Reference Based Quantification Method of Perfusion without using Arterial Input Function in Dynamic Susceptibility Contrast MRI : Clinical Assessment with Pulsed Arterial Spin Labeling

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Abstracts

The purpose of this study is to assess reference based quantification methods that are robust to measurements of arterial input functions (AIF) in DSC-MRI. Difference of appearance time (deltaAT) and the ratio of maximum gradient of tissue curve between contralateral regions instead of CBF were assessed for cerebral clinical data. Pulsed arterial spin labeling (PASL) was used for correlation study. The CBV ratio calculated with the area under curve and the CBF ratio calculated with the maximum gradient method for tissue curve indicated clinical usefulness especially in stroke patients because of its simplicity and robustness to the AIF dependent errors.

Introduction

The ideal quantification of DSC-MRI data is analyzed based on the following Indicator dilution theory: $C(t)=Ka\ CBF\int_0^t Ca(t-s)\ R(s)ds$ (1),

where, C(t) : time intensity curve (TIC) for tissue, Ka: scaling factor depends on hematocrit difference between capillaries and large vessels, Ca(t): arterial input function(AIF), and R(t): residue function. Generally, measurements of accurate AIF are indispensable for quantification of perfusion parameters such as MTT, CBV, and CBF based on the indicator dilution theory using vascular contrast materials. Quantification trials of cerebral perfusion using deconvolution method based on the equation 1 have reported on DSC-MRI [1,2]. However, it is difficult to measure accurate AIF in DSC-MRI because of nonlinearity and limited dynamic range between deltaR2* and concentration of contrast agent compared to the dynamic CT perfusion. Furthermore, transit delay and dispersion of measured AIF introduces considerable errors in the quantification of MTT and CBF, even if AIF is measured and applied especially in stroke patients [3,4]. On the other hand, assessment of AIF dependency using summary parameters for tissue curve was reported [5]. In this study, we have assessed simple quantification methods of perfusion parameters using referential values of the summary parameters without measuring AIF for cerebral ischemic clinical data.

Methods

Definition of summary parameters in TIC shown in Fig.1 are AT: appearance time, PT: peak time, PH: peak height, MT1: 1'st moment, FWHM: full width at half maximum, US: maximum gradient, and AC: area under curve. Absolute perfusion index used here were as follows:

deltaAT=AT-ATref, CBVratio=ACratio=AC/ACref, CBFratio=USratio=US/USref, MTTratio=CBVratio/CBFratio,

where, "Xref" means reference value of parameter "X", and " Xratio" is defined the ratio of parameter "X" to the reference. In the CBVratio calculated with the ACratio, hematocrit and nonlinearity dependent factor (Ka) is cancelled in Equation 1. In the CBFratio obtained with the maximum gradient method [6], maximum intensity of Ca(t) is cancelled in Equation 1. Perfusion imaging was performed on a 1.5T imager (Toshiba Visart/Hyper). For DSC-MRI, immediately after 10ml Gd-DTPA-BMA followed by 15ml saline were injected intravenouly, 30 dynamic scan with single shot gradient-echo EPI sequence (TR/TE=2000/40ms) were performed within 60sec. TICs in the region of interest (ROI) were measured on the symmetrical region of MCA area in the slice across basal ganglia, then summary parameters were obtained with fitting with gamma-variate function on the MR imager. Contralateral region was selected as a reference. Cerebral stroke patients except for bilateral cases (N=40), including MCA occlusion (N=8), ICA occlusion (N=12), stenosis (N=14), and lacuna infarction (N=6) were examined. For arterial spin labeling (ASL), ASTAR method [7] which was a kind of pulsed ASL we developed was used for correlation study. Conditions of ASTAR sequence were as follows: fast gradient field echo (FFE:TR/TE/FA=9ms/3.6ms/15deg,TI=1.4s), 10cm tag located on the inferior region of 1cm imaging slab with the gap between imaging slab and tag was selected as 1cm in order to minimize transit delay errors, and a pre-saturation pulse (0.8s after tag) on the tagged region for decreasing blood signal were applied. ASL_CBF was calculated with the linear scaling method [8]. The CBF and CBFratio were obtained with following three methods: MT1_CBF=AC/MT1, FWHM_CBF=AC/FWHM, and US_CBF=US. The former two were already assessed in DSC-MRI [5]. Correlation of CBF and CBFratio obtained with each method in the DSC_MRI and those obtained with the ASL, and the deltaAT in each patients group were statistically analyzed.

Results and Discussion

Correlation coefficient "r" of the CBF calculated using US with the ASL_CBF was significantly greater compared to the CBF calculated using MT1 which is used generally, and the CBF calculated using FWHM. And also the CBFratio calculated using USratio showed the best correlation with the ASL.CBFratio compared to the others (see Table1). These results were consistent with our numerical simulation shown in the other report in this meeting. The deltaAT in the MC occlusion was significantly longer than the other cases (p=0.09, 0.05, and 0.01,respectively) (see Table2), which is considered to be the affects of collateral flow from the contralateral side. Mapping the relationship between CBVratio calculated with the area under curve and CBF ratio calculated with the maximum gradient method is shown in Fig.2. This data is considered to become a comparable index of perfusion in different study and patients independent of AIF. Furthermore, A ROI analysis as well as pixel by pixel mappings of these referenced parameters are also available, if a single ROI on a subject such as a cerebellum is chosen as reference. The maximum gradient method requires that bolus duration must be sufficiently brief. Combination of the maximum gradient and reference based method on DSC-MRI can use a brief and concentrated bolus injection as far as possible, because transit delay and non-linearity errors of AIF are not serious problem as compared to the deconvolution methods. DSC-MRI can use a brief injection compared to CT because DSC-MRI requires far less contrast agent than CT. In addition, gradient-echo as well as spin-echo sequences having strong nonlinearity can be applied.

In conclusion, CBV ratio calculated with the area under curve and CBF ratio calculated with the maximum gradient method without using AIF indicated clinical usefulness especially in stroke patients because of its simplicity and robustness to AIF dependent errors, and these parameters can become database as reflecting absolute indexes of cerebral perfusion.

References

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Table 1: Correlation coefficients "r" of CBF and CBFratio with three methods in DSC-MRI and with ASL_CBF in sickness side (N=40).

correlation	ASL_CBF
MT1_CBF	0.40
FWHM_CBF	0.43
US_CBF	0.56

correlation	ASL_CBFratio
MT1_CBFratio	0.46
FWHM_CBFratio	0.44
US_CBFratio	0.58

Table 2: Difference of transit delay time between sickness and contralateral side obtained by deltaAT=AT-ATref with DSC-MRI.

pathology	N	MEAN[sec]	SD[sec]
MC occlusion	8	1.01	0.59
IC occlusion	12	0.52	0.38
stenosis	14	0.23	0.41
lacuna infarction	6	0.10	0.53
total	**40**	**0.47**	**0.48**

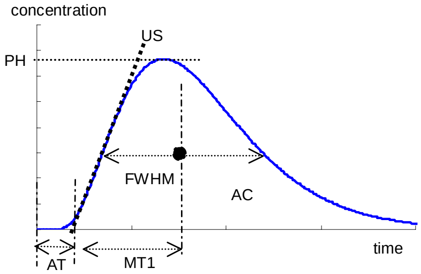

Fig.1: Time intensity curve of tissue and definition of summary parameters.

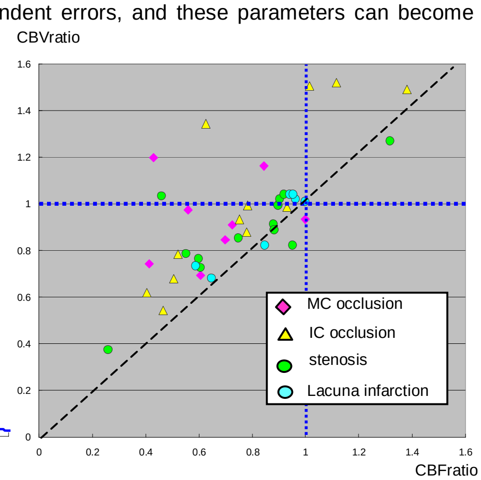

Fig.2: CBVratio vs. CBFratio in the four types of cerebral occlusion cases obtained with maximum gradient (US) for CBF and area under curve (AC) for CBV. (N=40)