

Diffusion-weighted MR Imaging in Intracranial Infections

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Abstract

Introduction: Diffusion-weighted magnetic resonance (MR) imaging (DWMRI) is valuable in the assessment of acute cerebral infarction and may be useful for other diseases of the central nervous system (CNS). In this study, we present the DWMRI appearance of intracranial infection. **Materials and Methods:** Thirty patients with clinical diagnosis of CNS infection were reviewed. All patients underwent conventional contrast-enhanced MR examination and DWMRI using single-shot echo-planar imaging at $b = 1000 \text{ s/mm}^2$. **Results:** Cerebral abscess, tuberculoma, subdural empyema and epidural abscess were hyperintense on DWMRI. Neurocysticercosis showed hypointense lesions on DWMRI. Four of 5 patients with encephalitis showed DWMRI hyperintensity; the appearance of toxoplasmosis lesions was variable. Patients suffering from meningitis without parenchymal involvement did not exhibit any abnormality of diffusion. One patient with tuberculous meningitis developed abnormality on DWMRI from acute cerebral infarction. **Conclusion:** DWMRI increased lesion conspicuity and may be useful in assessment of cerebral infection. There were striking differences in the DWMRI appearances caused by different organisms and diseases.

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Introduction

Diffusion-weighted magnetic resonance (MR) imaging (DWMRI) is becoming essential¹⁻³ to the assessment of acute cerebral infarction and has also been applied to distinguish cerebral abscess from necrotic intracranial neoplasm.⁴⁻⁸ There have also been a few case reports on DWMRI of encephalitis.⁹⁻¹¹ We perform a retrospective analysis of appearances on DWMRI in patients with intracranial infection.

Materials and Methods

We reviewed the case records of patients with final diagnosis of intracranial infection and who had DWMRI performed in the National Neuroscience Institute over a 12-month period from July 1999 to June 2000. The final diagnoses, method of diagnosis and MR imaging findings were recorded. Clinical diagnoses not supported by histological examination of tissue or cerebrospinal fluid (CSF), serology or follow-up imaging were excluded.

All patients underwent MR examination on a 1.5T clinical scanner (Signa Nvi; GE Medical Systems, Milwaukee, WI,

USA). Conventional MR pulse sequences included fast spin echo T2-weighted images 4000/90 (repetition time/echo time), contrast-enhanced T1-weighted images (540/15 to 600/15) and, in some instances, fluid-attenuated inversion recovery (FLAIR) images (10,000/125/inversion time 2200). DWMRI using single-shot echo-planar imaging (10,000/100) at $b = 1000 \text{ s/mm}^2$ was performed in all cases. The signal intensity of all intracranial lesions was individually assessed. Parenchymal changes in signal intensity were described for encephalitis and meningitis. MR images in all studies were reviewed by a consensus reading by radiologists on the picture archive and communication system.

Results

Thirty patients were studied; 9 patients had more than 1 MR examination. There were 9 patients with pyogenic meningitis and 3 with tuberculous meningitis. Five patients had viral encephalitis and 4 patients had toxoplasmosis. There were 4 patients with brain abscess, 3 with neurocysticercosis and 1 each with subdural empyema and

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epidural abscess. One of the 3 patients with tuberculous meningitis also had a tuberculoma. Five patients had concurrent human immunodeficiency virus infection. Final diagnosis was by histology ($n = 7$), serology or culture ($n = 12$), CSF analysis ($n = 9$) and clinical and imaging criteria ($n = 2$). The MR imaging results of these patients are shown in Table I.

Cerebral abscesses (Fig. 1), tuberculoma and extra-axial collections (Fig. 2) were hyperintense on DWMRI. Neurocysticercosis showed hypointense lesions on DWMRI. Four of 5 patients with encephalitis showed DWMRI hyperintensity (Fig. 3); the appearance of toxoplasmosis lesions was variable. Patients suffering from bacterial meningitis without parenchymal involvement did not exhibit any abnormality of diffusion.

All lesions detected on DWMRI were also detected on T2-weighted imaging, but were more conspicuous in the former. However, not all T2 lesions were detected on DWMRI. One patient with tuberculous meningitis underwent multiple follow-up MR examinations and developed diffusion-weighted hyperintensity from cerebral infarction.

Discussion

DWMRI provides unique information reflecting the functional status of the brain. Random movement (diffusion) of water at the molecular level in the brain can be studied: if water molecules are free to diffuse, there will be dephasing and, hence, loss of signal. Conversely, if there is restricted (decreased) water diffusion, there will be less dephasing and, therefore, higher signal intensity.¹ DWMRI imaging has found the most widespread clinical usage in the detection of acute cerebral infarction, where cytotoxic oedema causes cell swelling and restricted water diffusion that lead to increased signal intensity.¹⁻³

The high lesion contrast, early detection after infarct onset and rapid acquisition techniques make DWMRI attractive as an additional pulse sequence in the assessment of brain diseases, besides cerebral infarction. Our review brings together multiple intracranial infective conditions, including diffuse lesions such as meningitis and encephalitis, as well as focal liquefied lesions such as abscesses, neurocysticercosis and empyema. Several reports have described DWMRI in differentiating necrotic tumour from pyogenic abscess in ring-enhancing mass lesions.⁴⁻⁸ This ability has important implications for surgical treatment, especially as both conditions can present with similar appearances on MR imaging. The restriction in water diffusion within the abscess cavity is probably caused by high cellularity and viscosity^{6,8,12} Macromolecular components of pus, such as fibrinogen and other proteins, are postulated to impede water mobility.¹³ Recently, there have also been a few case reports on similar findings in subdural empyema,¹⁴ probably caused by similar mechanisms.

The DWMRI findings in our patients with abscess, tuberculoma and empyema were consistent with published literature and resulted in increased diagnostic confidence.¹⁵ Although these were useful findings, the differentiation between abscess and tumour may not always be reliable.^{16,17} As there are no large-scale studies, DWMRI cannot be interpreted in isolation and must be read together with conventional MR images.

The findings in neurocysticercosis and toxoplasmosis are poorly documented in the literature. We found the cystic lesions in neurocysticercosis to be distinctly different from abscesses on DWMRI, but were unable to draw further conclusions due to the small number of patients studied. Similarly, DWMRI studies in patients with toxoplasmosis were difficult to interpret with certainty.

TABLE I: APPEARANCES OF INTRACRANIAL INFECTION ON DWMRI

Diagnosis	Number of patients/lesions on T2-weighted MR imaging	Number of patients/lesions on DWMRI	Appearance on T2-weighted MR imaging	Appearance on DWMRI	Remarks
Cerebral abscess	4/10	4/5	Hyperintense	Hyperintense	-
Tuberculoma	1/1	1/1	Hyperintense	Hyperintense	Patient had tuberculous meningitis
Subdural empyema/ epidural abscess	2/2	2/2	Hyperintense	Hyperintense	-
Neurocysticercosis	3/16	3/12	Hyperintense	Hypointense	Less conspicuous on DWMRI
Encephalitis	5	4	Hyperintense	Hyperintense	Cortical Involvement
Toxoplasmosis	4/24	3/12	Variable	Variable	-
Bacterial meningitis	9	0	Normal	Not applicable	-
Tuberculous meningitis	3	1	Hyperintense	Hyperintense	Cerebral infarction

DWMRI: Diffusion-weighted magnetic resonance imaging

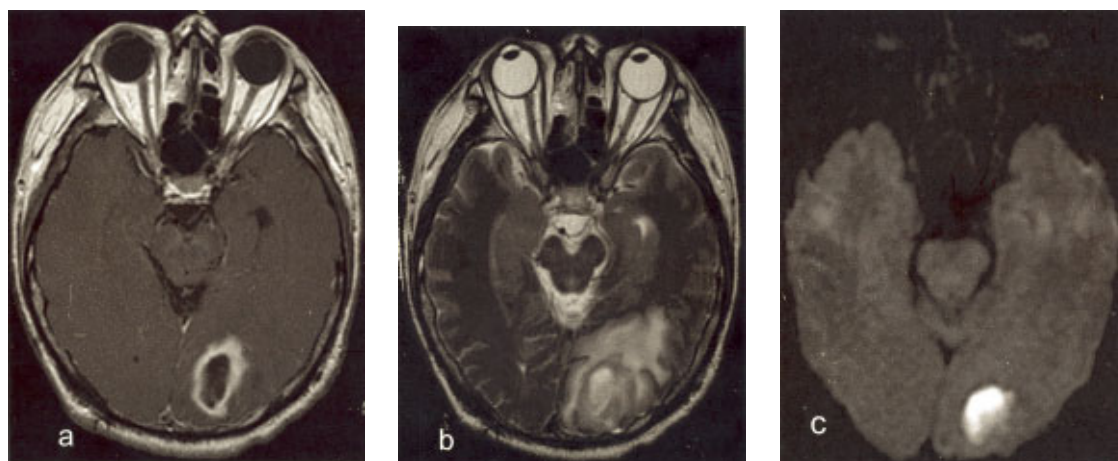


Fig. 1. Cerebral abscess. (A) A ring-enhancing mass is seen after contrast injection. (B) The mass shows thick-walled abscess cavity with increased signal intensity on T2-W MR image. (C) The abscess cavity is hyperintense on diffusion-weighted MR image.

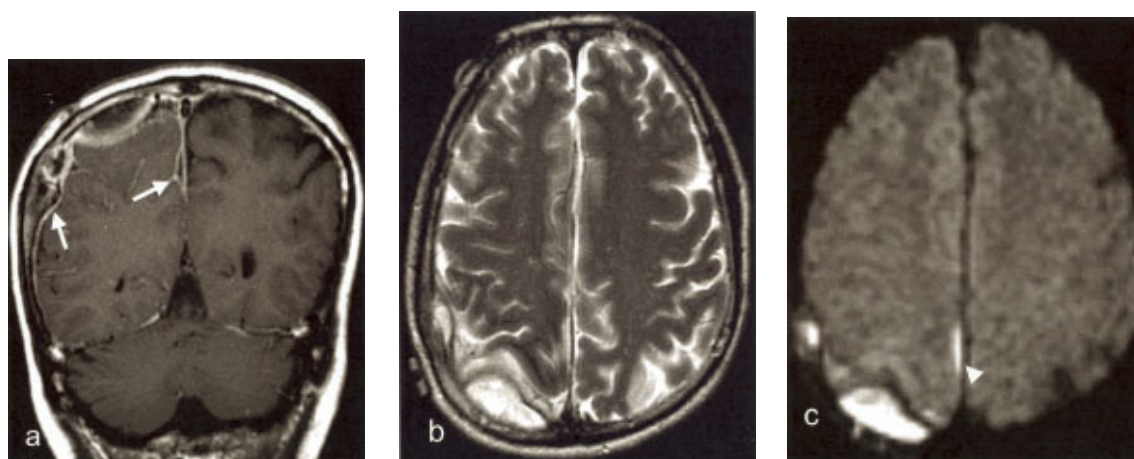


Fig. 2. Epidural abscess. (A) Enhanced coronal MR image shows loculated extra-axial fluid collections with abnormal focal dural enhancement (arrows). Note the loss of normal signal in the adjacent bone marrow from osteomyelitis. (B) T2-W MR image shows high signal intensity fluid. (C) Corresponding diffusion-weighted MR image shows increased signal and better visualisation of the midline subfalcine collection (arrowhead).

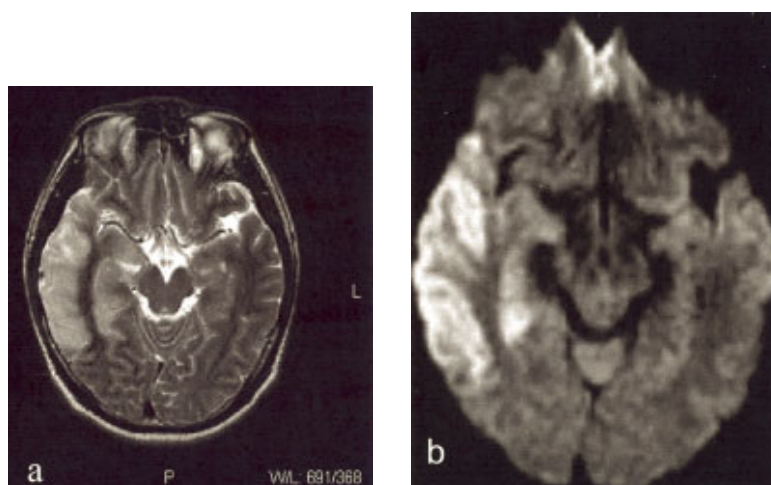


Fig. 3. Viral encephalitis. (A) T2-W MR image shows high signal intensity in the temporal lobe cortex sparing the white matter. (B) Diffusion-weighted MR image shows corresponding hyperintensity.

Case reports on DWMRI in herpes^{9,10} and influenza¹¹ encephalitis have described hyperintensity of the affected cortex and underlying white matter, which is similar to our findings. Recent studies in Nipah virus encephalitis, caused by a previously unknown pathogen, have also shown hyperintense lesions on DWMRI.¹⁸⁻²⁰ In that disease, virus-induced occlusion of small blood vessels leading to cerebral infarction has been postulated as a contributor to these findings, supported by pathological examination and evidence of occluded retinal arteries.²¹ However, in contrast to confluent cortical encephalitis, the DWMRI findings in Nipah virus infection consisted of subcentimetre lesions found predominantly in the subcortical white matter. Although DWMRI was able to visualise areas of involvement, it is not known if this finding has any prognostic significance in encephalitis in general.

Tuberculous meningitis is known to cause a variety of complications, including hydrocephalus and occlusion of small blood vessels. Exudative meningitis leading to cerebral infarction from obstruction of the perforating arteries has been well documented.^{22,23}

Conclusion

DWMRI increased lesion conspicuity in a variety of central nervous system (CNS) infections. Cerebral abscess, empyema and encephalitis showed increased signal intensity, whilst neurocysticercosis showed decreased signal. The presence of diffusion-weighted hyperintensity increases the diagnostic confidence for early clinical management. Although initial results are encouraging, further work needs to be done to assess the role of DWMRI in CNS infections.

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