Consistency of permeability measurement using arterial input function and venous output function in DCE-MRI for metastatic brain tumors

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Introduction

In dynamic contrast-enhanced MRI (DCE-MRI), ideally arterial input function (AIF) should be measured in a feeding vessel as close as to the tissue to be analyzed. But in real cases, the AIF measurements are the major sources of errors for quantification of permeability in DCE-MRI, because of the partial volume and flowing blood effects from the small-size and tortuous feeding vessels (ie. middle cerebral artery (MCA). Venous output function (VOF) in the larger superior sagittal sinus (SSS), with similar shape of the concentration time curves as AIF, has been often used in permeability measurement for the reasons of less sensitivity to the above limitations and also ease in contouring VOF voxels [1, 2, 3]. However, there is a lack of comprehensive studies how to sample the vessel voxels for achieve a good consistency in permeability measurement of DCE-MRI. The aim of this study is to investigate how to improve the reproducibility of permeability measurement by using VOF and AIF with the commercial-available automatic software.

Methods

Eight cases have metastatic brain tumor with treatment or recurrent tumor in this study. DCE-MRI was performed on a 1.5T Siemens symphonyTim clinical system while a bolus of 0.1 mmol/kg Gd (Gadovist 1.0 M) was injected at a speed of 3 ml/s antecubital vein followed by a 20 ml saline flush. DCE imaging was used a 3D-T1-GRE (TR/TE=3/1.07 s, flip angle=15°, FOV=260*179 mm, matrix size=128*88), time resolution is 4.6 s. And we also get images to calculate T_1 maps by changed flip angles from 5 to 25 which were used for measurement of Gd concentration for the pharmacokinetic modeling of the tumor.

Images were analyzed by software of MIStar (Apollo Medical Imaging Technology), which can automatic to computed K^{trans} by several models. We using Tofts's model [4] in this study, and also using T_1 maps to calculate tissue concentration time curves voxel by voxel. In each case, we just simply change the AIF to calculate K^{trans}. First, we manually picked various numbers of vessel voxels in MCA randomly from 1-2 slices to measure AIFand in the SSS randomly from 4-6 slices to measure VOF. Repeated foregoing steps 4 times to get different AIFs and VOFs in each case. Finally, we could get 8 K^{trans} maps in each case. For comparisons, regions of interest (ROIs) were applied to tumors in K^{trans} maps of eight cases to get values of mean and standard deviation. Then we calculated the coefficient of variation (CoV) from the values of K^{trans} used AIF or VOF methods to find which had better consistency.

Results

In this study, the results showed that the permeability measurement variability of DCE-MRI was much improved by raising the selected number from 1-5 to 10-12 vessel voxels for VOF and AIF. The mean values of K^{trans} were larger of using AIF from MCA than those using VOF in SSS, in the ranges of 102.86 to 366.9 (1 min/1000) and 28.27 to 81.14 (1 min/1000). The CoVs of VOF were significantly lower than those of AIF (pair t-test, $p< 0.005$), shown in Table 1.

case	AIF			VIF		
	Mean	SD	CoV	Mean	SD	CoV
1	199.54	18.09	9.07	47.67	2.82	5.91
2	239.72	12.58	5.25	58.28	1.99	3.42
3	104.61	10.48	10.02	28.27	2.07	7.31
4	218.28	18.29	8.38	81.14	3.36	4.14
5	178.19	20.10	11.28	48.96	4.80	9.81
6	366.90	53.97	14.71	39.00	2.38	6.11
7	342.05	25.37	7.42	40.43	0.90	2.23
8	294.44	20.69	7.03	74.83	3.93	5.25

Table 1. The values of mean, standard deviation, and coefficient of variation from 4 different of AIF and VOF measurements in each of eight cases.

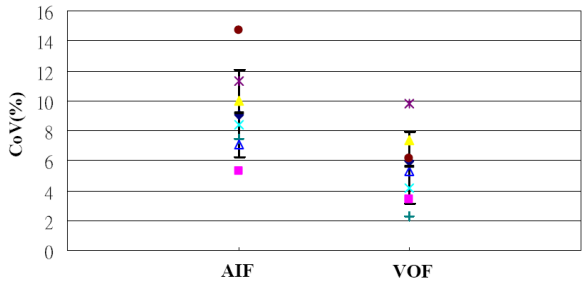

Figure 1. The scattergram showed the values of CoV used AIF and VOF measurements in eight cases.

Conclusion

The measurement of lesion permeability would be a useful imaging biomarker for determining the disease activity and guiding the treatment strategies in patients of metastatic brain tumor. The preliminary results of the experiment illustrated that the consistency of K^{trans} measured by using VOF in SSS would also be improved by selecting a higher number of vessel voxels. The consistency of permeability measurements with VOF in SSS was also better than that by using AIF in MCA. Based on our study, we believed that the reproducibility of permeability measurement in DCE-MRI would be effectively improved by using VOF with more vessel voxels from the larger and straighter SSS, and the measurement of K^{trans} with the commercial-available automatic software would be clinically applicable for longitudinal follow-up of brain metastatic tumors.

References

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