A Novel Method for Automatic Estimation of M0 used by ASL CBF Quantification

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Introduction: Cerebral Blood Flow (CBF) computation in Arterial Spin Labeling (ASL) consists of calculating the number of spins that reach a particular imaging voxel, accounting for T1 decay, and comparing this unit-less ratio to the equilibrium magnetization (M0)(1). This final critical step can be accomplished by either taking proton density (PD) images of the entire volume, and utilizing this as the equilibrium magnetization on a voxel by voxel basis (referred to as the tissue based model), or by estimating M0 as being equal to that of Cerebral Spinal Fluid (CSF) in the blood based model (2). One of the advantages of the second approach is that it requires only a few extra images (for CSF signal), and not the re-imaging of the full volume, thus decreasing overall scan time. However, current approaches require the operator to manually locate the area in the ventricles (CSF signal) thus slowing down the overall process and introducing human inconsistencies to quantification. The method described here has the potential to alleviate this problem by automatically finding the optimal location in the ventricle to determine the M0 value. Volunteer experiments were performed to determine the robustness of this method.

Methods: The program locates the vicinity of the ventricles within a set of images by performing an autocorrelation of each image with a general pattern representing the ventricles. The pattern was designed to have an average intensity of zero, and thus is not biased towards selecting areas of either low or high intensity, instead only favoring those locations in the image that are the best match, regardless of average intensity. The shape of the pattern was designed by qualitatively comparing the method's results with those obtained by an expert in the field, and then iterating until the regions chosen for M0 estimation matched (see Figure 1 for final pattern). The area used for calculating M0 is selected from the lower half of the ventricles as there is no choroid plexus in the frontal horns, and, in order to avoid partial voluming, the highest signal intensity within this region is utilized. The method has an overall processing time of 0.33 seconds per image using MATLAB (Natick, MA) running on a 2.4GHz (T7700) Intel Core 2 Duo with 4MB on-chip L2 cache. The input images for studying the feasibility and robustness of the method were acquired using a 2D FSE sequence with the following imaging parameters: Imaging matrix=256x256, FOV=22-24cm, number of locs=24-28, nex = 1, TE = 104.2ms, TR = 4000ms. The algorithm was tested for a wide range of resolutions (from 64x64 to 256x256) and ventricle geometries.

Following informed consent, volunteer head scans were performed on a 1.5T GE Signa HDx scanner (Waukesha, WI). A 3D ASL (3) sequence was run to get the perfusion weighted image and also reference proton density weighted image. Additional T2 weighted images were also acquired using the 2D FSE sequence mentioned above. CBF values were calculated using both blood based and tissue-based models (1, 3). CBF values from a set of three different regions of interest from two volunteers were quantitatively compared.

Results: The design process resulted in a complete agreement in regards to the areas of the images to be used for M0 estimation between the method and an expert in the field (Figure 2). In the *in vivo* experiments, the CBF value, averaged over three regions of gray matter in two volunteers, was calculated using both the blood and tissue based models. A difference of 6.28% was recorded between the CBF values obtained by the two approaches.

Discussion: The novel method described here to automatically estimating M0 has the potential to remove the inconsistencies in M0 estimation for tissue based model thus improving the accuracy of the method. Future work will include more in vivo to further establish the robustness of this method.

References: (1) Buxton et al. MRM 40:383-396, 1998 (2) Zaharchuk et al, 1365, ISMRM 2004, (3) Dai W, et al. MRM 60, 1488-1497, 2008