Role of Diffusion-Weighted Imaging and Proton MR Spectroscopy in Distinguishing between Pyogenic Brain Abscess and Necrotic Brain Tumor

Ping-Hong Lai[1,4], Shu-Shong Hsu[2,4], Yuk-Keung Lo[3,4], and Shang-Wu Ding[5]

Abstract- Brain abscesses and brain tumors may have similar clinical presentations. For example, only 50% brain abscess patients have fever, which could be masked by corticosteroid therapy. Also, the differential diagnosis of brain abscesses versus cystic or necrotic tumors may be difficult based on computed tomography (CT) or magnetic resonance (MR) imaging findings. However, the strategies of management for abscess and neoplasm are very different, and it is especially imperative to have a correct diagnosis before any surgical intervention of cystic brain lesions. The MR special techniques, e.g. diffusion-weighted imaging (DWI) and proton (1H) MR spectroscopy, are useful as additional diagnostic modalities for differentiating brain abscesses from cystic or necrotic brain tumors. DWI shows high signal intensity in most cases of pyogenic abscesses and low signal intensity in most cases of cystic or necrotic tumors. MR spectroscopy shows characteristic metabolites in pyogenic abscesses, distinct from those in cystic or necrotic tumors.

Key Words: Brain abscess, Brain tumor, Diffusion MR imaging, MR spectroscopy

Acta Neurol Taiwan 2004;13:107-113

INTRODUCTION

Differentiation between brain abscesses and cystic or necrotic tumors with computed tomography (CT) or magnetic resonance (MR) imaging may be difficult. Difficulties in the diagnosis of intracranial abscess are mainly due to the combination of nonspecific clinical findings and possible similarities in the radiological appearances of cystic gliomas, metastases, and brain abscesses[(1)]. With conventional magnetic resonance imaging (MRI), typical brain abscess has low signal intensity on T1-weighted images, high signal intensity on T2-weighted images, and ring enhancement after contrast medium administration. However, cystic or necrotic brain tumors may have very similar pictures, making the differential diagnosis difficult.

Diffusion-weighted imaging (DWI) and proton (1H) MR spectroscopy (MRS) are results of recent progress in MR technique, and could serve as useful diagnostic modalities for between brain abscesses and cystic or necrotic brain tumors. We would divide the following discussion into three parts: (a) DWI of Pyogenic Brain

From the Departments of [1]Radiology [2]Neurosurgery, and [3]Neurology, Veterans General Hospital-Kaohsiung, [4]National Yang-Ming University, Taiwan; [5]Department of Chemistry, National Sun Yat-Sen University, Taiwan.
Received May 17, 2004. Revised and Accepted July 18, 2004.

Reprint requests and correspondence to: Ping-Hong Lai, MD. Department of Radiology, Veterans General Hospital-Kaohsiung, No. 386, Ta-Chung 1st Road., Kaohsiung, Taiwan.
E-mail: phlai@isca.vghks.gov.tw

Abscesses and Necrotic Brain Tumors; (b) 1H MRS of Pyogenic Brain Abscesses and Necrotic Brain Tumors; and (c) DWI vs. 1H MRS of Pyogenic Brain Abscesses and Necrotic Brain Tumor.

DWI of pyogenic brain abscesses and necrotic brain tumors

DWI provides a unique way to evaluate the diffusion properties of water molecules in tissue (Brownian motion), and has been demonstrated to be useful in the diagnosis and treatment of ischemia, tumors, epilepsy and white matter disorders(2). Application of DWI in the differential diagnosis between brain abscess and cystic or necrotic brain tumors has been well documented in the literature(3-10). In 1996, Ebisu et al.(3) first reported a case of brain abscess with high signal intensity on DWI and a low ADC value. The pus itself (verified by aspiration) could account for the restricted diffusion and therefore high DWI signal intensity (Fig. 1). The other studies showed very similar or the same results(4-12).

The low ADC values for pyogenic abscesses varied(5-10). The variation might be ascribable to differences in the concentration of inflammatory cells, the necrotic tissue debris and bacteria, and the viscosity of the abscess fluid. These differences may be in turn related to the age of the abscess, the causative organism, and the host's immune responses(5-10).

The signal intensity of pyogenic brain abscess on DWI is not always high, and the ADC value could be higher than that of the normal brain parenchyma. Krabbe et al.(13) reported a cerebral abscess with a high ADC value, but did not mention the signal intensity on DWI. The explanation for this might be the partial volume effect proposed by Desprechins et al.(6). Guo et al.(14) reported two small cerebral abscesses (mean area of 90 mm^2) with high signal on DWI but ADC values similar to that of normal parenchyma (the ADC ratios were 1.01 and 1.03). This similarity was postulated to be due to a partial volume effect or to intrinsic differences in diffusion properties of the smaller abscesses. However, signal intensity on DWI was high and ADC value was low regardless of the lesion size, and these results were supposed to have improved in-plane resolution(8).

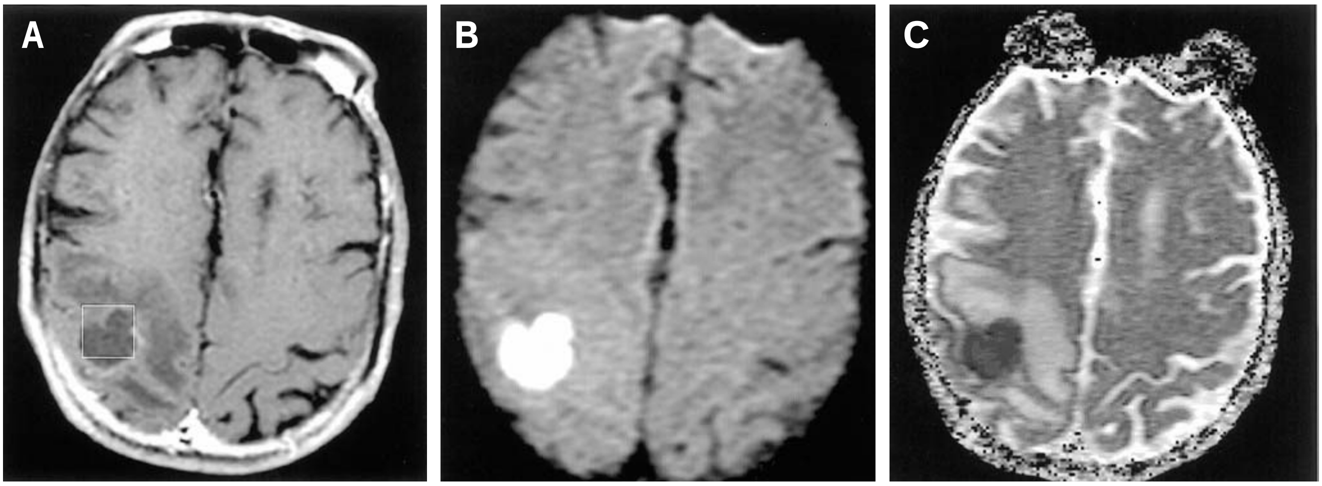
All tumors showed low signal intensities on DWI in the cystic or necrotic area, and their cystic or necrotic areas had high ADC values [(2-10,13,15)-Fig. 2]. However, contradictory DWI findings of cystic or necrotic tumors do exist in the literature(7,8,16). Park et al. reported two cases of cystic or necrotic brain metastasis with markedly high signal intensity on DWI, with surgical findings showing that the cyst had a thick and creamy necrotic content similar to pus(7). Chang et al. reported a ring-enhanced fibrillary low-grade astrocytoma with high signal intensity on DWI and a low ADC value, mimicking that of abscesses, and viscous creamy fluid within the tumor was found at surgery(8). Holtas et al. reported a ring-enhanced brain metastatsis with hyperintensity on DWI and a low ADC value in the necrotic part of the tumor. The reason for restricted diffusion was possibly due to early necrosis with intracellular edema of the lesion(16).

In summary, DWI may be a much more valuable diagnostic tool in the differential diagnosis between brain abscesses and cystic or necrotic brain tumors than conventional MRI. However, there are some conflicting DWI reports in the literature, and we still need to be cautious about making the diagnosis with DWI findings.

1H MRS of pyogenic brain abscess and necrotic brain tumors

Findings from several studies have suggested that in vivo proton magnetic resonance spectroscopy (1H MRS), a non-invasive examination, might contribute to the establishment of the differential diagnosis between brain tumors and abscesses(17-29). The predominant resonance lines (N-acetyl-aspartate, choline, and creatine/phosphocreatine) that are usually observed in the parenchyma of the normal brain were hardly detectable in either tumor or abscess necrosis. The main characteristic features of pyogenic abscesses were the resonances of amino acids (valine, leucine, and isoleucine) (0.9 ppm), acetate (1.9 ppm), alanine (1.5 ppm), lactate (1.3 ppm), and succinate (2.4 ppm) (Fig. 1). In contrast, Spectra in patients with cystic or necrotic tumor showed only the peak attributed to lactate (1.3 ppm) (Fig. 2). Lipid (0.8-1.3 ppm) may also be found in patients with a tumor.

Lactate and lipids are nonspecific metabolites pro-



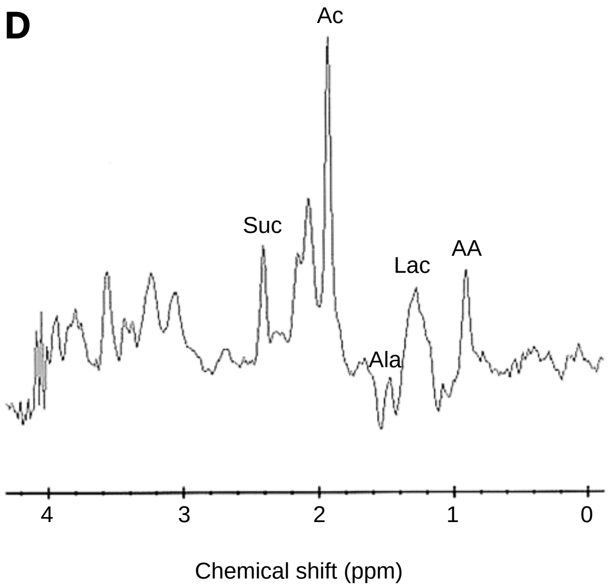
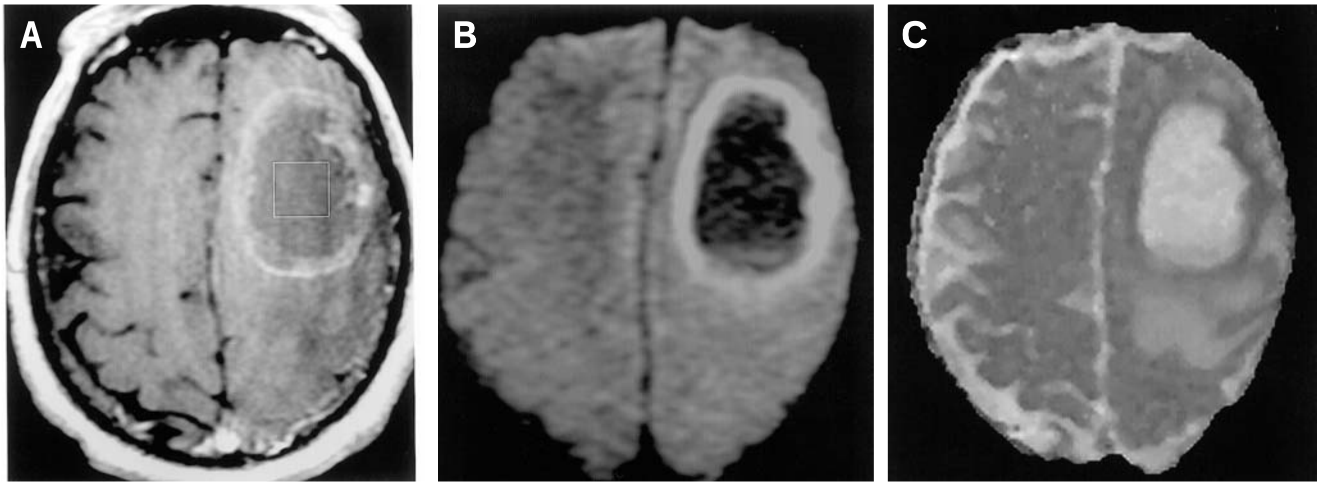


Figure 1. A 58-year-old man with surgically proven pyogenic brain abscess in the right parietal lobe. (A) Axial contrast-enhanced T1-weighted (500/30[TR/TE]) MR image shows a ring-shape cystic lesion and surrounding edema. The 2×2×2-cm voxel (box) in the center of the lesion represents the 1H-MRS volume of interest. (B) Diffusion-weighted image (10,000/93; b = 1000 s/mm^2) shows markedly hyperintensity in the abscess cavity and isointensity surrounding the edema. (C) Apparent diffusion coefficient map reveals hypointensity in the abscess cavity, indicating restricted diffusion and hyperintense areas surrounding the edema. (D) In vivo 1H spectrum (2000/270) from the abscess cavity shows resonances representing succinate (Suc) at 2.4 ppm, acetate (Ac) at 1.9 ppm, alanine (Ala) at 1.5 ppm, lactate (Lac) at 1.3 ppm, and the other amino acids (AA) at 0.9 ppm.

duced by anaerobic glycolysis and necrotic brain tissue in brain abscesses. Both lactate and lipids peaks can also be observed in necrotic tumors[19,20,22-25]. Increases in acetate and succinate presumably originate from the enhanced glycolysis and fermentation by the infecting microorganisms[19-26]. Amino acids such as valine and leucine are probably end products of proteolysis by enzymes released from neutrophils in pus[19-26].

Discrimination between amino acids (i.e., valine, leucine, and isoleucine at 0.9 ppm) and lipid (at 0.8 to 1.2 ppm) is important. Lipid signals may exist in both brain tumors and abscesses, whereas amino acids are not seen in proton MR spectra of brain tumors in vivo and are only detectable in vitro[21]. It is known that with an echo time of 135, phase inversion occurs as a result of J-coupling between lactate and amino acids, but not in lipid, a feature which may be helpful in differential diagnosis between brain abscess and tumor[19,22].

The findings of lactate and lipid peaks after long term treatment with antibiotics may become nonspecific and thus can be easily missed in patients with cystic or necrotic tumors [25,27-29]. Dev et al. demonstrated a decline of the acetate and pyruvate in 5 patients after 1 week of aspiration and medical treatment. The authors proposed that the disappearance of metabolites of bacterial origin might suggest a positive response to therapy[25].



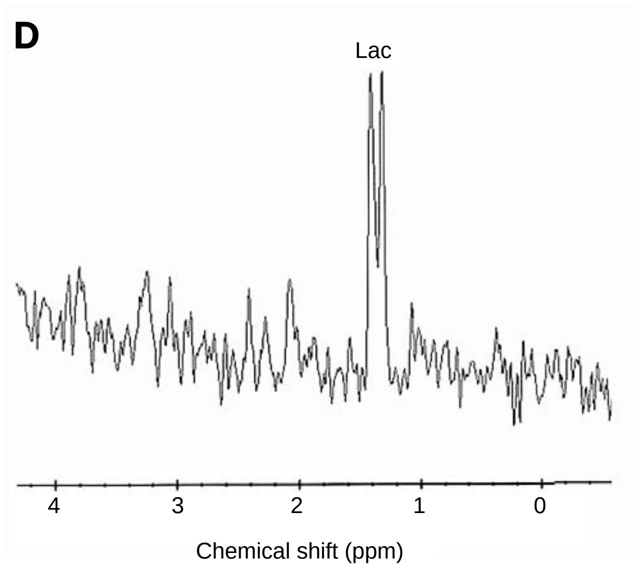


Figure 2. A 65-year-old man with a pathologically proven left frontoparietal lobe metastasis from primary lung adenocarcinoma. (A) Contrast-enhanced T1-weighted (500/30) MR image shows a ring-enhanced lesion in left frontoparietal lobe. The 2×2×2-cm voxel (box) in the center of the lesion represents the 1H-MRS volume of interest. (B) Diffusion-weighted image (10,000/93; b = 1000 s/mm^2) shows markedly low signal intensity in the necrotic part of the tumor. (C) Apparent diffusion coefficient map reveals high signal intensity in the necrotic part of the tumor that is similar to cerebrospinal fluid, indicatin marked diffusion. (D) In vivo 1H spectrum (2000/270) from the necrotic center of the tumor shows a lactate (Lac) peak at 1.3 ppm.

Burtscher et al. also showed dramatic changes in the follow-up MR spectroscopy of abscesses 29 and 113 days after the beginning antibiotic treatment. All resonances (representing succinate, acetate, alanine, and amino acids) except that of lactate disappeared[27].

The fact that these spectral changes disappear with effective antibiotic treatment, as shown in previous studies[25,27-29], underlines the need for 1) the neuroradiologist or spectroscopist interpreting the spectra to be aware of the case history and 2) the MR spectroscopic examinations to be performed as early as possible, preferably before the start of antibiotic therapy. Knowledge of the expected spectral changes after treatment also offers the possibility of evaluating the efficacy of nonsurgical treatment of brain abscesses. Further prospective studies with a large number of cases will be necessary for thorough evaluation of particular spectral peaks and time courses of the spectral changes with antibiotic treatment.

In recent studies, it is possible to differentiate anaerobic from aerobic brain abscesses on the basis of metabolite patterns observed on in vivo 1H MRS[30,31]. The spectral metabolite pattern of the lactate, amino acids, alanine, acetate, and succinate would suggest an obligate anaerobic or a mixture of obligate and facultative anaerobic abscess. On the other hand, the lack of acetate and succinate signal would suggest an obligate aerobic or a facultative anaerobic abscess. This information may be useful for a timely and appropriate treatment of the abscesses.

Compared with the in vivo spectra, a number of additional resonance peaks of lysine at 1.73 and 3.0 ppm, of glutamate/glutamine at 2.09-2.36 ppm, of taurine at 3.24 and 3.42 ppm, of glycine at 3.55 ppm; and of the other amino acids at 3.75 ppm could be observed on the in vitro one-dimensional single-pulse or spin echo spectrum, and in the two-dimensional correlation spectroscopy 1H MR spectra(19,23,30,31). It is noteworthy that the in vitro measurements may offer complementary information that cannot be extracted from in vivo MRS spectra.

DWI vs. 1H MRS of pyogenic brain abscess and necrotic brain tumor

DWI is a more practical and accurate method compared with 1H MRS(28). There are several reasons for this conclusion. First, DWI scan time is very short (about 40 sec), whereas MR spectroscopy takes a much longer scan time. Single-voxel 1H MRS takes around several minutes and 2D chemical shift imaging takes about 10 minutes according to the repetition time, excitation number, etc. DWI thus is more practical in clinical use, especially in emergent conditions. Second, single-voxel 1H MRS is more limited in voxel size (roughly 1.5×1.5×1.5-cm to 2×2×2-cm) than DWI, and the smaller lesion in MRS will be more affected by the partial volume effect. This is true even in chemical shift imaging, although 2D chemical shift imaging may have a smaller voxel than the single-voxel technique in the case of small lesions. In any case it is likely that 2D chemical shift imaging would still be more time consuming. If the lesion is located peripherally, images of the lesion produced by either single-voxel MRS or 2D chemical shift imaging might be contaminated by the signals from the fat close-by. Third, the treated pyogenic abscess may have high signal on DWI, whereas MR spectroscopic examination shows only lactate/lipid peaks (no amino acid peak [end-products of bacterial breakdown]), a spectrum the same as what is found in necrotic tumor.

Nevertheless, there are some advantages of 1H MRS. First, 1H MRS may provide valuable information on the changes of metabolites after nonsurgical treatment of brain abscesses, and may thus helpful for the evaluation of the efficacy of antimicrobial therapy(25,27-29). Second, 1H MRS may differentiate anaerobic from aerobic brain abscesses on the basis of metabolite patterns(30,31). This would be an important information for prompt and appropriate treatment of patients with brain abscesses.

In summary, DWI and 1H MRS are useful tools for the differential diagnosis between brain abscesses and cystic or necrotic brain tumors. The combination of DWI and 1H MRS modalities may provide a more accurate diagnosis of brain abscesses and cystic or necrotic brain tumors than the use of only a single modality.

CONCLUSION

The MR special techniques, e.g. DWI and 1H MRS, are useful tools for the differential diagnosis between brain abscesses and cystic or necrotic brain tumors. Moreover, it is possible to differentiate anaerobic from aerobic brain abscesses based on the metabolite patterns on the in vivo 1H MRS. Further studies should evaluate the possibility of the detection of the overlapped metabolites that cannot be differentiated with one-dimensional localized spectroscopy. Probably one may be able to subcategorize these abscesses in the future with the application of two-dimensional or three-dimensional localized in vivo spectroscopy.

ACKNOWLEDGEMENTS

National Science Council NSC-92-2314-B-075B-003 (PHL) and NSC-93-2314-B-075B-010 [RG3](PHL) and NSC-92-2113-M-110-019 (SD) and Ministry of Education A-92-N-FA01-2-4-5 (SD) provided financial support for this project.

REFERENCES

1. Lau DW, Klein NC, Cunha BA. Brain abscess mimicking brain tumor. Heart Lung 1989;18:634-7.
2. Rowley HA, Grant PE, Roberts TP. Diffusion MR imaging. Theory and applications. Neuroimaging Clin N Am 1999;

9:343-61.
3. Ebisu T, Tanaka C, Umeda M, et al. Discrimination of brain abscess from necrotic or cystic tumors by diffusion-weighted echo planar imaging. Magn Reson Imaging 1996;14: 1113-6.
4. Kim YJ, Chang KH, Song IC, et al. Brain abscess and necrotic or cystic brain tumor: discrimination with signal intensity on diffusion-weighted MR imaging. AJR Am J Roentgenol 1998;171:1487-90.
5. Noguchi K, Watanabe N, Nagayoshi T, et al. Role of diffusion-weighted echo-planar MRI in distinguishing between brain abscess and tumour: a preliminary report. Neuroradiology 1999;41:171-4.
6. Desprechins B, Stadnik T, Koerts G, et al. Use of diffusion-weighted MR imaging in differential diagnosis between intracerebral necrotic tumors and cerebral abscesses. AJNR Am J Neuroradiol 1999;20:1252-7.
7. Park SH, Chang KH, Song IC, et al. Diffusion-weighted MRI in cystic or necrotic intracranial lesions. Neuroradiology 2000;42:716-21.
8. Chang SC, Lai PH, Chen WL, et al. Diffusion-weighted MRI features of brain abscess and cystic or necrotic brain tumors: comparison with conventional MR imaging. Clin Imaging 2002;26:227-36.
9. Guzman R, Barth A, Lövblad K, et al. Use of diffusion-weighted magnetic resonance imaging in differentiating purulent brain processes from cystic brain tumors. J Neurosurg 2002;97:1101-7.
10. Desbarats LN, Herlidou S, de Marco G, et al. Differential MRI diagnosis between brain abscess and necrotic or cystic brain tumors using the apparent diffusion coefficient and normalized diffusion-weighted images. Magn Reson Imaging 2003;21:645-50.
11. Ikeda K, Kuwajima A, Tamura M, et al. Dynamic changes of MRI in brain abscesses. Neuroradiology 2002;44:1011-2.
12. Rana S, Albayram S, Lin DD, et al. Diffusion-weighted imaging and apparent diffusion coefficient maps in a case of intracerebral abscess with ventricular extension. AJNR Am J Neuroradiol 2002;23:109-12.
13. Krabbe K, Gideon P, Wagn P, et al. MR diffusion imaging of human intracranial tumours. Neuroradiology 1997;39: 483-9.
14. Guo AC, Provenzale JM, Cruz LC Jr, et al. Cerebral abscesses: investigation using apparent diffusion coefficient maps. Neuroradiology 2001;43:370-4.
15. Tien RD, Felsberg GJ, Friedman H, et al. MR imaging of high-grade cerebral gliomas: value of diffusion-weighted echoplanar pulse sequences. AJR Am J Roentgenol 1994; 162:671-7.
16. Holtas S, Geijer B, Stromblad LG, et al. A ring-enhancing metastasis with central high signal on diffusion-weighted imaging and low apparent diffusion coefficients. Neuroradiology 2000;42:824-7.
17. Demaerel P, Van Hecke P, Van Oostende S, et al. Bacterial metabolism shown by magnetic resonance spectroscopy. Lancet 1994;344:1234-5.
18. Harada M, Tanouchi M, Miyoshi H, et al. Brain abscess observed by localized proton magnetic resonance spectroscopy. Magn Reson Imaging 1994;12:1269-74.
19. Remy C, Grand S, Lai ES, et al. 1H MRS of human brain abscesses in vivo and in vitro. Magn Reson Med 1995;34: 508-14.
20. Poptani H, Gupta RK, Jain VK, et al. Cystic intracranial mass lesions: possible role of in vivo MR spectroscopy in its differential diagnosis. Magn Reson Imaging 1995;13: 1019-29.
21. Grand S, Lai ES, Esteve F, et al. In vivo 1H MRS of brain abscesses versus necrotic brain tumors. Neurology 1996;47:846-8.
22. Kim SH, Chang KH, Song IC, et al. Brain abscess and brain tumor: discrimination with in vivo H-1 MR spectroscopy. Radiology 1997;204:239-45.
23. Martinez-Perez I, Moreno A, Alonso J, et al. Diagnosis of brain abscess by magnetic resonance spectroscopy. J Neurosurg 1997;86:708-13.
24. Chang KH, Song IC, Kim SH, et al. In vivo single voxel proton MR spectroscopy in intracranial cystic masses. AJNR Am J Neuroradiol 1998;19:401-5.
25. Dev R, Gupta RK, Poptani H, et al. Role of in vivo proton magnetic resonance spectroscopy in the diagnosis and management of brain abscesses. Neurosurgery 1998;42:37-43.
26. Grand S, Passaro G, Ziegler A, et al. Necrotic tumor versus brain abscess: importance of amino acids detected at 1H MR spectroscopy - initial results. Radiology 1999;213:785-93.
27. Burtscher IM, Holtas S. In vivo proton MR spectroscopy of untreated and treated brain abscesses. AJNR Am J

Neuroradiol 1999;20:1049-53.

28. Lai PH, Ho JT, Chen WL, et al. Brain abscess and necrotic brain tumor: discrimination with proton MR spectroscopy and diffusion-weighted imaging. AJNR Am J Neuroradiol 2002;23:1369-77.
29. Akutsu H, Matsumura A, Isobe T, et al. Chronological change of brain abscess in 1H magnetic resonance spectroscopy. Neuroradiology 2002;44:574-8.
30. Garg M, Gupta RK, Husain N, et al. Brain abscesses: etiologic categorization with in vivo proton MR spectroscopy. Radiology 2004;230:519-27.
31. Lai PH, Li KT, Hsu SS, et al. Proton Magnetic Resonance Spectroscopy of the Pyogenic Brain Abscess: In vivo 1.5 T and In vitro 11.7 T Findings. AJNR Am J Neuroradiol 2004. (in press)