Effects of Artery Input Function on Dynamic Contrast Enhanced MRI for Determining Grades of Gliomas

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Introduction: The volume transfer constant (K^{trans}) and the fractional extracellular-extravascular space volume (V_e) can be determined from dynamic contrast enhanced magnetic resonance imaging (DCE-MRI), and have been used to distinguish low from high grade gliomas [1-3]. Selection of an arterial input function (AIF) is required to determine these values, but it is not currently known which AIF is optimum. In this study, we compared the values of K^{trans} and V_e obtained by using different AIFs in four grades of gliomas (determined by biopsy) for evaluating impacts of the AIFs on grading the tumors. **Materials and Methods:** 28 patients (10 females, 18 males; age range, 19–74 years with mean of 47.11±14.18 years) with histologically confirmed gliomas were examined using a 1.5 T MRI scanner (Siemens Syngo 2002B) with a standard birdcage head coil. Histopathologically 14 of the 28 gliomas were low grades (8 grade I and 6 grade II) and 14 high grades (6 grade III and 8grade IV). After a T1-weighted high spatial resolution imaging (TR/TE: 450/10ms, slice thickness: 5mm and10 axial slices for covering both tumors and anterior cerebral artery (ACA), middle cerebral artery (MCA), and posterior cerebral artery (PCA)), each patient was injected intravenously with Gd-DTPA (0.1 mmol per kilogram of body weight) at a rate of 4 mL/sec; a DCE perfusion imaging was performed for the contrast bolus tracking by using multi slice 2D Turbo-flash with a 20° flip angle over 6 minutes for a total of 90 volumes (TR/ TE: 199/1.05 ms, field of view (FOV): 211 mm×260 mm, image matrix: 256×208, slice thickness: 5mm, 10 slices). AIFs from ACA, MCA, and PCA were respectively derived from the time courses of the DCE scans. Tracer kinetic parameters K^{trans} and V_e were calculated from a modified two-compartment model [4,5] with the AIFs, and were compared using Two Related Samples Tests (TRST) (i.e., Wilcoxon Signed Ranks Test) and Mann-Whitney U-test in the low and high grades with a value of $P<0.05$ regarded as statistically significant. **Results:** Individual AIFs of ACA, MCA, and PCA of a patient with representative grade I glioma were plotted in Figure 1. A sharp wash-in phase and wash-out phase were observed in the AIFs. In Figure 2, mean values of K^{trans} and V_e corresponding to the AIFs were respectively plotted against the four grades. Regardless which AIF was applied, K^{trans} and V_e increased with the increase of histological grades from I to IV. P values of TRST for comparing K^{trans} and V_e between any two AIFs in the low or high grade were summarized in Table 1. P values of Mann-Whitney U-test for the K^{trans} and Ve derived from the AIFs of ACA, MCA, and PCA in the low vs high grades and grade II vs III groups were listed in Table 2. Specificity and Sensitivity of the K^{trans} and V_e to differentiate the low from high grade gliomas were calculated and the corresponding ROC curves were drawn in Figure 3. The areas under the ROC curves of the AIFs of ACA, MCA, and PCA for K^{trans} and V_e, were 0.983, 0.983, and 0.942, and 0.908, 0.942, and 0.892, respectively.

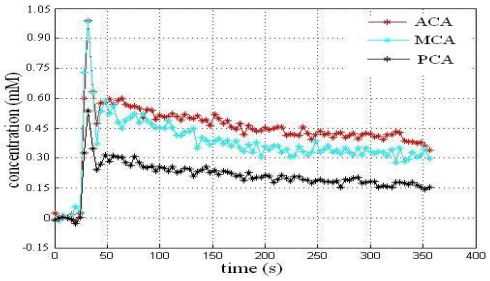

Figure 1 Individual AIFs of ACA (red curve), MCA (cyan curve), and PCA (black curve) of a representative grade I glioma.

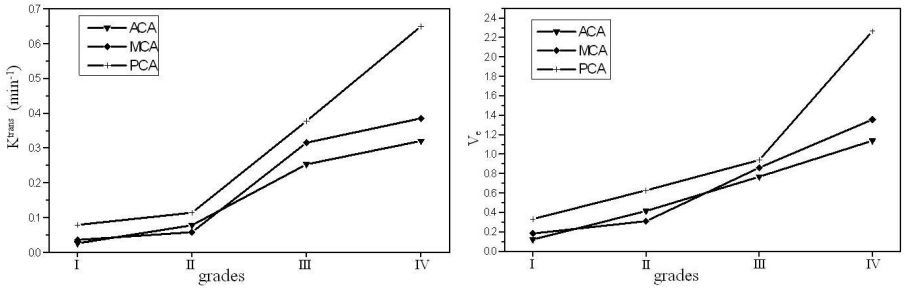

Figure 2 Mean values of K^{trans} (the left) and V_e (the right) corresponding to the AIFs of ACA, MCA, and PCA versus the histological grades.

Discussions: In the study, the AIFs from ACA, MCA, and PCA of a patient were applied to analyze the DCE data for assessing the impact of the AIF on grading gliomas. The peak height (PH) value of an AIF was lower for PCA than for AMA and MCA (Figure 1), resulting in the higher values of K^{trans} and V_e derived from PCA than the ones from ACA and MCA in all histological grades (Figure 2), and the difference was statistical significance since the results of Two Related Samples Tests exposed only p values between PCA and other two arteries (ACA and MCA) were less than 0.05 (Table 1). This may result from partial volume effect (PVE) for which reduces the accuracy of generating the AIF from the PCA. Despite difference of the AIFs generated from the ACA, MCA, and PCA, K^{trans} and V_e derived from the AIFs increase with the histological grades from I to IV (Figure 2), and can be applied to distinguish the low from high grades (Table 2, $p<0.05$) with high sensitivity and specificity (Figure 3). The ROC curves (Figure 3) indicated that K^{trans} of ACA and MCA were better indicators to distinguish the low from high grades since they had a better sensitivity and specificity. However, for distinguishing grade II with III, the data in the Table 2 suggest that only K^{trans} derived from the AIF of MCA has a p value less than 0.05. **Conclusions:** We can apply an AIF from any one of ACA, MCA, and PCA to a DCE data for distinguishing the low from high grade gliomas, however, the best choice for the goal is to apply an AIF from MCA.

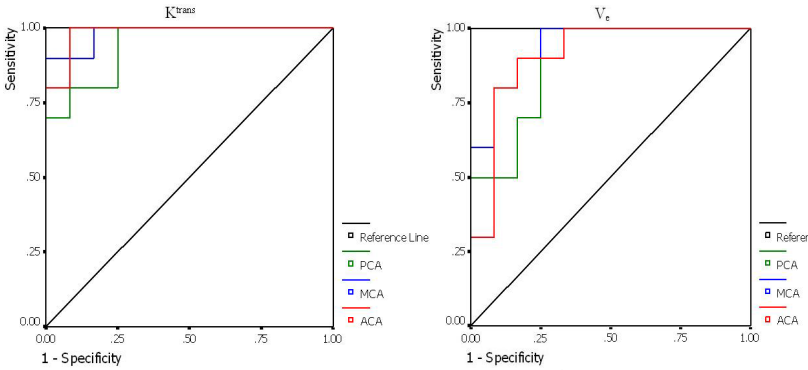

Figure 3 ROC curves of the AIFs of ACA, MCA, and PCA for K^{trans} and V_e, to differentiate the low with high grade gliomas.

Table 1 P (TRST) values for K^{trans} and Ve in the low or high grades

	K^{trans}		V_e	
	low	high	low	high
ACA vs MCA	0.683	0.386	0.638	0.059
ACA vs PCA	0.002	0.007	0.002	0.007
MCA vs PCA	0.002	0.013	0.002	0.028

Table 2 P (U -test) values of K^{trans} and Ve derived from the AIFs of ACA MCA, and PCA in the low vs. high grades and the grade II vs III groups

	K^{trans}			V_e		
	ACA	MCA	PCA	ACA	MCA	PCA
Low vs high	<0.001	<0.001	<0.001	0.001	<0.001	0.002
II vs III	0.050	0.014	0.086	0.221	0.086	0.142

References [1] Provenzale JM, et al. AJR Am J Roentgenol 2006; 1036-1042;[2] Jain R, et al. AJNR Am J Neuroradiol 2008; 694-700;[3] Patankar TF, et al. AJNR Am J Neuroradiol 2005; 2455-2465;[4] Tofts PS, et al. J Magn Reson Imaging 1999; 223-232;[5] Hou, BL, et al. 18th ISMRM Conference, Stockholm, 2009.