slab cycling scheme was "CT LL LC RL RC CT PL PC" repeated 20 times (see fig. 1). In three subjects, the planning was done for measuring real perfusion territories with CT slab placed parallel to POST but shifted by 4cm posteriorly. For a given slab, subtractions with three other "controls" were tested. Another experiment was designed to test the effects of known RF frequency offsets. All the slabs were placed parallel to the sagittal plane with one test slab placed in the left hemisphere (-4 cm from isocenter) and three others in the right (at +3,4,6 cm from isocenter respectively). The corresponding RF frequency offsets at these locations were 0.88, 1.2 and 1.84 kHz. Using only "control" images, the ratios $(M_{R4}-M_{L3,4,6})/M_0$ were calculated in three large ROIs: left, right hemispheres and the middle part of the brain not intersected by any labeling slab. The average of the last time point of all control acquisitions was used as an estimate for M_0.

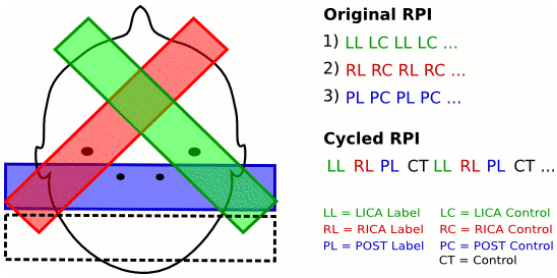

Fig.1: Position of the labeling and control slabs for the original and cycled RPI.

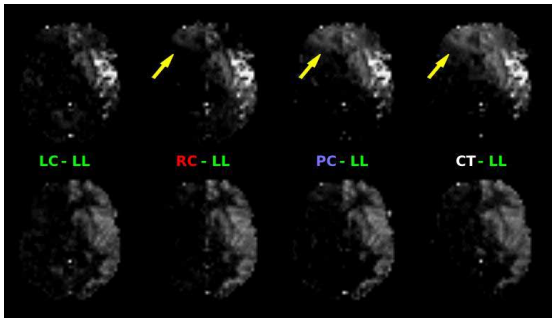

Fig.2: $\Delta M/M_0$ images for subtraction LICA label from different contols at 600 ms (top) and 1500 ms (bottom)

RESULTS and DISCUSSION: Figure 2 shows normalized ΔM images obtained by subtracting LICA label from four possible controls at two inversion times. At the early phase of the bolus (600ms), there is a clear subtraction artifact in the right anterior hemisphere (arrows) when controls from other slabs are used. In addition, residual MT effects are also present (see CT-LL). These artifacts disappear progressively with time. Similar but mirrored artifact is present for RICA label (data not shown). For POST label, the artifact is in the posterior part of both hemispheres and is also present when a closely located extra control is used for subtraction. Subtracting images from pairs of different control experiments gives $\Delta M/M_0$ values close to ±1% in areas of intersection between slabs and imaging volume indicating either direct tissue saturation within the slabs during control acquisitions or incomplete imaging volume presaturation. Results from the frequency offsets experiment are shown in figure 3. Again, the differences are greatest in the regions where the slabs intersect the imaging volume. Outside of the intersection (curves without symbols), a small residual MT effect is present, which is only cancelled out completely for exactly the same frequency offset (both slabs at ±4cm from isocenter, black line). The general conclusion of these experiments is that the use of a single control slab for different labeling conditions in an RPI scan is likely to introduce errors in calculation of perfusion territories. Even though artifacts become smaller after 1.5 sec, its earlier presence cancels the benefits of using multiple time point ASL sequences that allow assessment of perfusion dynamics [5]. An improvement of post labeling saturation of the imaging volume could be a solution to this problem. Alternatively, the use of post-processing methods such as PCA might also reduce these effects [4].

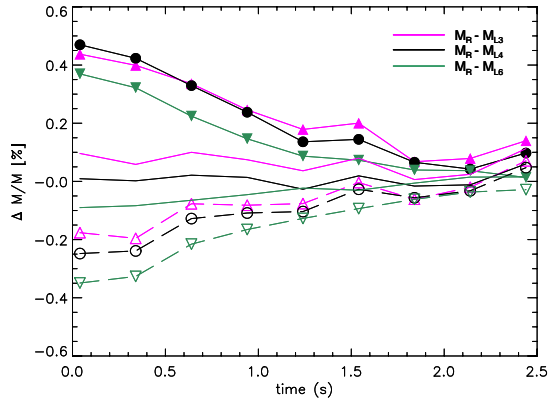

Fig.3: Mean normalized difference in the left hemisphere (filled symbols), right hemisphere (open symbols) and outside of all labeling slabs

REFERENCES: [1] Hendrikse J et al., Stroke 35:882 (2004) [2] Golay X et al., MRM 53:15 (2005) [3] Zimine I et al., MRM 56:1140 (2006) [4] Günther M, MRM 56 :671 (2006) [5] Petersen ET et al., MRM 55:219 (2006) [6] Petersen ET et al., Proc. ISMRM 07 (submited)

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