

A Method to Remove Large Blood Vessel Contribution in Brain Tumor Perfusion Imaging

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Introduction Dynamic susceptibility contrast perfusion imaging (DSC PWI) is commonly used in brain tumor assessment. Measures of regional cerebral blood volume (rCBV) normalized to contralateral white matter (nCBVw) have been shown to correlate with tumor grade, to be an independent predictor of patient survival and to be useful for detection of tumor progression in antiangiogenic therapy [1,4]. Large blood vessels in or around the tumor, especially large veins, can confound the nCBVw assessment. Currently no practical operator independent method exists to separate the contribution from blood vessels in the tumor, so reliable nCBVw measurement requires expert operator review of high resolution radiological images such as post-contrast T1 weighted images to identify blood vessels. Operator review is time consuming, decreases reproducibility and subject to error because it is difficult to exclude partial volume averaging of the susceptibility effect of large blood vessels which can extend well beyond the physical size of the vessels. Multi-parametric voxel-by-voxel classification methods have been reported but require careful validation at each site and are difficult to implement reproducibly in a real clinical settings due to the added processing time, software complexity, and registration error introduced. We propose a simple alternative automated method to segment the macroscopic vessel contribution to whole brain DSC PWI rCBV maps by removing voxels that have high regional cerebral blood flow (rCBF) normalized to gray matter (nCBFg). This simple threshold method is possible because the inherent properties of a previously reported perfusion deconvolution algorithm that allows more accurate cerebral blood flow rate estimation at high blood volume and high blood flow rate [3].

Methods With IRB approval, data from glioblastoma patients (n=8) were retrospectively reviewed. including DSC PWI performed on a 3T MRI system (General Electric, Milwaukee, WI) with a gradient echo EPI sequence (TR=2000ms, TE=40ms, matrix=128x128, voxel size=1.8x1.8x5mm³, scan time 1.5 minutes) during bolus injection of 0.1mmol/kgGd-DTPA (Magnevist®) contrast. In-house perfusion software [3] was used to generate rCBF and rCBV maps. For validation, blood vessels were identified from high resolution post-contrast 3D spoiled gradient recalled (SPGR) T1 weighted images (1x1x1.5mm³) and high resolution fluid attenuated inversion recovery spin-echo post-contrast T1 weighted (FLAIR T1w) images (0.5x0.5x5.5mm³). To facilitate comparison of voxels identified on the nCBFg map with the location of the blood vessels on the post-contrast SPGR and FLAIR T1w image, these datasets were realigned to the perfusion image volumes using SPM2 (University College of London).

Results Fig. 1 shows a representative case. Fig. 1a and 1f show two consecutive post-contrast SPGR T1 weighted images. The corresponding post-contrast FLAIR T1w images are shown in Fig. 1b and 1g respectively. The white arrows indicate vessels inside the enhanced tumor. The vessels clearly have a very high nCBF (nCBFg>=2) but the are not easily distinguishable from adjacent tumor on the rCBV map as shown in Fig. 1d and 1i respectively. A whole brain post-contrast T1 weighted image is shown in Fig. 1e which corresponds well with the rCBF map in Fig 1j. Some of the veins had higher rCBF than small arteries.

Discussions We report a novel, simple method to identify blood vessels contribution to DSC PWI rCBV measurements using gray matter normalized nCBFg maps, permitting automated elimination of pixels on rCBV maps with high rCBV due to high flow in and around macroscopic vessels. The method is easily automatable, highly reproducible and thus should be easy to implement in the clinic. Compared to previously reported automatic methods, this technique is theoretically and computationally simpler, compensates for extended susceptibility effects and partial volume effects caused by large blood vessels, eliminates the need for inter-sequence registration, eliminates the need for validation of multi-parametric voxel classification. The major assumption underlying the method is that of a faster flow rate in macroscopic blood vessels than in tumor microvasculature, an assumption that is well founded in the rheology of brain tumor neovessels. If ongoing validation in a larger cohort confirms our preliminary findings, this technique promises to significantly improve routine clinical estimation of tumor nCBVw which should significantly aid in translation of DSC PWI based techniques for brain tumor grading, prediction of survival and followup.

References 1. AJNR Am J Neuroradiol. 2006 Apr;27(4):859-67.; 2. Magn Reson Med. 2009 May;61(5):1210-7.; 3. Magn Reson Med. 2009 Feb;61(2):418-28. 4. Caseiras GB et al. Eur J Radiol. 2009 Feb 5.

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