Improved rCBV calculation with leakage correction and first pass extraction

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Introduction: In T2*-weighted DSC-PWI, contrast agent leaking into extravascular space due to impaired BBB will induce additional T1 and T2 relaxation during and after the first pass of the bolus. The accumulated contrast leakage effect is enhanced during recirculation phase, resulting in overestimation of CBV which might lead to misdiagnosis. Traditionally, a manually selected integration ending point on the contrast concentration time curve, *C*(*t*), is required in CBV calculation to reduce the contribution of recirculation. However, this method is subjective and it becomes invalid when regional vascular delay is present. We introduced a method by first correct for contrast leakage effect then extract the first pass of *C*(*t*) by decomposing the tissue residue function *R*(*t*). We evaluate the use of the proposed method in CBV calculation in a longitudinal follow-up study of GBM patients undergoing gene therapy.

Materials and Methods: Serial scans were acquired for 7 post-resection GBM patients for treatment effects monitoring. Three of the patients were diagnosed with progressing disease and four patients were non-progressing. GE-EPI (TR/TE=2000/40ms) perfusion scans (n=16) were used in this study. Leakage contaminated concentration curve $\Delta R2^*_{eff}(t)$ for each voxel is modeled as a linear combination of $\overline{\Delta R2^*(t)}$ and its time integral similar to a previous publication[1]: $\Delta R2^*_{eff}(t) = K_1 \cdot \overline{\Delta R2^*(t)} + K_2 \int_0^t \overline{\Delta R2^*(\tau)}\,d\tau$, where K_1 is scale factors and K_2 reveals relative permeability. Our protocols contain significant recirculation, which is retained in $\overline{\Delta R2^*(t)}$ computed as averaged curve in normal tissue. Parameters K_1 and K_2 can be estimated through a linear least-squares curve fitting. Then $\Delta R2^*_{eff}$ can be corrected as: $\Delta R2^*_{corr}(t) = \overline{\Delta R2^*(t)} - K_2 \int_0^t \overline{\Delta R2^*(\tau)}\,d\tau$. In definition, *R*(*t*) is a monotonic decreasing function from 1 (t=0) to 0 (t=∞). By fitting AIF with a gamma variate function, the first pass and recirculation of *R*(*t*) can be expressed as: $C(t) = CBF \times AIF \otimes [R_{1stPass}(t) + R_{1stPass}(t) \otimes G(t-d)]$, where *G* is a circulation transfer function and *d* is the recirculation time. We determine *R*(*t*) using least-absolute-deviation (LAD) regularization, which has been shown to preserve the shape of *R*(*t*), while significantly reducing baseline oscillation compared to sSVD and rSVD[2]. An example of *R*(*t*) results from LAD is shown in Fig.1a. Since the second pass in *R*(*t*) corresponds to contrast recirculation, we assumed the inflection point T_s (as shown in Fig.1a) is close to the actual starting time of recirculation. *R*(*t*) is truncated at T_s and then convolved with $C_a(t)$ to reconstruct the first pass of *C*(*t*). The rCBV was calculated by summing the area under the extracted first pass of C(t) curve. The rCBV ratio of the lesion area was determined by dividing it with the contralateral normal side using a similarly sized ROI.

Results: In the initial scan of 3 patients that were diagnosed with progressing disease state, the rCBV ratio in the lesion areas were corrected from (3.25±0.92) to (3.21±0.72) using the proposed correction method. In two of the non-progressing cases, the initial scans showed stable or decreased rCBV ratio before (1.10±0.19) and after (0.92±0.15) correction. In two other non-progressing cases, high rCBV ratios were detected in the initial scans before correction (1.75±0.21) but the rCBV ratios were normal (1.04±0.13) after correction, consistent to clinical outcomes. An example slice from this group of patient is shown. Contrast enhanced T1 images with time interval of 2.8 month apart showed decreased size of lesion (not shown). Rectangle ROIs placed in lesion and surrounding area were shown in Fig.1b. Original concentration time curves (*C0*(*t*)), leakage-corrected *C0*(*t*) (*C1*(*t*)) and reconstructed first pass (*C2*(*t*)) for each ROI were shown in (c). rCBV map before correction (not shown) indicating tumor growing in lesion. Strong relative permeability was observed in the lesion as shown by K2 map (Fig.1d). rCBV map after correction (Fig.1e) showed normal blood volume which is consistent with clinical outcome of therapeutic response. Difference between those two rCBV maps was shown in Fig.1f, showing the bias of leakage induced overestimation of rCBV in the lesion area correlating with the high relative permeability on the K2 map.

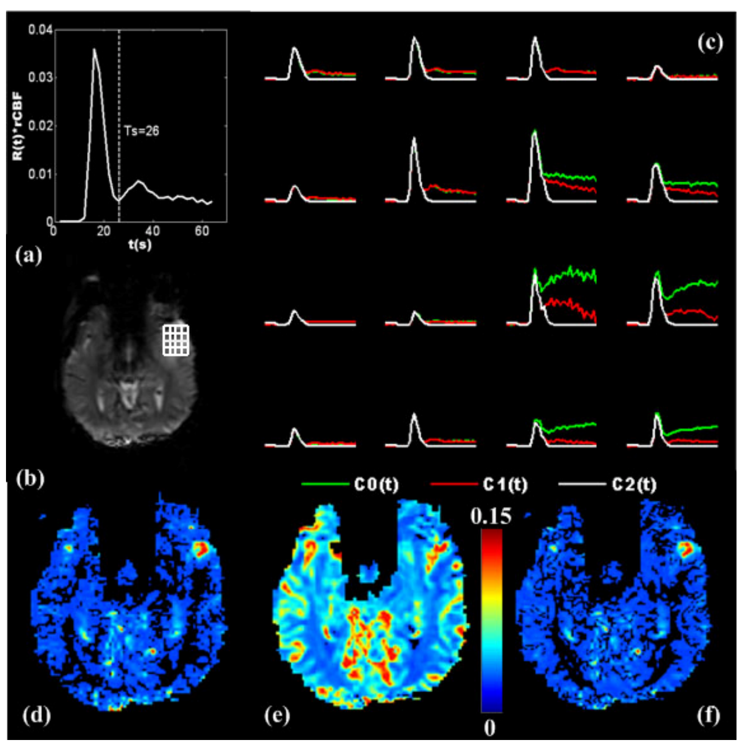

Fig.1: Example of a non-progressing case.

Discussion and Conclusions: Leakage effect correction and first pass extraction are necessary for accurate rCBV calculation using T2*-weighted DSC-PWI for GBM patients undergoing radiotherapy. Clinical datasets proved feasibility of proposed method.

References: 1. Johnson JL et al., Measuring blood volume and vascular transfer constant from dynamic T(2)*-weighted contrast-enhanced MRI, MRM 51:961-68(2004). 2. Wong KK et al., Improved Residue Function and Reduced Flow Dependence in MR Perfusion Using Least-Absolute-Deviation Regularization, MRM, in press.