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Diffusion Tensor Magnetic Resonance Imaging as a Prognostic Indicator in the Deep Intracerebral Hemorrhage

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ABSTRACT

Objective : Diffusion tensor MR imaging (DTI) provides a means to visualize the course of the corticospinal tract within the white matter. The purpose of this study was to investigate the corticospinal tract in patients with deep intracerebral hemorrhage (ICH) involving the posterior limb of the internal capsule, to correlate with the motor impairment of the extremities, and to predict with motor improvement after stereotactic evacuation of the ICH. **Methods** : Ten patients with deep intracerebral hemorrhage (ICH) on the basal ganglia or thalamic region were included to this study. All patients underwent the stereotactic catheter insertion. The DTI was obtained within 5 days after the hemorrhagic attack, focusing on the posterior limb of the internal capsule (PIC). The patients were evaluated using the motor grading system (grade 0 to 5) initially and 2 months later. The Mann-Whitney U test was used for the statistical analysis. **Results** : The motor scales improved only in the patients with the partially or non-involved PIC. The p value was 0.007 for upper extremities and 0.008 for lower extremities. In patients with the totally preserved PIC, follow-up motor scales improved in comparison with the preoperative state. In patients with the partially preserved PIC, follow-up motor scales improved according to the hierarchical organization principles. **Conclusion** : The DTI can show the degree and locations of the involvement by the hemorrhages to PIC and the DTI may be used as a good indicator to the motor function outcome in the patients with hemorrhagic stroke at basal ganglia or thalamic region. **(Kor J Cerebrovascular Surgery 8:267-72, 2006)**

KEY WORDS : Intracerebral hemorrhage · Diffusion tensor imaging · Corticospinal tract · Internal capsule

Introduction

Deep intracerebral hemorrhage (ICH) is a common disease that has been reported to account for approximately 10-13% of all strokes.[2)3)17)] The common locations of the deep ICH are the basal ganglia (putamen and caudate) or the thalamus. The initial symptoms of the deep ICH in those regions include vomiting with or without headache, sensorimotor deficits and worsening level of consciousness. These symptoms and signs including sensorimotor deficits improve with the medico-surgical treatments in some patients but not in the others. The motor function improvement depends on the severity of corticospinal tract injury which can be evaluated by the neurological examination (paresis, plegia, etc) or by the neuroimagings (CT, MRI, etc).[9)] The limb paresis was reported to be one of the prognostic factors in the patients with deep ICH but it is not always true as some patients showed the surprising motor function improvement.[5)] Among the neuroimaging techniques, diffusion tensor imaging (DTI) can demonstrates the structures of the corticospinal tract with the three dimensional images.[9)11)16)]

DTI is a newly developed technique with which we can explore the intrinsic diffusion properties of the deep tissues such as white matter tracts in the central nervous

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system.[8)12)18)] The anisotropic diffusion can be obtained and measured maximally in the white matter as axonal membranes and myelin sheaths serve as for the barriers which restrict the motion of water molecules within the directions parallel to their own orientation.[8)12)]

The goal of this study was to visualize the corticospinal tract involvement by the hemorrhages using three dimensional tractographies and to demonstrate that the tract involvement expressed by tractographies may be one of the indicator to the motor function outcome, which can replace the paresis as the prognostic factor.

Materials and Methods

Ten patients with deep ICH were studied. ICHs were located in the area of basal ganglia or the thalamus. The mean age of the patients was 56 years, ranging from 45 to 76 years. There were 8 men and 2 women (men : women ratio = 4:1). They had sudden onset of hemibody weakness with mental deterioration. The mean volume of the hemorrhages was 24.8 cc, ranging from 10 to 55 cc. All patients were operated with the stereotactic catheter insertion and the removal of hematoma at the day of hemorrahgic attack. The catheter was maintained for 2~5 days with urokinase irrigation. The DTI was obtained within 5 days after the hemorrhagic attack. The neurological examination was checked 2 times, preoperatively and 2 months later using the motor grading system rated on a scale of 0 to 5. 0 represents no contraction; 1, a twitch with inability to move the joint; 2, ability to move without gravity; 3, inability to resist opposition but ability to move a joint against gravity; 4, reduced strength but ability to resist an opposing force; 5, normal strength.

We performed DTI using 2.0 tesla MR scanners (Siemens, The Germany). Single-shot spin-echo echoplanar sequence was used for DTI with these parameters: TR 8800ms, TE 93ms, matrix 128x128, field of view 24x24 cm, 55 interleaved contiguous 2.5 mm axial images covering the entire brain and b 1000 s/mm^2 with 12 noncollinear directions. We also obtained T2-weighted images.

After obtaining all the source images of DTI, the diffusion tensors were calculated and 3D fiber-tract maps were made using the software (DTI task card) which is contained in the MRI. We drew a region of interest on the lower anterior pons from which we could trace the corticospianl tract bilaterally, in the affected and non-affected side. The tracing of non-affected side was for the control. The tracing was performed in both ante- and retrograde direction in 3D space from seed region along the major eigenvector. The 3D tract was superimposed on 2D (axial) T2 weighted images.

We focused on the posteior limb of the internal capsule (PIC) on which we evaluated the involvement of the hemorrhage to the corticospinal tract. According to the degree and location of involvement, we divided the group into four, partially involved group (anterior portion and posterior portion), non-involved group and totally involved group. We compared the motor function changes (in both upper and lower extremity) in these four groups. We divided

Table 1. Clinical summary of ten patients with deep intracerebral hemorrhage

Case No.	Lesion Side	Age (yrs)	Sex	Time to MRI (day)	Past history	Presence of IVH	Hematoma Size (c.c)	Motor scale (Upper Extremity)*	Motor scale (Lower Extremity)*
1	Left	63	F	5	HiBP	No	44	1 → 1	1 → 1
2	Right	54	M	2	HiBP	No	14	1 → 1	1 → 1
3	Right	53	M	1	HiBP, DM	No	17	4 → 4+	4 → 4+
4	Right	59	M	1	HiBP, DM	No	24	2 → 4	2 → 4
5	Right	45	M	1	HiBP	No	14	0 → 4	1 → 4
6	Left	64	M	5	HiBP, DM, Sm	Yes	10	2 → 3	1 → 2
7	Left	46	M	5	HiBP, Sm	Yes	55	1 → 1	2 → 2
8	Right	51	M	1		Yes	35	1 → 2	1 → 4
9	Right	48	F	1		No	25	2 → 3	2 → 3
10	Left	76	M	2	HiBP, Sm	Yes	10	2 → 2	2 → 2

HiBP : hypertension, DM : diabetes mellitus, Sm : smoking
* Preoperative state and 2 months follow-up were described

the group into two by the other factors such as age, sex, presence of intraventricular hemorrhage (IVH) and hematoma size and we compared the motor function changes, too. The Mann-Whitney U test was used for the statistical analysis.

Results

Table 1 summarized the characteristics and neurological states of patients. The motor scales improved in six patients and didn' t improve in four patients (Table 1).

Table 2 summarized the types classified according to the degree and location of involvement by the hemorrhages to corticospinal tract in association with the motor scales. Type I contained one patient whose DTI showed that the anterior part of the PIC was involved (Fig. 1). His follow-up motor scale improved very much, especially in the lower extremity (from grade 1 to 4). Type II contained one patient whose

Table 2. The types of the corticospinal tract involvement by the hemorrhage

Motor scale improvement by the involvement region		Type I (Anterior PIC involvement)	Type II (Posterior PIC involvement)	Type III (No PIC involvement)	Type IV (Entire PIC involvement)
Upper extremity	Improved	Case No. 8	Case No. 6	Case No. 3,4,5,9	
	Not improved				Case No. 1,2,7,10
Lower extremity	Improved	Case No. 8	Case No. 6	Case No. 3,4,5.9	
	Not improved				Case No. 1,2,7,10

PIC : posterior internal capsule

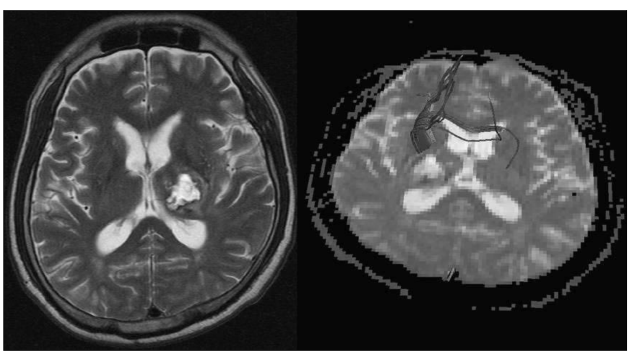

Fig. 1. T2-weighted axial image (left), tractographies (right) show the partially preserved PIC. The anterior part of PIC is preserved.

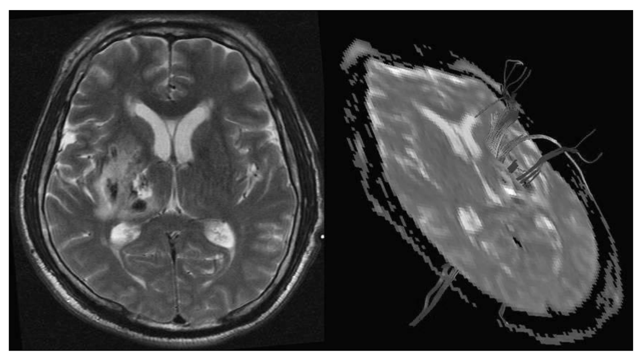

Fig. 2. T2-weighted axial image (left), tractographies (right) show the partially preserved PIC. The posterior part of PIC is preserved which is located in the hemorrhage.

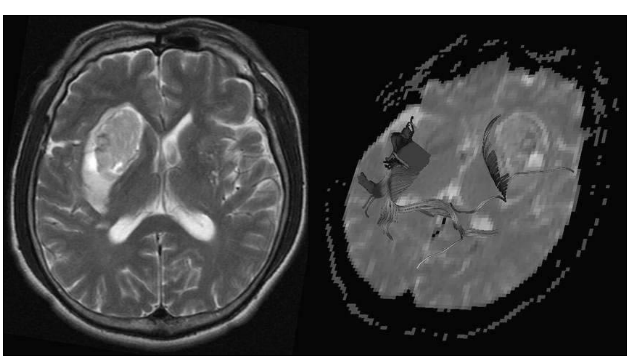

Fig. 3. T2-weighted axial image (left), tractographies (right) show the preserved PIC. The right PIC is displaced medially.

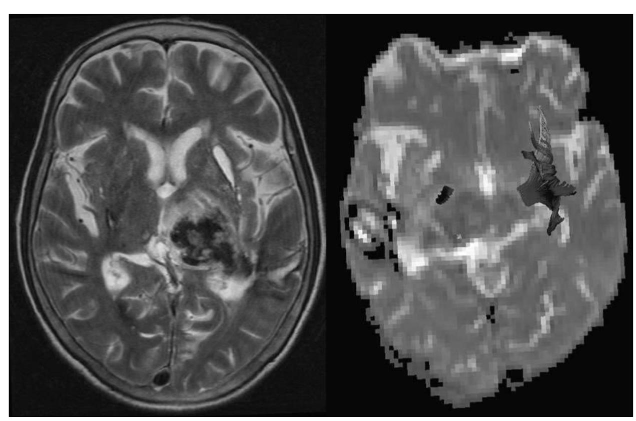

Fig. 4. T2-weighted axial image (left), tractographies (right) show the totally involved PIC. The whole part of left PIC is totally involved and disappeared.

DTI showed that the posterior part of the PIC was involved (Fig. 2). His follow-up motor scale improved, especially showed the better neurologic state in the upper extremity. Type III contained four patients in whom the DTI showed us that the PIC was totally preserved (Fig. 3). All follow-up motor scales improved in comparison with the preoperative state in type III. Type IV contained four patients whose DTI showed that the entire PIC was involved (Fig. 4). Their follow-up motor scales showed no change in comparison with the preoperative state. These results showed us that the motor scales improved only in the patients with the partially (type I and II) or non-involved PIC (type III). The p value was 0.007 for upper extremities and 0.008 for lower extremities (Table 3).

The motor scale changes by the other factors such as age, sex, presence of intraventricular hemorrhage (IVH) and hematoma size presented no difference between two groups (Table 3). Each p values were described in Table 3.

Discussion

In this study we obtained the DTI in the patients with deep ICH at the basal ganglia or thalamus and traced the white matter tracts and analyzed the relationships between the prognosis of the motor function outcome and the corticospinal tract involvement by the hemorrhages. The DTI was demonstrated by the three dimensional tractographies with T2 weighted images. Our results showed that the corticospinal tract involvement by the hemorrhages to PIC was related to the motor function outcome and the relationships presented according to the hierarchical organization principles.

DTI is a brand-new technique that can depict the structures and orientations of white matter tracts noninvasively and its clinical application is very promising. Although its usefulness is still under investigation, it already has been applied in many clinical circumstances. Those include the evaluations of the diseases such as ischemic strokes,[10)11)16)] brain tumors,[8)19)] or neurodegenerative diseases.[1)4)7)14)15)20-22)]

The DTI patterns in the cerebral neoplasm was classified into four types such as deviated, infiltrated, edematous and destroyed.[8)] This classification actually can help the surgeon make a plan and perform the surgery.[19)] If we apply this classification to our cases, the DTI patterns in the cerebral hemorrhage are presented as not infiltrated but deviated or destroyed since the hemorrhagic attack usually happens at a moment. In our cases, the involvement to PIC was related to the motor function outcome. If the PIC was destroyed, the motor function outcome might be worse and if deviated, motor function outcome might be better.

The relationship between the corticospinal tract and the motor function outcome in the patients with the cerebral infarcts has been reported many times.[10)11)] The degree of corticospinal tracts involvement within the infarcts was closely related to stroke severity and functional recovery and the DTI may be helpful to anticipate the prognosis of the motor function outcome.[10)11)] These are very suggestive of the relationship between the degree of corticospinal tracts involvement by the cerebral hemorrhage and the motor

Table 3. Comparison of motor scales between the groups according to the factors

Factors		Motor scales: Upper Extremity	Motor scales: Lower Extremity
Age (year)	>= 55 (n=4)	0.824	0.580
	< 55 (n=6)		
Sex	Male (n=8)	0.682	0.588
	Female (n=2)		
Presence of IVH	Yes (n=4)	0.504	0.825
	No (n=6)		
Hematoma Size (cm^3)	>= 30 (n=3)	0.284	0.636
	< 30 (n=7)		
Involvement to PIC	Partially or non (n=6)	0.007	0.008
	(Type I – III)		

PIC : posterior internal capsule

function outcome, which is consistent with our results.

The organization of the internal capsule was confirmed by the macaque monkey experiments.[6] It is reported that the axons of primary motor cortex pass through the middle third of PIC, premotor cortex pass through the capsular genu and the supplementary motor cortex pass through the anterior limb of the internal capsule.[6] And the classic hierarchical organization principles of the internal capsule in human was verified by some authors.[9][13][16] Our results are consistent with these principles; the corticospinal tract involvement in the anterior portion was correlated with motor impairment of the upper extremity and the corticospinal involvement in the posterior portion was correlated with motor impairment of the lower extremity.

In our study, the motor function improvement was achieved in the group of patients with the partially (type I, type II) or non-involved PIC (type III) regardless of the initial motor function, which results were the same in both upper extremities and lower extremities. This is consistent with the fact that the paresis can be one of the prognostic factor but not always. It may be due to nerve concussion, nerve compression by the hemorrhages or edema which happen initially and resolve in the course of time or by the medico-surgical treatments. Therefore initial motor function is not always reliable and we can depict the PIC by three dimensional tractography and we can anticipate the motor function outcome more exactly.

Our study has some limitations. First, we followed-up the patients for just 2 months. This is relatively short time. If we lengthen the follow-up period, we can get a long-term result, which is need in the future study. Second, the number of cases is very small especially for the statistical analysis. We can get the results which are more reliable with more cases. Third, we used the motor grading system rated on a scale of 0 to 5, which has been spread very widely. If we used another motor grading system which is more precise, we could find any difference in the group of patients with totally involved PIC (type IV). Fourth, we took the DTI one time initially. We could compare the motor function with the preservation of internal capsules expressed by DTI if we took the DTI again at the time of 2 months follow-up. Fifth, we have used the DTI with 12 channels, which technically could be a limitations to the tracing the white matter tracts. If we use the 32 or more channels, we can trace the white matter tracts very well.

In spite of these limitations, this study could suggest that the DTI is a useful method which demonstrates the degree and locations of the involvement by hemorrhages to PIC. Although the follow-up period is so short, we can anticipate the long-term motor function by whether or not the preservation of PIC expressed by DTI. That is, the degree and locations of the involvement by hemorrhages to PIC, expressed by DTI, may be regarded as a good indicator to the motor function in the patients with the hemorrhagic stroke in the basal ganglia or thalamic region. Someday it might replace the motor paresis as a good prognostic factor. The limitations listed above can be corrected with more experiences and data.

Conclusion

The DTI is a newly developed technique which can trace the inner structures in the central nervous system. This technique has been applied in the evaluation of the diseases such as infarction, brain tumors and neurodegenerative diseases. We applied the DTI to the hemorrhagic stroke and verified the close relationships between the involvement by the hemorrhages to PIC and motor functions outcome. We suggest that the DTI can show the degree and locations of the involvement by the hemorrhages to PIC and the DTI may be used as a good indicator to the motor function outcome in the patients with hemorrhagic stroke at basal ganglia or thalamic region.

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