SENSITIVITY OF BOLD AND PERFUSION CONTRASTS DERIVED FROM DUAL-ECHO ASL IN LOCALISING ACTIVE AND IMAGERY MOVEMENTS

Silvia Francesca Storti[1], Ilaria Boscolo Galazzo[2], Francesca Pizzini[2], Stefania Montemezzi[2], Paolo Manganotti[3], and Gloria Menegaz[1]

[1]*Department of Computer Science, University of Verona, Verona, Italy,* [2]*Department of Neuroradiology, AOUI of Verona, Verona, Italy,* [3]*Department of Neurological and Movement Sciences, University of Verona, Verona, Italy*

Target audience: Neuroscientists interested in new approaches for functional magnetic resonance imaging (fMRI).

Purpose: Dual-echo arterial spin labeling (DE-ASL) techniques have been recently proposed for the simultaneous acquisition of ASL and blood-oxygenation-level-dependent (BOLD) fMRI data[1]. The images acquired at the first echo time are perfusion weighted (ASL), while the images from the second echo are primarily T2* weighted, thus sensitive to the BOLD signal[2]. The sequence is particularly useful when the simultaneous estimation of blood flow and BOLD signal are targeted and moreover, since the separate acquisition of ASL- and BOLD-fMRI scans is no more necessary, it allows to significantly reduce the scan time[3]. To the best of our knowledge, the simultaneous comparison of these two sequences is still unexplored[4]. The overall aim was to assess the sensitivity of the DE-ASL sequence in comparison to the conventional one (BOLD-fMRI) in detecting brain activations elicited by active and motor imagery hand movements.

Methods: Four right-handed volunteers were scanned on a 3T Philips Achieva scanner using a pseudo-continuous multi-slice DE-ASL sequence (TR = 3,900 ms; TE_1 = 10 ms, for ASL data set; TE_2 = 35 ms, for concomitant BOLD [ccBOLD] data set; label duration/post-label delay = 1,500/1,000 ms; 26 slices, 3x3x3 mm^3, slice gap = 1 mm) and using a conventional BOLD-fMRI (cvBOLD) sequence (TR = 2,200 ms; TE = 35 ms; 36 slices, 3x3x3 mm^3, slice gap = 1 mm). The protocol consisted of a block design paradigm alternating between a right-hand movement and the imagery of a right-hand movement (7 blocks each, 10 volumes for each block) and a rest condition (14 blocks, 6 volumes for each block). Data analysis consisted in: *1) Single-subject analysis.* Preprocessing and analysis were performed at the single-subject level by using the general linear model within a FSL software package (FMRIB Software Library, Oxford University, UK). Activation maps were obtained for each subject to highlight the activation during movement and motor imagery, respectively. *2) Group analysis.* A fixed-effects group analysis was applied to estimate the group mean activation for the three data sets. *3) Statistical Analysis.* Statistical comparisons were performed at group level by using the higher level analysis "Tripled" T-Test. Three contrasts were formed to test the differences between the data sets (*ccBOLD* > *cvBOLD*, *ccBOLD* > *ASL*, and *cvBOLD* > *ASL*) under the two active conditions. Lower- and higher-level statistical maps were thresholded by using clusters determined by $Z > 2.9$ and a (corrected) cluster significance threshold of $p < 0.05$, using the Gaussian random field theory.

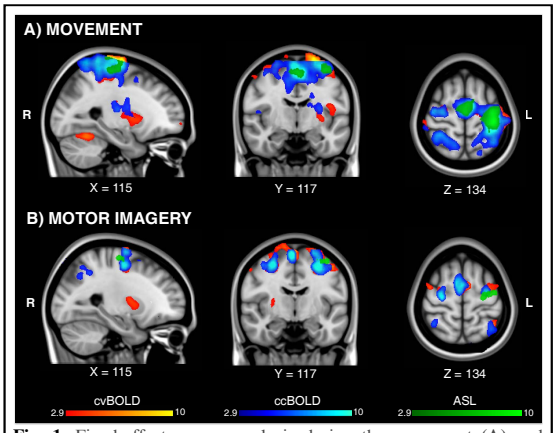

Fig. 1. Fixed-effects group analysis during the movement **(A)** and motor imagery **(B)** conditions. Maps are thresholded by using clusters determined by $Z > 2.9$ and a (corrected) cluster significance threshold of $p < 0.05$.

Results: During the movement task, group analyses showed the involvement of the same brain areas for the three data sets, with activations over the contralateral sensorimotor cortex, supplementary motor area (SMA), ipsilateral cerebellum, inferior parietal lobes and thalamus[5]. During motor imagery task, the activations involved the same regions with weaker intensity. ASL showed smaller activation volumes than cvBOLD and ccBOLD but the areas had a high degree of co-localization. Differences were detected when comparing active versus imagery movements in terms of number of activated voxels and coordinates of centre of mass **(Fig. 1)**. The "Tripled" t-test showed the statistical differences between the results obtained from the three types of data sets. ccBOLD images showed activations larger than the other two during the movement, but with few differences (in particular SMA) from the cvBOLD compared to the ASL images **(Fig. 2A).** In the motor-imagery condition, the results obtained were comparable **(Fig. 2B).** The contrast (*movement – motor imagery*) highlighted the activation differences, in terms of voxels and intensity between the two tasks, and between the three sequences together **(Fig. 2C)**.

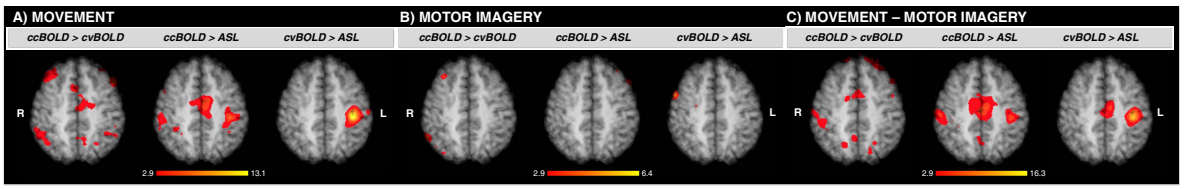

Fig. 2. "Tripled" T-test results with a (corrected) cluster significance threshold of $p < 0.05$ and $Z > 2.9$. The map shows combination of differences for the sequences: *ccBOLD* > *cvBOLD*, *ccBOLD* > *ASL*, and *cvBOLD* > *ASL*, respectively, during the movement **(A)**, motor imagery **(B)**, and movement - motor imagery **(C)** conditions. Hot color represents areas more prominently activated during the first compared to the second term.

Discussion: This study is the first to investigate the differences between the DE-ASL sequence and the fMRI-BOLD one during motor and imagery tasks. The results in terms of cortical activity support the hypothesis that motor imagery and motor performance possess similar neural substrates[6]. DE-ASL sequence has shown to be suitable for mapping these brain functions as well as the fMRI-BOLD. Despite the different temporal resolution, ccBOLD results well matched to the cvBOLD ones in terms of activation areas and number of voxels.

Conclusion: Considering the comparable sensitivity of the ccBOLD and cvBOLD sequences in detecting activated brain regions, the results demonstrate that DE-ASL can be successfully applied in functional studies allowing to obtain both ASL and BOLD information within a single sequence.

References. [1]Woolrich et al. Magn Reson Med 2006 [2]Leontiev and Buxton Neuroimage 2007 [3]Ghariq et al. Neuroimage 2014 [4]Liu et al. Proc Intl Soc Mag Reson Med 2013 [5]Boscolo Galazzo et al. J Magn Reson Imaging 2014 [6]Lotze et al. J Cogn Neurosci 1999.