CLINICAL ARTICLE

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Preoperative Assessment of Cystic Brain Lesion : Significance of Diffusion-Weighted Image and ADC (Apparent Diffusion Coefficiency) Values

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Objective : The aim of this study was to investigate the usefulness of diffusion-weighted imaging (DWI) and apparent diffusion coefficiency (ADC) in distinguishing brain abscesses from cystic or necrotic brain tumors, which are difficult to be differentiated by conventional magnetic resonance imaging techniques.

Methods : Seven patients with brain abscesses and ten patients with cystic brain tumors were studied from September 2003 to October 2005. Abscess, subdural empyema and ventriculitis were categorized to the abscess group and cystic or necrotic brain gliomas or metastatic brain tumors into the tumor group. Preoperative magnetic resonance images were perfomed in all patients and diffusion-weighted images and apparent diffusion coefficiency values of lesions were calculated directly from software of 1.5 tesla MRI (General Electrics, USA). The ratio of the ADC of the lesion to contralateral regional ADC was also measured (relative ADC, rADC).

Results : The average ADC value of pyogenic abscesses group was $0.82+/-0.14 \times 10^{-3}$ (mean+/-S.D.) mm^2/s and mean rADC was 0.75. Cystic or necrotic areas had high ADC values ($2.49+/-0.79 \times 10^{-3} mm^2/s$, mean rADC=2.14). ADC and rADC values of abscesses group showed about three times lower values than those of cystic or necrotic tumor group.

Conclusion : This study results based on numerical comparison of signal intensities and quantitative analysis to distinguish between brain abscess and cystic or necrotic tumor, DWI and ADC mapping are thought to be very useful diagnostic tools.

KEY WORDS : Abscess · Brain tumor · Magnetic resonance imaging · Diffusion-weighted imaging · Apparent-diffusion coefficiency.

Introduction

Purulent intracranial lesions including brain abscess potentially threaten the life. Clinically, cerebral abscess resembles some brain tumors and may result in dangerous conditions due to mass effect. Abscess take various clinical courses from indolence to central nervous system or systemic infection. Sometimes, delayed or mistaken diagnosis, adverse steroid use, rupture of abscess capsule and cerebritis lead to the catastrophic results. Thus, the prompt differentiation between brain abscess and cystic tumor is needed and very important.

Computed tomography (CT) and magnetic resonance imaging (MRI) are used in the diagnosis of brain abscess, but these conventional diagnostic tools have difficulties in differentiation of abscesses from cystic tumors. Also, in some cases, radioisotope or spectroscopy are used in the diagnosis, but are not routinely performed. In most cases, brain abscesses are identified in the operative field, so many clinicians feel keenly the necessity of convenient and noninvasive preoperative diagnositc modalities.

The authors made an investigation about diffusion-weighted image (DWI) and apparent diffusion coefficiency (ADC) in preoperative differential diagnosis between brain abscess and cystic brain tumor. Also, we made a quantitative analysis of diffusion coefficiency and surveyed the importance and effectiveness of DWI and ADC in comparison with conventional diagnostic modalities.

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Methods and Materials

Seventeen patients who underwent surgery and diagnosed in our hospital from September 2003 to October 2005 were enrolled in this study. Seven patients were diagnosed as purulent intracranial lesions and ten patients as cystic brain tumors. There were amid purulent intracranial lesions, and intracerebral abscesses and one case of ventriculitis. One patient with amid intracerebral abscesses was diagnosed as renal cell carcinoma previously. The average age of these patients was 51.1 years and male-to-female ratio was 1.3 : 1 (4 : 3) (Table 1).

All patients who had brain abscess underwent craniotomy or burr hole trephination and abscess drainage, and completely recovered, but the patient who had ventriculitis died despite of treatments. Amid cystic brain tumors, anaplastic astrocytomas were three cases, metastatic brain tumors were two cases, glioblastomas were two cases, ependymoma was one case, gliosarcoma was one case and hemangioblastoma was one case. The average age of these patients was 43.8 years and male-to-female ratio was 1.5 : 1 (6 : 4) (Table 2). All patients who had cystic brain tumors underwent craniotomy and tumor removal, and were made pathological diagnosis.

Preoperative brain CT and MRI were performed. With the use of 1.5-tesla MRI (General Electrics, USA), diffusion-weighted images and apparent diffusion coefficiency values were taken and ADC values of ROI (Region Of Interesting) were calculated directly from the software (Fig. 1). The gradient factor (b-value) was 1000 sec/mm^2. To compare the relationship between lesions and normal architecture, the ratio of contralateral side of ROI to ROI was referred to the relative ADC (rADC). We analysed the ADC and rADC values with using the SPSS software (SPSS, Chicago, IL), between the groups of brain abscesses and cystic

Table 1. Clinical characteristics in 7 patients with brain abscess

No.	Age	Sex	Diagnosis	Lesion location
1	46	F	Abscess	Occipital, Right
2	53	M	Abscess	Temporal, Right
3	5	M	Abscess	Cerebellum, Left
4	62	M	Abscess	Cerebellum, Left
5	67	M	Ventriculitis	Lateral ventricle, Left
6	57	F	Abscess	Parietal, Left
7	68	F	Abscess	Frontal, Left

Table 2. Clinical characteristics in 10 patients with cystic or necrotic brain tumor

No.	Age	Sex	Diagnosis	Lesion location
1	41	M	Anaplastic astrocytoma	Frontal, Right
2	45	M	Metastatic tumor	Occipital, Right
3	58	M	Metastatic tumor	Occipital, Right
4	34	F	Ependymoma	Lateral ventricle, Right
5	18	F	Anaplastic astrocytoma	Frontal, Right
6	67	F	Glioblastoma	Occipital, Right
7	52	M	Gliosarcoma	Temporal, Right
8	58	M	Anaplastic astrocytoma	Frontal, Right
9	33	F	Glioblastoma	Parietal, Right
10	32	M	Hemangioblastoma	Cerebellum, Left

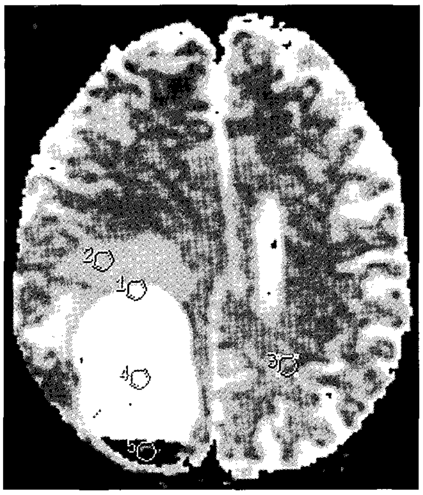

Fig. 1. ADC mapping image obtained from the software of the magnetic resonance image system. Each small circles represent the region of interesting (ROI) and apparent diffusion coefficiency (ADC) values were calculated directly from the software. Number 4 indicates the center of the lesion and number 3 indicates the opposite site of lesion.

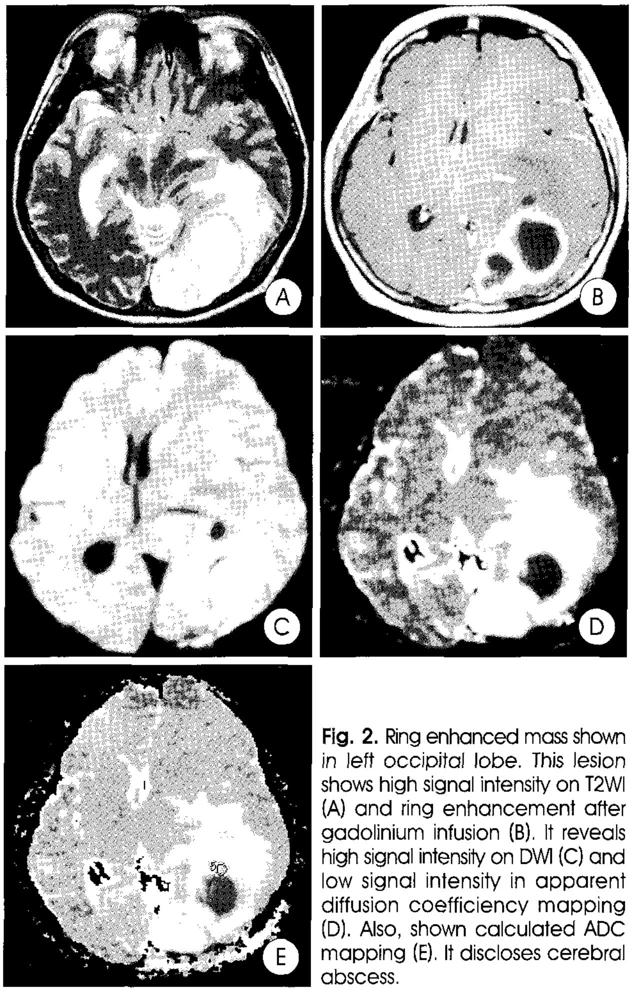

Fig. 2. Ring enhanced mass shown in left occipital lobe. This lesion shows high signal intensity on T2WI (A) and ring enhancement after gadolinium infusion (B). It reveals high signal intensity on DWI (C) and low signal intensity in apparent diffusion coefficiency mapping (D). Also, shown calculated ADC mapping (E). It discloses cerebral abscess.

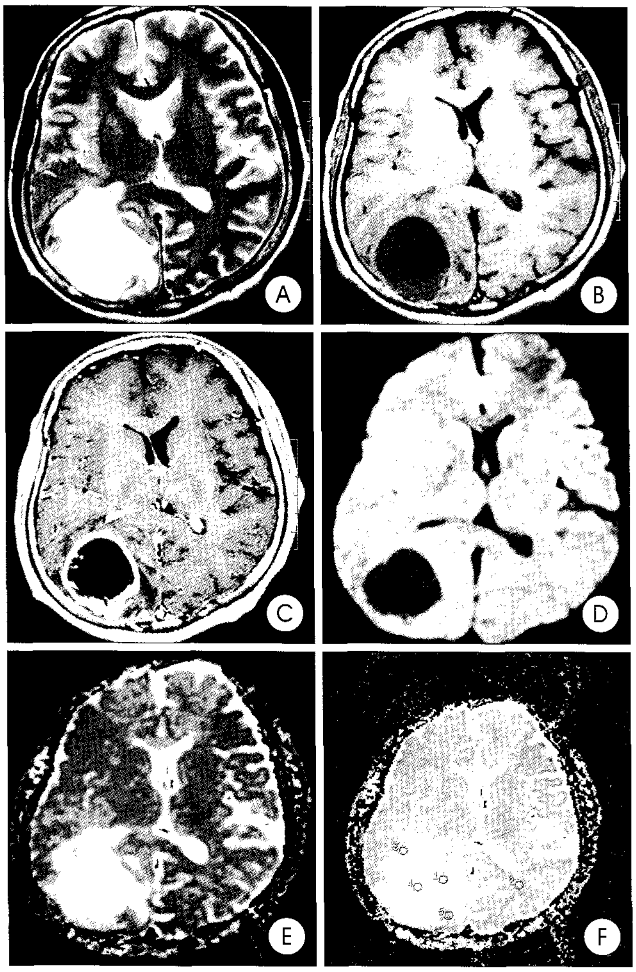

Fig. 3. Ring enhanced mass located in right parietal lobe. This mass shows high signal intensity on T2WI (A), low signal intensity on T1WI (B) and ring enhancement (C). Low signal intensity on diffusion weighted image (D) is seen and high signal intensity on apparent diffusion coefficiency mapping (E). Also ADC mapping drawn by ROI is shown (F). Histological diagnosis was glioblastoma.

brain tumors and statistically paired-t test was used in this study (p-value$<$0.05).

Case Illustrations

Cases listed below are characteristic diseases that could be differentiated from each other with the use of DWI and ADC.

Case 1

A 47-year-old man presented with confusional mental state. He had performed nephrectomy because he had diagnosed as a renal cell carcinoma 9 months ago. A ring enhanced cystic mass was identified on the left occipital lobe. On brain MRI, this cystic mass showed low signal intensity on T1WI, high signal intensity on T2WI and ring enhancement after gadolinium infusion. Also, it showed that high signal intensity in DWI and low signal intensity on ADC mapping (Fig. 2). The postoperative diagnosis was a brain abscess.

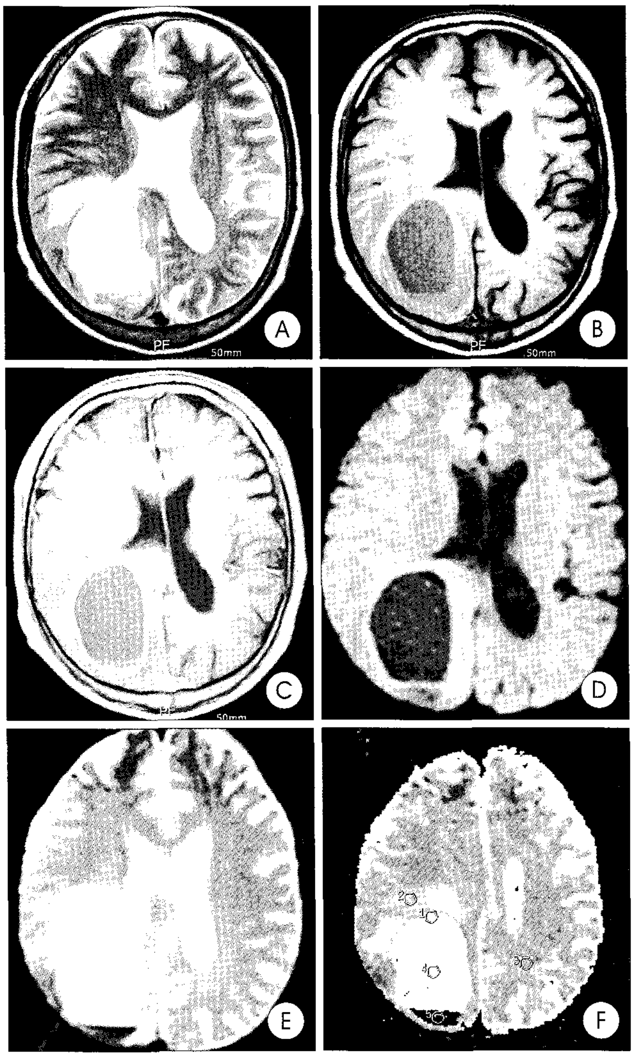

Fig. 4. Ring enhanced mass located in right parietal lobe. This mass shows high signal intensity on T2WI (A), low signal intensity on T1WI (B) and ring enhancement (C). Low signal intensity on diffusion weighted image (D) is seen and high signal intensity on apparent diffusion coefficiency mapping (E). Also ADC mapping drawn by ROI is shown (F). Histological diagnosis was metastatic brain tumor.

Case 2

A 67-year-old woman presented with headache for 2 months. A ring enhanced cystic mass was identified on the right parietal lobe. On brain MRI, this cystic mass showed low signal intensity on T1WI, high signal intensity on T2WI and ring enhancement after gadolinium infusion. Also, it showed that low signal intensity in DWI and high signal intensity on ADC mapping (Fig. 3). The postoperative diagnosis was a glioblastoma.

Case 3

A 58-year-old man presented with drowsy mentality. He was diagnosed as a lung cancer and underwent lobectomy 2 years before admission. A ring enhanced cystic mass was identified on the right parietal lobe. On brain MRI, this cystic mass

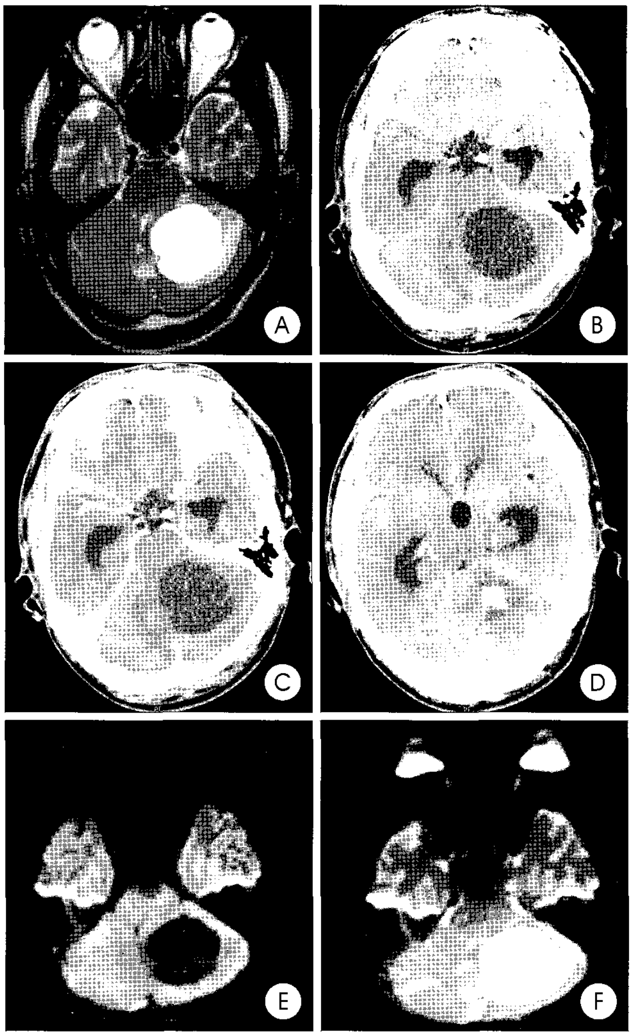

Fig. 5. Hemangioblastoma is observed in left cerebellar hemisphere. It is high signal intensity on T2WI (A) and low density on computed tomography (B, C). Focal enhanced lesion is also seen (D). Similar to the above mentioned brain tumors, low signal intensity on DWI (E) and high signal intensity on apparent diffusion coefficiency mapping (F).

showed low signal intensity on T1WI, high signal intensity on T2WI and ring enhancement after gadolinium infusion. Also, it showed that low signal intensity in DWI and high signal intensity on ADC mapping (Fig. 4). The postoperative diagnosis was a brain metastasis from the small cell lung cancer.

Case 4

A 32-year-old man presented with dizziness and gait disturbance. A ring enhanced cystic mass was identified on the left cerebellum. On brain MRI, this cystic mass showed low signal intensity on T1WI, high signal intensity on T2WI and ring enhancement after gadolinium infusion. Also, it showed that low signal intensity in DWI and high signal intensity on ADC mapping (Fig. 5). The postoperative diagnosis was a hemangioblastoma.

Table 3. The results of apparent diffusion coefficient (ADC) values and relative diffusion coefficient values (rADC) of cerebral abscess

No.	Age	Sex	ADC ($\times 10^{-3}$)	rADC
1	46	F	0.78	0.65
2	53	M	0.67	0.53
3	5	M	0.88	0.75
4	62	M	0.99	0.93
5	67	M	0.67	0.79
6	57	F	0.72	0.10
7	68	F	1.01	0.92

Table 4. The results of apparent diffusion coefficient (ADC) values and relative diffusion coefficient (rADC) values of cystic or necrotic brain tumors

No.	Age	Sex	ADC ($\times 10^{-3}$)	rADC
1	41	M	3.19	2.43
2	45	M	1.24	1.58
3	58	M	2.99	2.57
4	34	F	1.34	1.54
5	18	F	2.77	2.77
6	67	F	3.12	2.60
7	52	M	3.27	2.61
8	58	M	2.44	1.46
9	33	F	2.02	1.71
10	32	M	2.65	2.16

Results

Brain abscesses and cystic brain tumors enrolled in this investigation could not be clearly differentiated from each other with preoperative conventional diagnostic examinations such as brain CT and MRI. Central low density with peripheral ring enhanced mass on brain CT and low signal intensity on T1WI, high signal intensity on T2WI and ring enhancement after gadolinium infusion were revealed in each groups similarly.

The average ADC value of brain abscess group was 0.82 ± 0.14 $(0.67\text{-}1.01) \times 10^{-3}$ mm^2/sec (Table 3) and that of cystic brain tumor was 2.49 ± 0.79 $(1.24\text{-}3.27) \times 10^{-3}$ mm^2/sec (Table 4). Also, the average relative ADC value of brain abscess group was 0.75 ± 0.15 $(0.53\text{-}0.93) \times 10^{-3}$ mm^2/sec (Table 3) and that of cystic brain tumor was 2.14 ± 0.55 $(1.46\text{-}2.77) \times 10^{-3}$ mm^2/sec (Table 4). In the view of the results so far achieved, the ADC and rADC values of brain abscess was about three times lower than those of cystic or necrotic brain tumor and these relationship between two groups had statistical significancy ($p < 0.001$).

Discussion

In the law of physics, the molecules move freely and have very randomized motion (random translating motion or Brownian motion) in the state of liquid and gas, and this phenomenon is called as diffusion. The degree of diffusion is affected by surrounding environmental structures, viscosity and temperature. The molecules are able to diffuse more easily in the environment of liquid, lower viscosity and higher temperature. The degree of diffusion represented as diffusion coefficient. The higher diffusion coefficient value means that the molecules take more long distances in the unit time[4,7,9]. The human body is composed of water by 70-80%, in the every parts of body, diffusion phenomenon is occurring. The water molecules in every parts of human body have different diffusion coefficiency as different surrounding environments. The diffusion of water molecules in the human body comparing with the pure water is not free and restricted by cellular membrane, macro-protein molecules and neuronal fibers. In addition to these factors, heart beats and microvascular circulations contribute to this resriction. It is defined as apparent diffusion coefficient (ADC), considering of these factors. Thus, ADC would be measured much lower than that of pure water. In the cerebrospinal fluid, diffusion occurrs more easily than brain parenchyme and ADC value prone to be much higher. The diffusion-weighted image represented as the degree of diffusion[1,4,6].

To obtain diffusion-weighted image, the signal lowering effect by the maximization of proton phase-shift by diffusion should be maximized, but, the signal lowering by macromotion, such as cerebral blood flow or CSF flow should be excluded by taking high speed MR images. To maximize the phase-shift of proton by diffusion, the more stronger magnetic field as diffusion-sensitive gradient should be used additionally, and to take high speed MR images, echoplanar imaging technique should be performed. If the strength of the magnetic field gradient is more stronger, the emphasized diffusion weighted images can be obtained. This phenomenon is similar principle that the echo time is more prolonged in conventional MRI, the emphasized T2-weighted images can be obtained. The strength of magnetic field gradient termed as "gradient factor (b-factor)", and this value that is the amplitude of diffusion-sensitive gradient is integrated by time. If MRI is performed when the gradient factor is zero, conventional T2-weighted images are able to obtained, but when the gradient factor is much more, then diffusion-weighted images are able to be obtained. Thus, the decrease in signal intensity by diffusion is accentuated when the diffusion coefficiency of the tissues and the gradient factor are greater[4,5].

The gradient factor which currently used in clinical diagnosis is about 1000 sec/mm^2. But, this signal intensity is not only affected by diffusion coefficiency, but also the effect of T2-weighted images. So, in DWI, high signal intensities are represented by diffusion effect and T2-effect. This is termed as "T2 shine-through effect". To obtain the pure diffusion effect excluding "T2 shine-through effect", apparent diffusion coefficiency should be obtained[4,7].

Apparent diffusion coefficiency (ADC) values of pixels in each tissues can be obtained if over two MR images which are taken in the situation of same conditions except gradient factor is calculated mathematically. The images made from ADC values are called as "ADC mapping" or "Calculated Diffusion Images". ADC mapping images shows high signal intensity in the easily-diffused tissue and low signal intensity in the scarecely-diffused tissue[2].

The differential diagnoses which made by DWI and ADC are in the followings, (1) early detection of hyperacute cerebral ischemia and cerebral infarction, (2) differential diagnosis between early and chronic cerebral infarction, (3) differential diagnosis between early cerebral infarction and brain tumor, (5) differential diagnosis between cerebral abscess and cystic or necrotic brain tumor, (6) differential diagnosis between epidermoid cyst and arachnoid cyst, (7) differential diagnosis between low and high grade glioma[2,5,7,9].

On DWI, pus of cerebral abscess reveals as high signal intensity, but liquefaction necrosis of cystic or necrotic brain tumor reveals as low signal intensity. The reason that high signal intensity of pus on DWI is not so clear but is thought the pus to have high viscosity.

Among aforementioned diseases, the reliable field which the most widely used and diagnosed by DWI and ADC is the differential diagnosis between brain abscess and cystic or necrotic brain tumor. With the help of theses over 1.5-Tesla MRI systems since 1990, previously mentioned two diseases could have been clearly before operation identified. Most of previous reports have only, the simply compared of the signal intensities on DWI between these two diseases have been reported[3,5,7,8]. But, with the upgrade of MRI systems and softwares, the quantitaitve analysis by means of direct calculation can be possible. The authors regard this investigation to be significant because of quantitaive analysis of signal intensities by means of direct calculation. In this regard, the change from the signal intensities of brain abscesses and cystic brain tumors on DWI to numerical values is the importance of this report.

According to several reports, ADC values of gliomas sometimes have significant correlation with cellularity and grade. If the tumor shows high cellularity and high grade, DWI shows high signal intensity resulting from decreased ADC values, reversely ADC mapping shows low signal intensity. In high grade gliomas, the part of ring-enhancement shows higher signal intensity other than non-enhanced part or surrounding edema on DWI and lower signal intensity on ADC mapping.

ADC mapping is necessary to differentiate the decrease in diffusion coefficiency from the "T2 shine-through effect", if the lesion shows high signal intensity on DWI. Hyperacute and acute cerebral ischemic lesions show low signal intensity on ADC mapping because of decrease in diffusion coefficiency. But when high or isosignal intensity on ADC mapping is noted, it is thought that "T2 shine-through effect" is the cause of high signal intensity on DWI[8].

Conclusion

Delayed diagnosis and inappropriate treatment of intracranial purulent lesions such as brain abscess can be fatal. These lesions could be hardly differentiated from cystic or necrotic brain tumors by means of conventional diagnostic imaging tools. On the basis of our investigation, when differential diagnosis of ring-enhanced intracranial lesions is needed, DWI and ADC is thought to be very useful and significant.

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