대한임상신경생리학회지 4(1):000~000, 2002 ISSN 1229-6414

천막상부 뇌졸중에서 소뇌의 혈역학 변화 -Dynamic Susceptibility Contrast MR 영상을 이용한-

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Effect of Supratentorial Stroke on Cerebellar Hemodynamic Parameters - Assessment by Dynamic Susceptibility Contrast MR Imaging

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Background & Purpose : Dynamic susceptibility contrast MR imaging, one method of perfusion MRI, was developed to define cerebral hemodynamic status with good anatomical resolution. The authors investigated hemodynamic parameters using this imaging method, in an effort to identify hemodynamic changes on the remote crossed cerebellum of patients with a supratentorial infarct.

Methods : Dynamic susceptibility contrast MR imaging was performed in 15 patients with only unilateral supratentorial infarcts. Imaging was obtained at the anatomic level of the cerebellum. rCBF, rCBV, MTT and TP were determined over both cerebellar hemispheres of interest.

Results : The rCBF and rCBV values of the contralateral cerebellar hemisphere were significantly more decreased than those of the ipsilateral cerebellar hemisphere in 12 patients(p=0.028, 0.033). MTT and TP values of the contralateral and ipsilateral cerebellar hemispheres didn't reveal any differences(p=0.130, 0.121).

Conclusions : The results of this work suggest that the region which are remote from the ischemic brain lesion shows no changes of MTT or TP but show decrease of rCBF and rCBV, mean to diaschisis, it also demonstrates that perfusion MRI is an easily available method to evaluate the hemodynamic status of the brain.

Key Words : Diaschisis, Dynamic susceptibility contrast MRI, Cerebral blood flow, Cerebral blood volume, Mean transit time, Time to peak

INTRODUCTION

Understanding to the hemodynamic parameter in stroke is helpful to predict the functional outcome and to decide the rescue therapy to a potentially reversible area. Positron emission tomography(PET) studies show a variably altered interplay among local cerebral blood flow(CBF), cerebral blood volume(CBV), cerebral metabolism rate of oxygen(CMRO2) and cerebral metabolic rate of glucose(CMRGlu) value, allowing one to define distinct profiles of changes in physiologic coupling each understanding a different pathophysiologic situation[1-3]. PET, however, is not routinely available method and has poor anatomical detail. Recently, perfusion MRI can be another method to assess the tissue perfusion combined with good spatial resolution of MRI[4]. Early report suggests that CBV may be the best predictor of final lesion size, while recent report has found a measure of perfusion delay to be the best predictor[5-7]. Particularly neurally connected remote area with reversible hypofunction, referred as diaschisis, shows decreased regional CBF(rCBF) and regional CBV(rCBV) and increased oxygen extraction frac-

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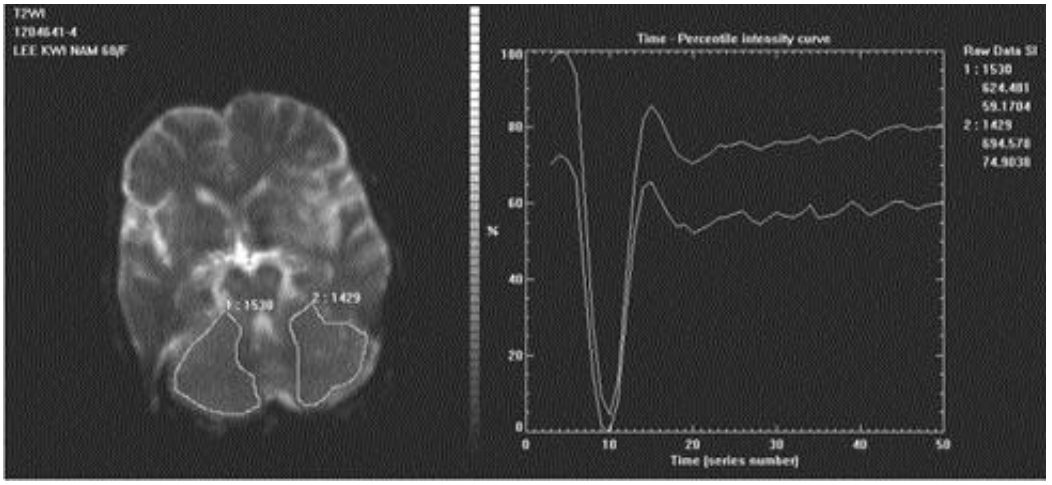

Figure 1. Patient 11. Fast SE T2 weighted image showed high signal intensity on left MCA territory without cerebellar lesion. Two ROIs is drawn in the bilateral cerebellar hemisphere for T2* rate change-time curve, and T2* rate change-time curve measured in ROIs in both cerebellar hemisphere shows a decrease in relative regional cerebellar blood flow in right cerebellar hemisphere.

Table 1. Patient data

Patients No./Sex/Age(y)	Lesion location	No of days after onset of symptoms
1.M/59	Lt lenticulostrate artery	3
2.F/40	Rt ICA	15
3.F/82	Lt M2 cortical branch	2
4.F/65	Rt M2 posterior branch	1
5.M/72	Rt M2 anterior branch	2
6.M/64	Rt MCA	3
7.M/57	Rt MCA	1
8.M/80	Lt MCA	8
9.M/45	Lt striatocapsular infarct	2
10.F/69	Lt striatocapsular infarct	12
11.F/68	Lt MCA	3
12.M/83	Lt MCA	4
13.M/49	Rt M2 anterior branch	4
14.M/60	Lt anterior choroidal artery	2
15. M/72	Lt anterior & posterior borderzone infarct	5

Lt : left, Rt : right

tion(OEF) in the studies using PET[8-10]. Although, a few studies observed decreased rCBF and rCBV with perfusion MRI[11,12], there is no report about mean transit time(MTT) and time to peak(TP) meaning the perfusion time. So, the authors analyzed the rCBF, rCBV and MTT and TP on the cerebellum in the patients with supratentorial stroke by using perfusion MRI.

PATIENTS and METHODS

Fifteen patients who had unilateral supratentorial stroke without cerebellar lesion(10 men and 5 women; age 40~83, mean 64.3 years) performed with dynamic susceptibility contrast MR imaging at 1 to 15 days after the onset of symptoms. Four patients had superficial middle cerebral artery(MCA) infarct, four had deep MCA infarct, six had ICA or proximal MCA infarct, and 1 had anterior choroidal artery infarct.

MRI

A 1.5T MR imaging system(Simens) was used to acquire fast spin-echo T2-weighted images before the administration of the contrast agent(repetition time/echo time = 3500 msec/100 msec; section thickness 7 mm; field of view 230; matrix 230×256). T2-weighted dynamic susceptibility contrast MR imaging was performed with a gradient echo echo-planar image(EPI) sequence(flip angle 90°, field of view 230; section thickness 7 mm; matrix 128(180). After three

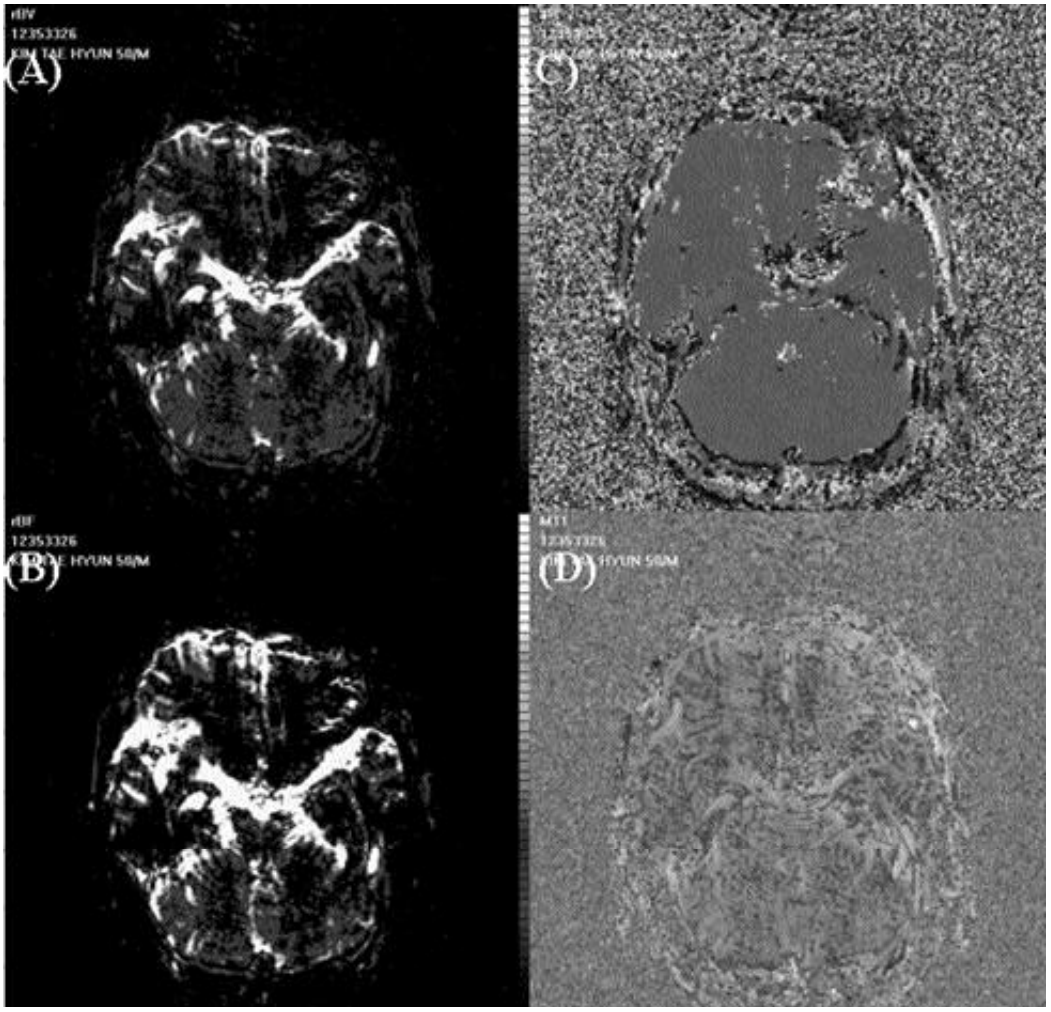

Figure 2. Patient 13(A). Map of regional cerebellar blood volume. The left cerebellum shows crossed cerebellar hypoperfusion(B). Map of regional cerebellar blood flow. The left cerebellum showed crossed cerebellar hypoperfusion(C). Map of MTT of cerebellum. There is no significant difference between both cerebellar hemispheres(D). Map of TP of cerebellum. There is no significant difference between both cerebellar hemispheres.

images were obtained, a bolus injection of 0.2 mmol per kilogram of body weight gadolinium(Magnevist; Schering, Germany) was administered through a 20-gauge intravenous needle, which was inserted into the vein of the right antecubital fossa. Imaging time was 1 sec per image without interimage delay; a total of 50 images were obtained. The T2-weighted dynamic images were obtained at the same location. The raw signal intensity time series data were converted to concentration-time data(fig. 1). The area under the concentration-time curve is proportional to the local blood volume[13]. The map of CBV was calculated as the sum of the first-pass T2 rate change image calculated on pixel-by-pixel basis. TP was defined as the time reaching to the peak of the concentration-time curve. MTT, then, was calculated as a time reaching to a half of CBV. CBF was computed from CBV/MTT ratio.

In the T2-weighted dynamic image, a skillful radiologist drew the region of interest(ROI) on both cerebellar hemisphere, and took care not to include the sinus in the ROI. The ROIs were then copied on the CBF, CBV, MTT, and TP images.

Statistics

Paired t test was used to analyze the differences among rCBV, rCBF, MTT, and TP in the ipsilateral and contralateral cerebellum to the cerebral lesion. The differences giving $p<0.05$ were considered significant.

RESULTS

All patients showed no morphologic alterations

Table 2. Parameters in ipsilateral and contralateral cerebellar hemisphere

Patient No	irBV	crBV	irBF	crBF	iMTT	cMTT	iTP	cTP
1	2590.28	2273.35	94.7428	83.0281	26.9318	27.0312	20.7937	21.2696
2	2973.75	2773.76	117.839	114.517	23.9919	23.2213	15.2748	15.2947
3	2448.15	2457.02	103.163	104.238	23.2722	23.8014	17.4486	17.8425
4	2704.3	2872.11	107.26	112.483	24.8343	25.24	19.5756	19.7467
5	2018.84	2002.45	70.6254	80.8093	28.425	28.2973	25.4153	24.977
6	6226.05	4537.58	271.953	206.37	22.4182	21.6211	18.0791	17.8072
7	3152.49	2881.42	151.501	139.465	20.348	20.3456	13.5623	13.6751
8	2641.98	2640.3	145.776	144.868	17.7146	17.6751	8.54306	8.71877
9	2689.62	2308.19	123.056	105.38	21.5219	21.4325	16.2943	16.33
10	2736.04	2802.08	174.207	177.873	15.169	15.3227	7.34337	7.68669
11	4560.01	3191.12	250.43	188.329	17.4766	16.6837	6.89503	6.72549
12	2811.18	2709.01	129.793	117.874	21.4223	22.9575	10.2736	10.5997
13	2524.24	2275.78	96.2424	87.4441	25.7365	25.4851	17.4782	17.6125
14	1279.29	1057.36	72.5764	60.3674	17.4346	17.202	13.5	13.5953
15	4709.85	4394	200.566	185.293	23.3831	23.663	16.6824	16.8107
Mean	3071.0713	2745.0353	140.6487	127.2226	22.1002	21.8896	15.1604	15.2471
SD	1217.5017	857.6772	60.4962	44.7437	3.8256	3.9083	5.2204	5.1609
P	.028*		.033*		.966		.133	

irBV: rCBV on ipsilateral cerebellum, crBV: rCBV on contralateral cerebellum, irBF: rCBF on ipsilateral cerebellum, crBF: rCBF on contralateral cerebellum, iMTT: MTT on ipsilateral cerebellum, cMTT: MTT on contralateral cerebellum, iTP: TP on ipsilateral cerebellum, cTP: TP on contralateral cerebellum, *p<0.05

on the cerebellum in conventional T2-weighted images.

There were no significant differences on the bilateral cerebellar hemispheres in diffusion and ADC(apparent diffusion coefficient) image. The rCBV and rCBF in the contralateral cerebellar hemisphere(rCBF = 127.2226±44.7437, rCBV = 2745.0353±857.6772) were lower than those in the ipsilateral side(rCBF = 140.6487±60.4962, rCBV =3071.0713±1217.5017)(p=0.009, 0.011). The MTT and TP had no significant differences between the ipsilateral(MTT = 22.1002±3.8256, TP = 15.1604±5.2204) and contralateral side(MTT = 21.8896±3.9083, TP = 15.2471±5.1609)(p=0.130, 0.121).(Figure2, Table 2). Three patients(case 5,6 and 11) showed higher rCBV and rCBF on the contralateral cerebellum than those on the ipsilateral cerebellum, but their values did not exceed above 10 % compared to the ipsilateral cerebellum.

DISCUSSION

In contrast MTT and TP, rCBF and rCBV were significantly decreased in the contralateral cerebellar hemisphere. These results agree with PET study by Yamauchi et al.[8], in which they evaluated the hemodynamic and metabolic parameters in the patients with unilateral supratentorial stroke that showed decreased the regional blood volume with normal ratio of regional blood flow to regional blood volume in the contralateral cerebellum.

In the ischemic brain, there are variable patterns in the hemodynamic failure according to the disruption in the physiologic flow-metabolism coupling, such as phase of autoregulation, misery perfusion with oligemia or true ischemia, irreversible complete infarct, luxury perfusion, and primary metabolic depression, namely diaschisis[1-3]. Because the identification of hemodynamic status provide the prediction of the reversible area within the therapeutic window and functional outcome in stroke, many modalities such as PET, SPECT and ^{133}Xe-CT have been studied. Even though PET is the excellent modality to assess the hemodynamic and metabolic status, it has the limitation due to expensive cost and poor anatomical resolution. Dynamic susceptibility contrast MR image utilizes the collection of a rapid series of echoplanar magnetic resonance images immediately following the Gd-DTPA infusion. It is able to operate simultaneously with MRI and to show good anatomical detail. The

decrease in observed transverse relaxation rate(T2*) is an approximately linear function of contrast agent concentration. It is thus possible to use tracer kinetic models to estimate the local cerebral blood volume[14]. And the MTT can be derived from these time-intensity curves, and the estimate of CBF can be derived from according to the central volume principle(CBF=CBV/MTT). Reduced CBF and CBV as well as increased MTT of blood through tissue were identified in the ischemic lesion. The early reports suggested that CBV is the best predictor of final lesion size, while recent studies insisted a measure of perfusion delay to the best predictor[5-7]. It is suggested that the decrease of CBF/CBV ratio below threshold value(reliable index of local cerebral perfusion pressure(CPP)[15,16]) and increase of CBV/CBF ratio(that mean MTT[17]), in which the CBF falls and the OEF rises, corresponds to getting over the limit of autoregulatory capacity.[15,16] Volume-flow mismatch as prolongation of MTT(=CBV/CBF) and TP may mean the increased blood pooling, vasodilatation due to increased demand for compensation of the lack of perfusion.

Remote metabolic effects in the brain are widely explained as functional deactivation that depressed synaptic activity at sites distant from the lesion, but neurally connected with that area. Crossed cerebellar diaschisis(CCD) is one of the striking phenomena and occurs in about 50% of the patients with supratentorial infarct[18-20]. We considered the cerebellum to be the appropriate site for assessing the remote hemodynamic changes in neurally connected anatomical area where excludes the oligemia. Although CBV and CBF decreased, maintaining of normal MTT and TP as our result indicates rapid transit of blood flow that causes vasoconstriction[8]. This may be the differential point between the ischemic area and the area with primary metabolic depression. Three cases showed lower CBF and CBV on the ipsilateral cerebellum. It is likely that the unexpected data are secondary to ROI including vascular structure and considered to the non-significant results because the asymmetries of CBF and CBV between both cerebellar hemispheres were not exceeding 10%.

The authors suggest that perfusion MR is a useful imaging modality to assess the cerebral hemodynamics in ischemia, and MTT and TP are the differential point of the reversible area. Although perfusion MR cannot assess metabolism and OEF, it is superior to PET or SPECT in the aspect of the availability or anatomic resolution.

Acknowledgment

We thank Dr Kwang-Soo Lee at the Department of Neurology and Dr Byung-Gil Choi at the Department of Radiology, College of Medicine, the Catholic University of Korea for their support and technical help.

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