Quantitative Cerebral Perfusion in Rodents Assisted by Susceptibility Weighted Imaging

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Introduction: Dynamic susceptibility contrast (DSC) MRI is widely used clinically for evaluating cerebral perfusion. However, its application to rodents is limited because of many technical challenges. One of those challenges is the partial volume averaging arising from the venous structures. Therefore, it is important to identify the venous structures to minimize this problem. Susceptibility weighted imaging (SWI) [1] allows clear visualization of venous structures. EPI images show significant image distortions. These distortions can be reduced by registering the SWI with EPI images. The purpose of this study was to identify the venous structures with susceptibility weighted imaging (SWI) and minimize the contributions to the hemodynamic parameters that include cerebral blood volume (CBV), cerebral blood flow (CBF) and mean transit time (MTT).

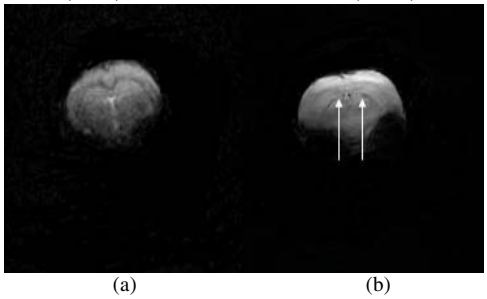
Theory and Methods: High resolution SWI images were acquired using a flow compensated 3D gradient echo sequence on a 7T Bruker scanner with a horizontal bore. The acquisition parameters were: TR/TE=40msec/16msec, flip angle of 15°, slice thickness of 1mm with an in-plane resolution 0.068mm. DSC MRI was acquired on Sprague-Dawley rats. Following the tri-pilot scan, shimming, and optimization of EPI, GdDTPA was administered via a catheter attached to the jugular vein. Single-shot gradient echo EPI images were acquired with TR/TE= 1000msec/15.6msec, acquisition matrix of 128x80, slice thickness = 1 mm, 8 slices, and 150 dynamics. The total scan time for acquiring the perfusion data was 2 minutes and 30 seconds. The SWI images were registered to the EPI images using the automatic image registration (AIR) [2].

The contrast agent concentration, $C_t(t)$, in the tissue was calculated from the convolution of arterial input function (AIF), ($C_a(t)$), with the residue function (R(t)), where $C_a(t)$ is the arterial concentration of the contrast agent. Singular value decomposition (SVD) was used to estimate R(t). In the SVD method, the n x n matrix, *A,* is constructed from $C_a(t)$[3], and is computed as the product of a n x m orthogonal array *U*, a n x n diagonal array *W* composed of the singular values, and the transpose of a n x n orthogonal array *V*[3]: $A=UWV^T$. The AIFs needed for calculating the absolute values of CBV and CBF were selected automatically for each slice based on the following criteria: compared to $C_t(t)$, AIFs have higher peak (Peak(A)), narrower width at half maximum (FWHM(A)), shorter arrival time T0(A), shorter time to peak TTP(A), and larger area under the curve(AUC(A)). In our implementation, the AIFs were automatically searched within the whole brain after Gamma-variant fitting according to the following criteria: mean peak <Peak(A)<max peak, Δt<FWHM(A)<mean FWHM, mean AUC<AUC(A)<max AUC, T0(A)< mean T0, and TTP(A)< mean TTP. Then the selected AIFs satisfying above criteria on each slice were shifted to minimum T0 and averaged to generate the representative AIF for individual slices.

Results and Discussion: Figure 1(a) shows the gradient-echo EPI image of a rat brain. From this image the venous structures can not easily be identified. Figure 1(b) shows the corresponding SWI image. Figure 2 (a) shows the susceptibility weighted image after registering with the EPI image. The two arrows in Fig. 1 (b) and 2 (a) show the veins. Figure 2 (b) shows the CBV map calculated from the EPI image in Figure 1 (a). The hyperintense pixels in the middle of the brain in Figure 2(b) correspond to those pixels which were located at the large venous structure in Figure 2 (a), where the CBV values were significantly larger than those values in tissue. Figure 2 (c) shows the CBV map after eliminating the venous contribution. Given the geometric information about venous structures, we successfully excluded those pixels that included veins for better estimation of the hemodynamic parameters. The average CBF value of the whole brain measured by our proposed method was in good agreement with published CBF value measured by microsphere method [4] as shown in Table1.The AIF selection is also important for calculating the absolute value CBV, CBF and MTT. With our method, AIF can be automatically selected by setting proper criteria.

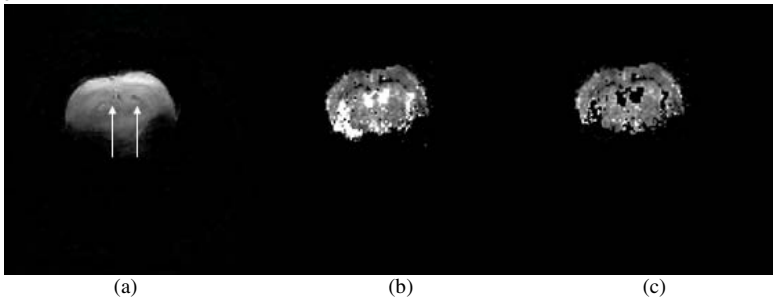
Our software is developed under IDL (IDL6.3, ITT Visual Solution Boulder CO) and implemented on a PC. The computational time for automatic determination of AIF is less than one minute and calculation of CBV, CBF and MTT maps by SVD method took less than 3 minutes.

References: [1]Haacke EM, et al.,MRM,2004,52(3):612-8 [2]Woods RP, et al.,JCAT, 1993,17:536-546 [3] Ostergaard L, et al., MRM, 1996, 36:715 – 735 - general [4] Yamakami I, et al, J Cereb Blood Flow Metab, 1991, 11:655-660



(a) (b)

Figure1. (a) Gradient-Echo EPI image
(b) Susceptibility Weighted image



(a) (b) (c)

Figure2. (a) SWI image following registration with EPI image
(b) CBV map calculated from EPI image
(c) CBV map after eliminating the venous contribution

Methods	CBV (mL/100g)	CBF (mL/100g/min)	MTT (second)	Total Brain CBF (mL/100g/min)	Publish Value of Total Brain CBF (mL/100g/min)
White Matter	17.03±6.18	95.6±24.09	10.68±0.92	135.37±28.62	127±27
Grey Matter	33.39±6.51	215.05±26.24	9.32±0.46		

Table1. Hemodynamic parameters calculated from EPI image.