Repeatability of Independent Component Analysis applied to Dynamic Susceptibility Contrast MRI in Newly Diagnosed Brain Tumor Patients with Two Baseline Imaging Scans

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TARGET AUDIENCE: Scientists and clinicians interested in brain perfusion modeling.

INTRODUCTION Independent component analysis (ICA) takes a data-driven, multivariate approach to voxel categorization based on temporal time-courses. Dynamic susceptibility contrast (DSC) data is acquired during a rapid injection of contrast agent, and provides a unique platform for ICA to separate arterial and venous vasculature based on the temporal characteristics of contrast agent perfusion[1]. Previous studies have demonstrated the utility of ICA-DSC in studies of brain tumors[2,3]. A previous study found that in 47 patients with 5 repeated scans (months apart), arterial and venous components were maximally repeatable when 3 components were modeled[1]. This study explores the relationship between the number of components modeled and the repeatability of the resulting arterial and venous components in patients with two scans only days apart with simultaneously acquired spin-echo (SE) and gradient-echo (GE) DSC data.

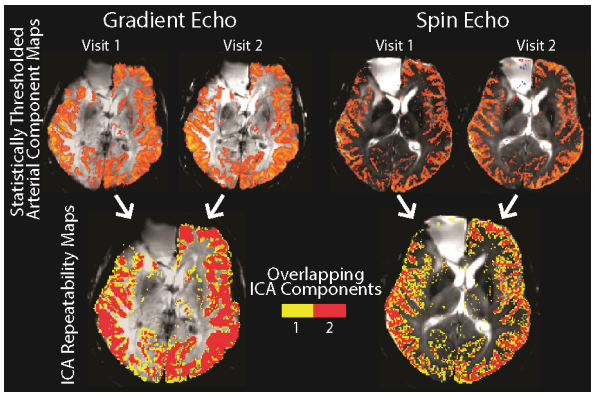

Figure 1. Demonstration of the creation of ICA repeatability maps for SE and GE acquisitions, combining each visit.

METHODS *Patient Population* 30 patients with newly diagnosed GBM were recruited prior to the onset of treatment (following surgery). *Imaging* Each patient was scanned twice, generally 3-4 days apart, using an identical imaging protocol on a 3T MRI system (TimTrio, Siemens, Malvern, PA). DSC-MRI was acquired using a dual-echo, combined GE and SE echo planar imaging sequence. To minimize T1-leakage effects, a preload of Gd was administered[4-6]. *Independent Component Analysis* SE and GE acquisitions were processed separately for each visit. Pre-processing of each DSC acquisition consisted of removing the first 4 time points and motion correction using MCFLIRT (FMRIB tool library). Data was then processed using probabilistic independent component analysis[7] as implemented in MELODIC (FMRIB tool library). For each patient, each visit, and for both SE and GE acquisitions, 2-10 components were modeled. The resulting components were then visually sorted to determine which best represented the arterial and venous phase of Gd perfusion. The statistically thresholded[3] arterial and venous maps were then binarized and brought into the visit 1 space by co-registering the mean SE DSC from visit 2 to visit 1 and the applying the transformation with a nearest neighbor interpolation. Repeatability maps were created to visualize the overlap of each session's arterial and venous components. Voxel values in these maps represent the number of overlapping sessions (of 2) with components present. An overall repeatability index (RI) was calculated for GE and SE and each number of components modeled using the equation shown, where N=2, and n_i is the number of voxels overlapping "i" times. The range of RI is between 0 and 1, where 1 indicates perfect repeatability. The RIs were compared across component numbers with a repeated-measures ANOVA corrected with Tukey's multiple comparison test.

$$RI = \frac{1}{(N-1)}\left(\frac{\sum_{i=1}^{N} i n_i}{\sum_{i=1}^{N} n_i} - 1\right)$$

RESULTS Figure 1 shows a demonstration of the creation of ICA repeatability maps, from which the RI was calculated. Figure 2 shows the results from the RI analysis. GE derived arterial and venous ICA components were significantly more repeatable than SE components. The mean RI for GE and SE for both arterial and venous components combined maximized at 3 components modeled (black lines in Figure 2), while the most repeatable maps overall were the arterial GE resulting from 3 components being modeled (dotted red line, Figure 2).

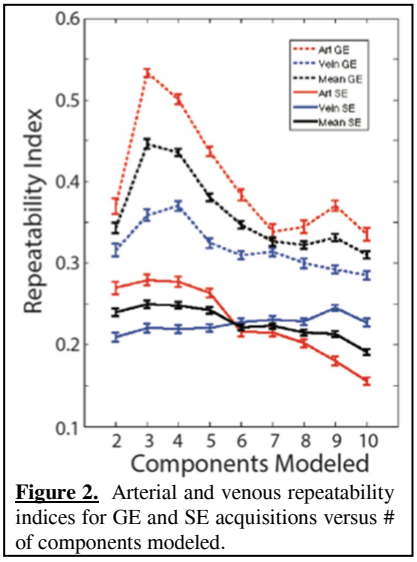

Figure 2. Arterial and venous repeatability indices for GE and SE acquisitions versus # of components modeled.

DISCUSSION This study shows that modeling three ICA-DSC components results in highly repeatable arterial and venous maps of the human brain. GE acquisitions are significantly more repeatable than SE acquired maps likely due to the greater signal to noise ratio. This dataset provided the unique opportunity to measure repeatability only days apart.

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