Automated Data Processing for Quantitative Cerebral Hemodynamics with Dynamic Susceptibility Contrast Perfusion-Weighted Imaging

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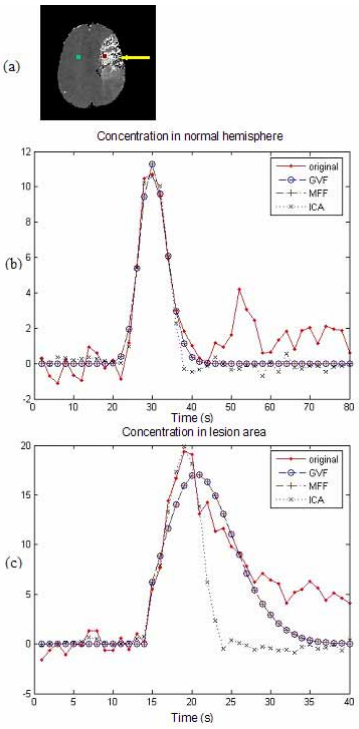
Introduction

While the dynamic susceptibility contrast (DSC) perfusion weighted imaging (PWI) approach has commonly been used in clinical studies of acute stroke patients to provide insights into brain tissue perfusion, only relative measurements are often used. This is due largely to the following reasons. First, the computation time for minimizing the effects of recirculation is rather long (~2.5hrs) with the gamma-variate fitting (GVF) approach. Second, the effectiveness of GVF is limited particularly in regions with hypoperfusion. Finally, it needs the user interaction to choose the arterial input function. Together, these factors have substantially limited our ability to offer quantitative measures of cerebral hemodynamics including CBF, CBV and MTT in the acute setting. In this abstract, we propose an automated toolbox aiming to overcome all of the above mentioned difficulties and to provide quantitative measures of cerebral hemodynamics for DSC. In addition, the effects of recirculation on the calculation of cerebral hemodynamics will also be shown.

Methods

DSC images were obtained from 10 acute stroke patients using an EPI sequence (TR/TE/FOV/Mat/Slice=2s/54ms/ 220mm^2/128/12) on a 1.5T clinical MR scanner. A bolus of contrast agent (0.1 mmol/kg Gd-DTPA) was injected at a rate of ~2 ml/s by hands after the completion of the 5th scan and 40 scans in total.



The acquired images were processed using the following steps. First, The MR signal-vs.-time curves were converted into concentration time curves C(t) through the commonly employed approach. Second, a hybrid approach was proposed to minimize the effects of recirculation. This new approach combined a matched filter fitting (MFF) method and the ICA approach recently proposed by Wu et al[1]. Specifically, a library consisting of all of the possible gamma-variate curves was established first for each patient. Subsequently, the ICA approach was utilized to minimize recirculation for regions with a prolonged time-to-the-peak (TTP > mean + SD of the normal hemisphere) while the MFF was used for the remaining regions in the brain. Third, five concentration curves with the earliest TTP, the highest relative concentration value at TTP and the narrowest full-width-half-maximum (FWHM) were identified as the candidates of AIF. The final AIF was defined as the mean of these five curves. Finally, singular value decomposition with a block-circulant deconvolution matrix was used to calculate CBF[2], CBV and MTT maps.

Results and Discussion

The ability of minimizing the effects of recirculation using different approaches at two ROIs, normal and ischemic ROIs is shown in Fig. 1. It is immediately clear that all of the approaches, including GVF, MFF and ICA, work equally well in the normal ROIs while only the ICA approach is capable of effectively minimizing recirculation effects. This finding suggests that the propsoed hybrid approach (ICA+MFF) will be capable of minimizing recirculation for the entire brain even in the acute stroke patients since ICA was employed for the hypoperfused regions while MFF was used for the remaining regions. In order to further investigate how reciruclation may affect the estimates of cerebral hemodynamics, regions with prolonged TTP (> mean+SD of the normal hemisphere TTP) were further subdivided into three regions: Reg 1 mean+SD<TTP<mean+2SD, Reg 2 mean+2SD<TTP<mean+3SD, and Reg 3 TTP>mean+3SD. The calculated CBF and CBV using GVF or the proposed MFF+ICA are shown in Table 1. As expected, CBF and CBV reduce as TTP becomes longer independent of the approaches used to minimize recirculation. In Reg 1, the proposed MFF+ICA approach reveals a significantly higher CBF ($p<0.0001$) and lower CBV ($p<0.0001$) when compared with that obtained using the GVF approach. Similar findings are also observed in Reg 2 although the differences between the two approaches are smaller. Finally, the CBF and CBV are statistically identical between the two approaches in Reg 3. It is worth pointing out that the observed underestimation of CBF in Reg 1 and 2 when recirculation is not minimized could have profound clinical implications in the management of acute stroke patients. For example, a region with a CBF value of 18 ml/min/100gm could be incorrectly interpreted as ~13ml/min/100gm when recirculation is not correctly minimized. The former CBF indicates tissue may still be viable while the latter value may suggest ischemic core. Finally, the overall computation time for the entire process using the proposed approach without user interaction is 2.47±0.97 min. This is in sharp contrast to the required computation time using either the GVF or ICA approach (~2.5hrs).

	CBF (ml/min/100gm)		CBV (%)	
	GVF	MFF+ICA	GVF	MFF+ICA
Reg 1	15.48±4.37	21.49±5.59	22.74±3.05	16.52±2.87
Reg 2	10.31±2.93	13.16±3.54	16.27±2.79	13.67±2.61
Reg 3	6.60±2.41	7.56±2.47	10.68±1.02	10.09±0.93

Table 1, Comparisons of CBF & CBV for three sub-regions within the prolonged TTP areas

Conclusions

Our results demonstrate that it is feasible to obtain quantitative estimates of cerebral hemodynamics without the need of user interaction. In addition, the proposed ICA+MFF approach is capable of minimizing the effects of recirculation independent of the presence or absence of ischemic lesions. More importantly, the entire process can be completed within 3 min which is well applicable even for the management of acute stroke patients.

Reference

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