Voxel-wise Comparison of Cerebral Blood Flow Using Arterial Spin Labeling and Dynamic Susceptibility Contrast-enhanced MR Perfusion Imaging

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Introduction

Cerebral Blood Flow (CBF) can be measured noninvasively with arterial spin labeling (ASL) techniques and dynamic susceptibility contrast (DSC) MR imaging. DSC provide a simple way to estimate relative CBF (rCBF) as well as relative cerebral blood volume with high SNR using widely available pulse sequences. ASL techniques provide an alternative mean to measure absolute CBF with MR imaging without contrast agent injection and dosage limitation as well as providing dynamic information although the SNR is low compare to DSC method. One previous study has shown a comparison of both techniques in measuring CBF in brain tumors (1). However, comparison studies on both techniques are very limited. Presented here is a direct voxel-wise comparison of both techniques using the same imaging sequences with the same subjects in the same scanning session. In addition, EPI-based T1 maps were obtained with inversion recovery techniques to assist comparison and tissue classification.

Methods

Normal volunteers were studied on a 3T scanner with a quadrature head coil. For the pulsed ASL, PICORE QUIPSS II (2) was used with TI1/TI2=700/1500 ms and 10 cm tagging slab with 1 cm gap to the imaging slices. 150 pairs of tagged/control 64x64 GE-EPI images were acquired with TE/TR=25/2000 ms and FOV=24 cm with five 7 mm skip 1mm axial slices. The QUIPSS II saturation pulses were applied twice in a row to achieve similar saturation in the tagging area as in Q2TIPS (3). ASL images were pair-wise subtracted and averaged to obtain perfusion images. The absolute CBF values were calculated with a general kinetic model (4) with an assumed T1 of blood of 1500 ms and 900 ms for the tagged blood to exchange into tissues. Blood magnetization was estimated from the white matter (WM) signal as described in (2). In addition, TI-stepping inversion recovery EPI images were obtained for the same slices with 16 TI values from 50 ms to 5999 ms varying logarithmically for a TR of 6 sec. T1 maps were generated by fitting the inversion recovery-time curves. The T1 of each voxel was also used in the kinetic model for estimating ASL CBF values. For the DSC imaging, 100 volumes of GE-EPI images with TE/TR=30/1000 ms of the same slices were acquired during a first-pass bolus injection of Gd-DTPA (0.15mmol/kg) at a rate of 3 ml/sec. The signal time-curves of brain voxels underwent the independent component analysis to obtain arterial ROIs for the calculation of the arterial input function (5). Relative CBF images were derived using singular value decomposition to the contrast-agent concentration time curves on a voxel-wise basis (6). All raw images were inspected visually in cine mode for alignment and were registered for bulk motion correction if applicable.

Results

Figure1 shows the ASL CBF (top), DSC rCBF (middle), and T1 (bottom) images. The first ASL slice shows an overall higher intensity than the rest of slices due to known imperfect static tissue signal subtraction (7). DSC images shows high rCBF values at voxels containing most likely arteries. Figure 2 shows the scatter plots of both perfusion images of the center slice vs. T1. In the T1 range of WM/GM, similar patterns are observed with an approximately linear relationship with T1 as reported earlier (8). However, DSC data shows somewhat more scatter rCBF values at high T1 voxels and is typically not observed in ASL data. The correlation coefficients (CC) between ASL and DSC data are 0.45, 0.43, and 0.31 in the 5-slice volume, gray matter (GM), and WM ROIs, respectively. Both GM and WM ROIs are selected based on T1 values with matching voxel numbers. The WM voxels are less correlated than GM and the whole volume voxels. Figure 3 shows the scatter plot of the center slice from ASL and DSC data. In the low flow voxels, ASL shows slightly lower values than DSC whereas in the high flow voxels, DSC shows more voxels with wider spread and higher values than ASL. All slices exhibit similar patterns in the scatter plots.

Discussion

WM perfusion is mostly likely underestimated using Pulsed ASL techniques since the transit time to WM is long compared to the relaxation decay of the tag. This may be one reason why ASL data shift to lower values relative to DSC data in the low flow range and why the correlation is low in the WM ROIs. ASL data have been shown to correlate with CBF data obtained with PET on a voxel-wise basis (CC=0.85) (9). DSC data are known to overestimate CBF in the voxels containing large vessels as seen in the images and the scatter plots. High T1 voxels are usually associated with sizable CSF content which can be CSF mixing with GM and/or large vessels surrounding by CSF. Since CSF does not give perfusion signal, the high estimated rCBF values from DSC are most likely blood vessels. Although the correlation of DSC and ASL is not very high, DSC does provide an approximately linear relationship to T1 values in the WM/GM range as does with ASL data.

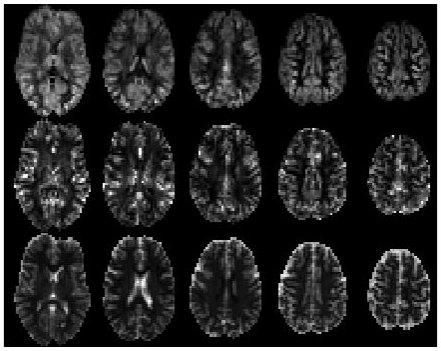

Fig 1. PASL (top), DSC (middle), T1 (bottom) images.

References

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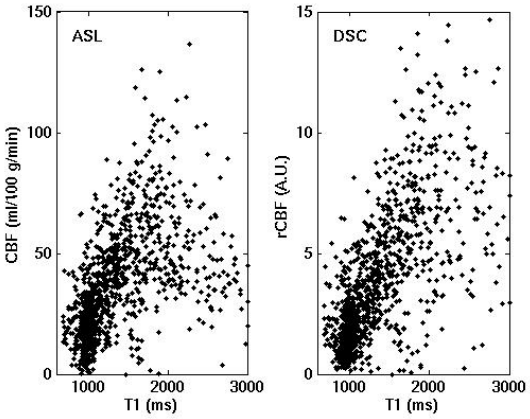

Fig. 2. Scatter plot of CBF vs. T1 from voxels of the center slice.

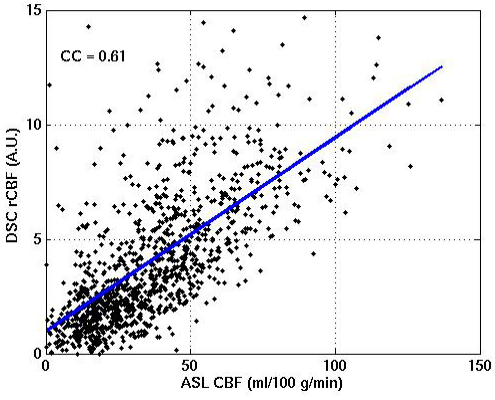

Fig. 3. Scatter plot of ASL CBF vs. DSC rCBF from voxels of the center slice with regression line.