Comparison of cerebral blood flow estimates in the ischemic area of rat brain obtained with dynamic susceptibility contrast and continuous arterial spin labeling

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[Introduction] Gadolinium (Gd) based dynamic susceptibility contrast (DSC) agents allow brain perfusion NMR images in both animal and human [1,2,3,4]. It is not easy to model the arterial input function (AIF) in small animals because of the small ratio of artery to tissue in a voxel. Hence, cerebral blood flow (CBF) values estimated from DSC images can be inaccurate. As an alternative, the maximum value of the logarithmic signal ratio ($\max\Delta R_2^*$) is occasionally used as an indicator of the CBF in the rat brain [3,4]. To investigate the accuracy of CBF indicated by $\max\Delta R_2^*$ in the ischemic rat brain, a comparison of the CBF values obtained with continuous arterial spin labeling (CASL) and $\max\Delta R_2^*$ was performed in an ischemic rat model.

[Methods] Four male Sprague-Dawley rats underwent surgery to allow the insertion of embolic thread into the middle cerebral artery to create an ischemic rat model. Anesthesia was maintained with halothane (0.5-1%) mixed with a 3:7 ratio of O_2 and N_2O. The animals were placed on a homemade cradle and then set in a 4.7-T imaging spectrometer (INOVA, Varian, USA). DSC images were acquired after the rapid intravenous injection of a Gd contrast agent into the tail vein. Gradient-echo images (TR/TE: 7 ms/3.5 ms, FOV: 45mm×45mm, 64×64 matrix) were acquired at 700 ms intervals. CASL was performed with a butterfly-type coil inverting blood spins at the neck position [5]. Before comparison, the CBF values estimated with the CASL and DSC methods were normalized by the average of the noninfarcted (right) hemisphere. The size of the ischemic area was then estimated from the number of voxels under a selected threshold.

[Results] Figure 1 shows the ischemic area as a function of threshold. The area under the threshold is shown in red for both the $\max\Delta R_2^*$ (DSC) and CBF (CASL) images and overlies a diffusion-weighted image. Figure 2 compares the fraction of ischemic tissue determined from each technique as a function of threshold. The mean and SD from four rats are plotted at each threshold. The ischemic brain area estimated from the DSC method in Fig. 2 was significantly smaller than that obtained with the CASL method ($p<0.05$) when the estimated CBF values were lower than 50% of the normal level. Figure 3 plots $\max\Delta R_2^*$ versus CASL CBF. The voxels from the brains of all four rats were included. The dotted line denotes the locus of points where the two techniques produce identical results.

[Discussion] The tendency for the DSC method to overestimate at low CBF values has already been reported using autoradiography [6,7]. This study indicates that the CBF estimated with DSC may be overestimated in ischemic brain areas by comparing it with the CASL technique.

[References] [1] Ostergaard L et al, MRM, 36: 715-725, 1996, [2] Calamante F et al., JCBFM 19: 701-735, 1999, [3] Muller TB et al, Stroke 26: 451-458,1995, [4] Hoehn M et al., JMRI 14: 491-509, 2001, [5] Silva AC et al., MRM 33: 209-214, 1995, [6] Wittlich F et al., PNAS 92: 1846-1850, 1995, [7] Muller TB et al., MRI 14: 1177-1183, 1996

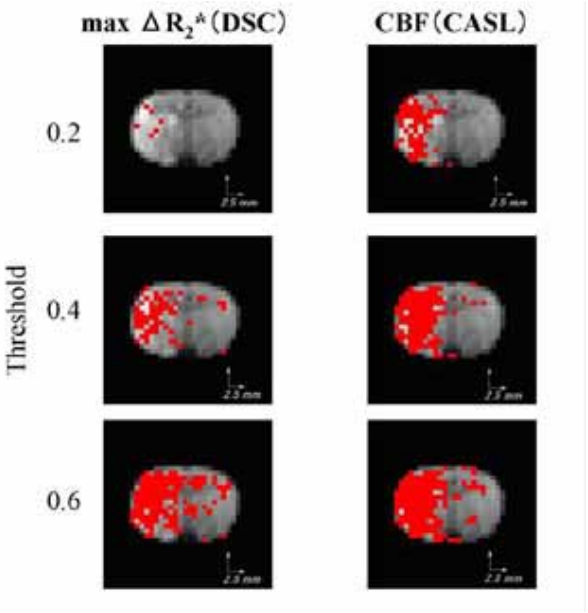

Fig 1. Comparison of the ischemic area (red) as a function of threshold.

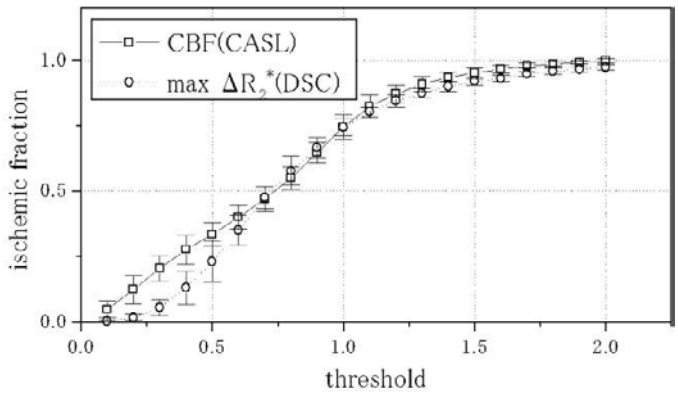

Fig 2. Comparison of the fraction of ischemic tissue as a function of threshold

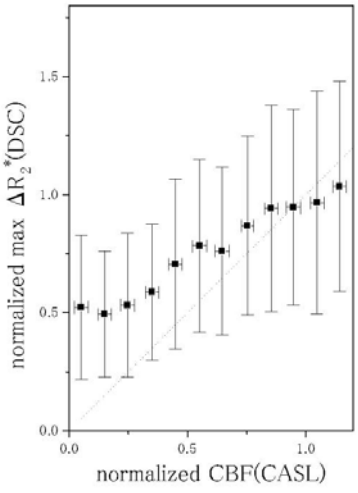

Fig 3. Plot of ΔR2* versus CASL CBF. The data has been binned in a histogram and the mean and SDs of each bin are plotted.