Original Article

Comparative Evaluation of Fungal, Tuberculous and Pyogenic Brain Abscess with Conventional, Diffusion, and Susceptibility-Weighted MR Sequences [SWMRS]

Theeraphol Panyaping MD[1], Thiparom Sananmuang MD[1], Wiboon Suriyajakryuththana MD[1]

[1] Department of Diagnostic and Therapeutic Radiology, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Objective: To compare the imaging findings among pyogenic, fungal and tuberculous abscess using conventional, diffusion-weighted imaging [DWI], and susceptibility-weighted magnetic resonance sequences [SWMRS].

Materials and Methods: A retrospective study was done in 43 patients with diagnosis of brain abscesses between January 2004 and January 2016 whose MRIs of the brain were available. Imaging characteristics on conventional MRI, DWI, and SWMRS were recorded in all abscesses.

Results: The present study included 43 examinations. The pyogenic abscesses had smooth or lobulated walls (82%) with complete hypointense T2 rim (95.4%), whereas fungal abscess showed crenated walls (66.7%) with intracavitary projections (n = 6/12) and heterogeneous DWI cavity (83.3%). Tuberculous abscess had smooth/lobulated wall (77.8%) or crenated wall (22.2%) with heterogeneous (50%) or homogeneous (50%) hyperintense DWI cavity. Dual rim sign, previously described as a specific sign for pyogenic abscess, was present in 6/13 cases of pyogenic brain abscess. This sign was also found in 2/9 cases of fungal brain abscess and 2/3 cases of tuberculous brain abscess. There was no statistically significant difference between mean ADC value of a wall, restricted portion and non-restricted portion of the cavity among pyogenic, fungal and tuberculous brain abscesses. However, fungal and tuberculous abscess had a higher proportion of cases with non-restricted portion within the cavity.

Conclusion: Combination of imaging findings in conventional, DWI, and SWMRS, differentiation among pyogenic, fungal and tuberculous abscess might be possible. "Dual-rim sign", previously described in pyogenic brain abscess, is not specific for pyogenic. This sign can be found in tuberculous and fungal abscess.

Keywords: Brain abscess, Diffusion-weighted imaging, Susceptibility-weighted MRI sequences

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Brain abscess developed as a sequelae of untreated focal cerebritis into central collection of pus surrounded by a vascularized collagenous capsule[1,2]. Magnetic resonance imaging [MRI] is the imaging modality of choice in the evaluation of patient suspected of brain abscess. The classic appearance of brain abscess on MRI is hypointense on T1-weighted and hyperintense T2-weighted of the cavity with rim enhancement of capsule surrounded by area of perilesional edema[3].

On conventional MR images, mature pyogenic and tuberculous abscesses typically show thin, smooth, or lobulated rim enhancement with hypointense T2-weighted rim[4]. Daughter abscesses may be seen along the medial wall of the parent abscess, whereas fungal abscess tends to have more irregular wall and heterogeneous signal of cavity on T2-weighted. However, there is still lacking of specificity on conventional MRI to the identified the causative microorganisms. Consequently, advanced MRI techniques, such as diffusion-weighted imaging [DWI], magnetization transfer, magnetic resonance spectroscopy, and recently SWMRS have been used to distinguish the offending organism[4-7].

In diffusion imaging, the pyogenic and tubercular abscess shows restricted diffusion in the wall as well as the cavity. In the fungal abscess, the cavity tends to be homogeneously hyperintense in DWI, and mean apparent diffusion coefficient [ADC] value of the cavity is reported variable[6,7,9]. Restricted diffusion of wall and intracavitary projection[4] and higher ADC of the cavity[7] have been reported. However, restricted diffusion of the cavity resembles that of pyogenic also revealed in one study[9].

Correspondence to:

Suriyajakyuthana W. Neuroradiology Division, Department of Radiology, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok 10400, Thailand.
Phone: +66-2-2011000
Email: wiboonsuriya@gmail.com

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Susceptibility-weighted MR sequences [SWMRS] are high-resolution gradient-echo sequences that are useful for detection of hemoglobin breakdown products, iron, or calcifications[10]. Susceptibility-weighted imaging [SWI] shows the value in the evaluation of pyogenic brain abscess[11,12] and differentiation of pyogenic brain abscess from necrotic GBM[11], emphasizing the "dual-rim sign", as the most specific imaging for pyogenic brain abscess. To date, there is only one study which differentiates pyogenic from fungal abscess and pyogenic abscess on the basis of SWMRS and presence dual rim sign[6] and concluded the dual-rim sign as a specific feature of pyogenic brain abscesses on SWI.

The purpose of the present study was to compare imaging characteristics of pyogenic, fungal and tuberculous abscess using conventional, DWI, and SWMRS.

Materials and Methods

A retrospective study of 43 patients diagnosed with brain abscess at Ramathibodi Hospital, Mahidol University was done between January 2004 and January 2016. The inclusion criteria were patients diagnosis with brain abscess with available initial brain MRI and organism-proved. In the cases without identified causative microorganism, available clinical and MRI follow-up must be provided to evaluate positive response of specific treatment. The lesions with previous biopsy would be excluded.

Procedures

All patients were randomly selected and retrospectively reviewed by two radiologists in a consensus and blinded manner. The first radiologist, who is Radiology Board certified and subspecialty Board of Advanced Diagnostic Neuroradiology. The second radiologist, who is a Radiology Board certified and currently a neuroradiology training fellow. Intraobserver variability was done by the reevaluation of imaging findings after at least 1-month interval.

MRI facilities

MRI was performed on 1.5 (Signa; GE Medical Systems, Milwaukee, Wis) and 3-T scanner (Philips Intera, Philips Medical Systems, Best, Netherlands scanners). On the 3-T scanner, the following sequences were acquired: axial FLAIR FS + Gd (TR/TE, 4,800/326); axial TSE T2-weighted image (WI; TR/TE, 4,158/86; flip angle, 90°); axial SWI (TR/TE 31/0 ms; section thickness 2.0 mm; flip angle 17°); and axial TSE T1-weighted image (TR/TE 662/10; flip angle 70°) with and without Gd-DTPA. DWI was performed using a single-shot echoplanar imaging pulse sequence (TR/TE, 3,000/90 ms). Diffusion-sensitizing gradients were applied sequentially along the three orthogonal planes, and images were obtained at b values of 0 and 1,000 m/s.

On the 1.5-T scanner, the following sequences were acquired: axial FLAIR FS + Gd (TR/TE 9000/127); axial TSE T2-weighted image (WI: TR/TE 2,500/88; flip angle 90°), axial SWI (TR/TE 78/47 ms; section thickness 1.5 mm; flip angle 15°); and axial TSE T1-weighted image (TR/TE 400/14; flip angle 90°) with and without Gd-DTPA. DWI was performed using a single-shot echoplanar imaging pulse sequence (TR/TE 8,000/90 ms). Diffusion-sensitizing gradients were applied sequentially along the three orthogonal planes, and images were obtained at b values of 0 and 1,000 m/s. ADC maps were generated for all patients using our vendors' standard software.

Imaging interpretation

Conventional imaging interpretation were considered in terms of lesion multiplicity, morphology, size, presence and completeness of hypointense T2 rim as well as homogeneity of the cavity based on T2W sequence. Rim enhancement wall was also analyzed in thickness, completeness, and irregularity in T1W + Gd, using outer margin. The outer margin of the wall was classified as smooth or lobulated (no angulations or few obtuse angles) or irregular (multiple acute angles).

On DWI image, homogeneity of hyperintense cavity was evaluated. ADC value of the wall, restricted portion and non-restricted portion of the cavity in the same lesion was measured manually by drawing of a circular region of interest [ROI] using vendor's standard software. The difference in ROI area was less than 1 mm^2 in each region. Normalized ADC value was calculated as an ADC ratio of lesion/ADC of the contralateral normal white matter[6]. An ADC value of less than $0.90\pm0.13 \times 10^{-3}$ is considered restricted[4]. Intracavitary projection, originally described by Luthra et al as an isointense to hypointense on T1W and hypointense on T2W projected from a wall of abscess specific for fungal abscess[4,6], was evaluated in all lesions.

SWMRS without minimum intensity projections [MIP] were used to determine the SWMRS characteristics of the lesions in terms of completeness and regularity of the hypointense T2 rim. Dual rim sign consisting of two concentric rims surrounding

the central cavity at lesion margins, with the outer one being hypointense and the inner one hyperintense compared with the cavity content on SWMR, was evaluated in both SWI and susceptibility-weighted angiography [SWAN].

Statistical analysis

Comparison was made between bacterial group and fungal abscess as well as pyogenic and fungal abscess. Bacterial group consisted of pyogenic and tuberculous abscesses. The statistical analyses between groups were performed by Chi-square, Fisher's exact analysis, and one-way ANOVA with SPSS V.22 (IBM, Armonk, New York) software. Statistical significance is defined as *p*-value of 0.05 or less.

Results

Clinical data

Twenty-two cases were diagnosed with brain abscess, age ranging between 1 month and 81 years (Table 1). In pyogenic abscess, solitary lesion was found in 14 patients and multiple lesions were found in 8 patients (36.3%). Twelve cases were culture sterile, others revealed gram positive cocci in chain (n = 2), gram negative bacilli (n = 1), *Nocardia* (n = 3), *Streptococcus* (n = 2), *Klebsiella* (n = 3). Predisposing factors for brain abscess were found in 6 cases, including valvular heart disease (n = 2), diabetes mellitus [DM] type II (n = 2), end stage renal disease (n = 1), and cancer currently on chemotherapy (n = 1).

Twelve cases were diagnosed as fungal abscess, age ranging between 12 to 77 years. Immunocompromised were found in 10 cases, including SLE (n = 1), hematologic malignancy (n = 3), DM type II (n = 2), and end stage renal disease (n = 1). Six cases had single lesion found in frontal lobe (n = 4) and temporal lobe (n = 2). Of the 12 cases of fungal abscess, the causative agents: *Aspergillus* (n = 6), *Rhizopus* (n = 1), *Pythium* (n = 1), *Mucormycosis* (n = 1), and *Histoplasma* (n = 1). The remaining 2 cases had no identified organism, but responded to antifungal treatment.

Tuberculous abscess was found in 9 of 43 cases. Eight cases were culture-positive for *Mycobacterium tuberculosis* and 1 case of *Mycobacterium avium complex*. Single lesion was found in 7 patients located at the frontal lobe (n = 3), occipital (n = 1), parietal (n = 1), and cerebellum (n = 2).

None of the cases were diagnosed and treated as co-infection.

Conventional imaging findings

All of the cases showed hypointense on T1-weighted image and hyperintense on T2-weighted image. Mean of the lesion size in pyogenic, fungal, and tuberculous abscess was measured 3.2 cm, 2.9 cm, and 2.7 cm, respectively (Table 1). The wall of pyogenic abscess was smooth or lobulated (n = 18, 82%). Irregular wall was found only in 4 cases (18%) of pyogenic abscess. In the tuberculous abscess, there were smooth/lobulated wall (n = 7, 77.8%) and irregular wall (n = 2, 22.2%). The fungal abscesses had irregular wall (n = 8, 66.7%) and smooth/lobulated wall (n = 4, 33.3%). There was significantly more irregular wall in fungal abscess compared with a bacterial group

Table 1. Clinical data and conventional MRI findings

Characteristic	Pyogenic	Fungal	Tuberculous	*p*-value ‡§	*p*-value †§
Number of patients, n (%)	22 (50.0)	12 (27.2)	9 (20.4)		
Age (years), mean ± SD	50.9±19.8	38.5±26.0	44.7±17.9		
Lesion size (cm), mean ± SD	3.2±2.3	2.9±1.9	2.7±1.8		
Multiple lesions	8/22 (36.3)	6/12 (50.0)	2/9 (22.2)	0.280	0.596
Wall thickness (mm), mean ± SD	3.14±1.4	2.4±0.5	3.17±2.1		
Number of lesion per patient, mean ± SD	2±1.8	3.7±5.3	1.3±0.7		
Presence of daughter abscess	11/22 (50.0)	5/12 (41.7)	5/9 (55.6)		
Presence of intracavitary projection	1/22 (4.5)	6/12 (50.0)	0/9 (0.0)		
Post-contrast T1W lesion enhancement				0.003	0.005
Smooth/lobulated	18/22 (82.0)	4/12 (33.3)	7/9 (77.8)		
Irregular	4/22 (18.0)	8/12 (66.7)	2/9 (22.2)		
Completeness of hypo T2 rim				0.005	0.007
Complete	21/22 (95.4)	7/12 (58.3)	6/9 (66.7)		
Incomplete	1/22 (4.5)	5/12 (41.6)	3/9 (33.3)		
Hyper T2 cavity	11/22 (50.0)	1/12 (8.3)	4/9 (44.4)	0.015	0.015

† Pyogenic abscess, ‡ Bacteria, § Fungal abscess

(p = 0.003). The mean of wall thickness was measured 3.1 cm, 2.4 cm, and 3.1 cm in pyogenic, fungal, and tuberculous abscess, respectively.

Two of five cases with cerebral Aspergillosis abscesses showed only minimal and thin wall enhancement. Daughter abscess was found in pyogenic (n = 11, 50%), fungal (n = 5, 41.7%), and tuberculous abscess (n = 5, 55.6%).

On T2-weighted image, hypointense T2 rim was present in all of the cases. There was significantly more complete hypointense T2 rim in pyogenic abscess (n = 21, 95.4%) as compared with fungal (p = 0.007). Tuberculous abscess could have both complete hypointense T2 rim (n = 6, 66.7%) and incomplete (n = 3, 33.3%). Heterogeneity of the T2W signal of cavity was found more in fungal abscess compared with pyogenic and bacterial group (n = 11, 91.6%) (p = 0.015).

Diffusion imaging findings

Diffusion image was available in all cases of pyogenic abscess, all of fungal and tuberculous abscesses (Table 2). Pyogenic, fungal and tuberculous brain abscesses showed restrict diffusion portion of the central cavity. There was significantly more heterogeneous of hyperintense DWI cavity in fungal abscess compared with pyogenic (n = 10, p = 0.009) (Table 3).

Mean ADC value of the wall, restricted and non-restricted portions of the pyogenic was 1.21±0.51, 0.76±0.22, and 2.34±1.09 $\times 10^{-3}$ mm^2/s. In fungal abscess, mean ADC of the wall, restricted and non-restricted portion was 1.33±0.50, 0.80±0.18, and 2.16±0.68 $\times 10^{-3}$ mm^2/s. Meanwhile, in tuberculous abscess, the mean ADC value of the wall, restricted, and non-restricted portions were 1.53±0.36, 0.84±0.29, and 2.44±0.73 $\times 10^{-3}$ mm^2/s. There was no significant difference in mean ADC wall, restricted, and non-restricted portions among these 3 groups of abscess. Intracavitary projection was present in 6 cases of fungal abscess (50%) and 1 case of pyogenic abscess (Figure 1). There was no intracavitary projection found in tuberculous abscess. In fungal abscess, there is a significantly lower ADC value of the projection than wall (p = 0.000).

Susceptibility-weighted MR imaging features

SWMRS were available in 13 cases of pyogenic abscess, 9 cases of fungal abscess, and 3 cases of Tuberculous abscess (Table 4). For SWMRS, 10/13 cases (76.9%) of pyogenic brain abscess showed complete low signal intensity rim [LSIR] with 8/13 cases (61.5%) regular LSIR. In fungal abscess, there were 5/9 cases (55.6%) with incomplete LSIR and 5/9 cases (55.6%) with irregular LSIR. Meanwhile, 2/3 cases (66.7%) of tuberculous abscess showed complete LSIR and 2/3 cases (66.7%) showed regular LSIR. There was no significant difference in LSIR completeness and regularity between fungal and pyogenic abscess. Central low signal intensity [CLSI] was found more in fungal abscess (n = 4, 44%) when compared with pyogenic (n = 2, 15.3%). None of tuberculous abscess showed CLSI. Dual rim sign was present in 6/13 cases of pyogenic abscess (Figure 2), 2/9 cases of fungal abscess (Figure 3), and 2/3 cases of tuberculous abscess (Figure 4). This sign could be

Table 2. Mean and SD of ADC values in the wall and cavities of brain abscess

	Apparent diffusion coefficient ($\times 10^{-3}$ mm^2/s), mean ± SD			
	Wall	Restricted portion of cavity	Non-restricted portion of cavity	Intracavitary projection
Pyogenic	1.21±0.51 (n = 16)	0.76±0.22 (n = 16)	2.34±1.09 (n = 3)	0.65
Fungal	1.33±0.50 (n = 12/12)	0.80±0.18 (n = 10/12)	2.16±0.68 (n = 7/12)	0.79±0.13
Tubercular	1.53±0.36 (n = 7)	0.84±0.29 (n = 7)	2.44±0.73 (n = 4)	-
p-value ‡§	0.099	0.197	0.300	
p-value †§	0.539	0.634	0.735	
p-value †‡§	0.33	0.70	0.62	

† Pyogenic abscess, ‡ Bacteria, § Fungal abscess

Table 3. Cavity appearance in DWI

	Pyogenic (n = 21)	Fungal (n = 12)	Tuberculous (n = 9)	p-value ‡§	p-value †§
Homogeneous hyperintense	14 (63.6)	2 (16.7)	5 (55.6)	0.018	0.009
Heterogeneous hyperintense	8 (36.3)	10 (83.3)	4 (45.4)		

† Pyogenic abscess, ‡ Bacteria, § Fungal abscess

Table 4. Characteristic of brain abscess in SWMRS

	Pyogenic (n = 13)	Fungal (n = 9)	Tuberculous (n = 3)	*p*-value ‡§	*p*-value †§
Number of patients					
SWI	11	4	3		
SWAN	0	3	0		
SWI + SWAN	2	2	0		
LSIR completeness, n (%)				0.160	0.120
Complete	10 (76.9)	4 (44.4)	2 (66.7)		
Incomplete	3 (23.1)	5 (55.6)	1 (33.3)		
LSIR regularity, n (%)				0.560	0.430
Regular	8 (61.5)	4 (44.4)	2 (66.7)		
Irregular	5 (38.5)	5 (55.6)	1 (33.3)		
CLSI	2 (15.4)	4 (44.4)	0 (0.0)	0.370	0.170
Presence of dual rim sign, n (%)	6 (46.1)	2 (22.2)	2 (66.6)	0.820	0.670
SWI	5	2	2		
SWAN	-	1	-		
SWI & SWAN	1	-	-		
Low signal intracavitary projection	1/1	2/6	-		

SWI = susceptibility-weighted imaging; SWAN = susceptibility-weighted angiography; LSIR = low signal intensity rim; CLSI = central low signal intensity
† Pyogenic abscess, ‡ Bacteria, § Fungal abscess

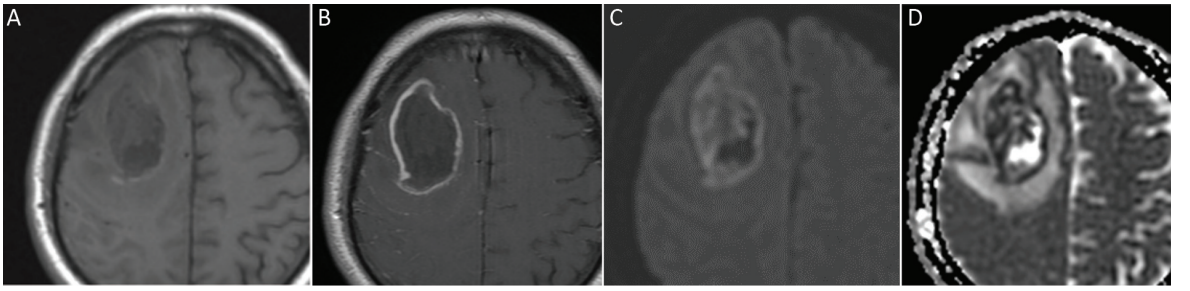

Figure 1. A 38-year old male with pyogenic brain abscess due to gram positive diplococci and cocci in chain. Axial T1-weighted image (A) shows a hypointense core with isointense intracavitary projections. Postcontrast axial T1-weighted image (B) shows peripheral enhancement of the wall without enhancement of intracavitary projections. Hyperintense projections with hypointense cavity are seen on diffusion-weighted image (C). ADC map (D) shows hypointense of projection.

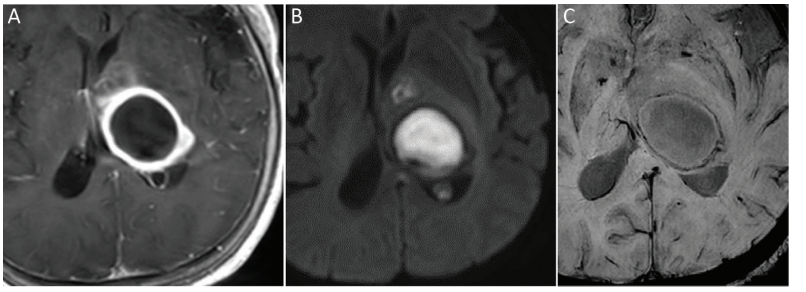

Figure 2. Pyogenic brain abscess due to Streptococcus. There is smooth rim enhancement on postcontrast T1-weighted image (A). Diffusion weighted image (B) shows homogeneous hyperintense signal in central cavity. On the axial SWI (C), the abscess shows the "dual-rim sign".

seen in both SWI and SWAN techniques (Figure 5).

Discussion

Imaging characteristics of pyogenic brain abscess varies with evolving stage from early cerebritis to late capsular formation[2,3]. In late capsular formation, abscess typically shows hypointense T1-weighted, hyperintense T2-weighted with well-defined ring-enhancement, and perilesional edema. However, in Aspergillus abscess ring-enhancement has been

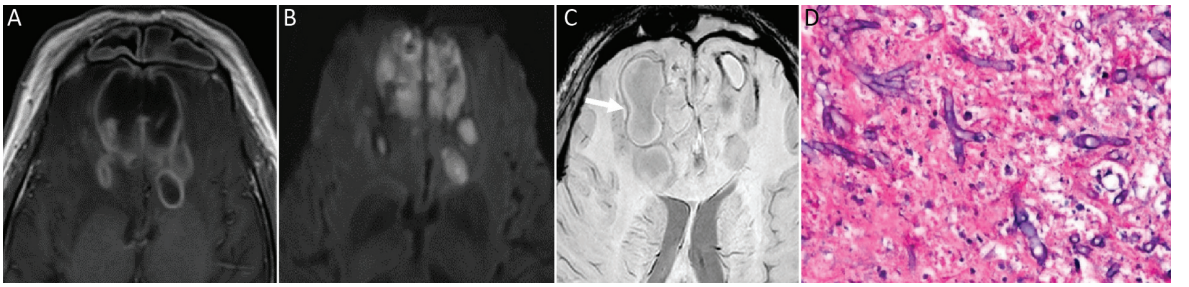

Figure 3. Invasive Aspergillus sinusitis with intracranial abscess formation. There is irregular rim enhancement on postcontrast T1-weighted image (A). Diffusion weighted image (B) shows heterogeneous hyperintense signal of the cavity. On the axial SWI (C), the wall of abscess shows the "dual-rim sign" (arrow). Hematoxylin-eosin stain (D) shows Aspergillosis.

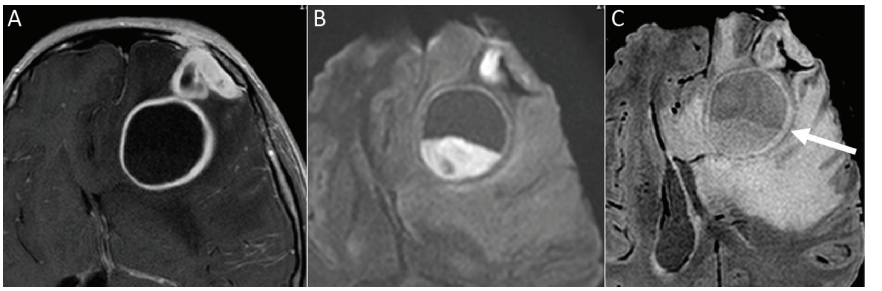

Figure 4. Disseminated tuberculosis with intracranial abscess formation. There is smooth rim enhancement on postcontrast T1-weighted image (A). Diffusion weighted image (B) shows heterogeneous hyperintense signal within the cavity. On the axial SWI (C), the wall of abscess shows the "dual-rim sign" (arrow).

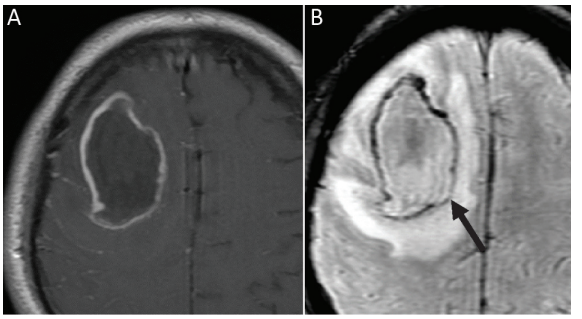

Figure 5. Pyogenic abscess. There is mildly lobulated rim enhancement of abscess on postcontrast T1-weighted image (A). On the axial SWAN (B), "dual-rim sign" is observed (arrow).

described as absent or weak[14,15].

On conventional MR images, mature pyogenic and tuberculous abscesses typically show smooth or lobulated rim enhancement[4]. The present study revealed a concordance result, in which the pyogenic and tuberculous abscesses showed more cases with smooth or lobulated ring-enhancement, while fungal abscess shows more irregular ring-enhancement (p = 0.003). Only 2 out of 5 Aspergillus abscess showed typical thin or vague ring-enhancement. Variable contrast enhancement pattern in fungal might be explained by different immune status of the patients[16].

Peripheral hypointensity on T2W image has been described in a variety of lesions, including brain abscess[16]. In pyogenic abscess, this is thought to result from the generation of free radicals by macrophage[17] in contrast to fungal lesions, which is thought to result from the dense hyphal element periphery[14] and iron or magnesium deposition[18]. Hypointense T2 signal rim can be seen in pyogenic and fungal abscess[6], and tends to be complete in pyogenic abscess[16]. In the present study, hypointense T2 signal rim was found in all cases of abscesses, but tends to be complete in pyogenic (95.4%) when compared with fungal abscess (58.3%) (p = 0.007). In tuberculous abscess, 6/9 (66.7%) have complete hypointense T2 rim and 3/9 (33.3%) have an incomplete hypointense T2 rim.

In the prior study of Schwartz et al[16], which showed the homogeneity of lesion center in T2W in various types of diseases, it was revealed that the abscess can exhibit both heterogeneous and homogeneous hyperintense T2 cavity. The present study reveals that fungal abscesses have significant more heterogeneous hyperintense T2W cavity compared with pyogenic abscess and tuberculous

abscess (p = 0.015).

On DWI, pus in the pyogenic abscess is normally strongly hyperintense on DWI and reduced ADC value. Viable cell density is the main biological parameter responsible for restricted diffusion in brain abscess[8]. Up to date, several comparative studies of DWI between pyogenic and fungal abscess have been reported[4,7,9]. Pyogenic abscess shows more homogeneously high DWI of the cavity compared with fungal abscess[7,9], and this is consistent with the present study.

Tendency of heterogeneity in both hyperintense T2-weighted and hyperintense DWI in cavity of fungal abscess could be explained by the presence of hemorrhage in pathologic samples of Aspergillus abscess[18-20], which is the most common causative agent of fungal abscesses in the present study.

The reported mean ADC value of the fungal abscess cavity is variable. In the prior study of Luthra et al, there was low ADC at central projection and wall while the rest of the core of the abscess showed no restricted diffusion[4]. However, fungal abscess might show central restricted diffusion similar to that of bacterial infection[9]. In the present study, fungal abscess may exhibit both restricted and non-restricted portions, with a higher proportion of cases with the presence of non-restricted portion within the cavity observed in the fungal group compared with the pyogenic abscess. The significant lower ADC value of central projection than the wall of fungal abscess has been observed (p = 0.000), in concordance with a prior study[4]. Low ADC value has also been observed in tuberculous abscesses[8], which is consistent with the present study. There is no significant difference between the mean ADC value of wall, restricted and non-restricted portion between pyogenic and fungal abscess. The mean ADC value of restricted portion between the three groups is overlapping. In tuberculous abscess, there is a widest range of mean ADC value of restricted portion among 3 groups (Figure 6).

Intracavitary projection is described previously only in fungal abscess[4,6], and was found in 6 cases of fungal abscess in the present study. It was also observed in the 1 case of pyogenic abscess. The authors assumed this might be a result of packed pus debris deposition along the wall.

To date, the SWMRS imaging findings of fungal in one study have been reported[6]. It is presented with combination of complete LSIR. In the present series, there was a higher proportion of fungal abscesses with incomplete LSIR and CLSI. CLSI was assumed

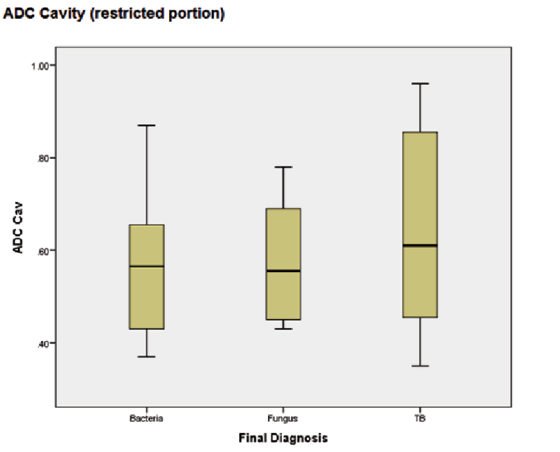

Figure 6. Mean ADC values in restricted portion in cavity of pyogenic, fungal, and pyogenic brain abscesses.

to be hemorrhage based on appearances in multiple sequence.

Dual rim sign is described in SWMRS as a distinctive feature of pyogenic abscess reported to be seen only with SWI sequence[6]. This sign was present in 6/13 cases of pyogenic abscess with SWI and SWAN. In the present study it was also present in 2 cases of fungal abscess (Aspergillus abscess) and 2 cases of tuberculous abscess (Figure 3, 4).

Microscopically, fungal abscess is presented with dominant foci of coagulative necrosis of brain parenchyma and fungal hyphae surrounded by neutrophilic infiltrate and hemorrhage[14]. Capsule formation with chronic inflammation and granulation tissue has also been reported in late disease[9]. Thin rim of peripheral "weak ring" enhancement correlated with a minimal inflammatory response has been described as typical imaging features of Aspergillus abscess[15]. However, marked rim enhancement resembling pyogenic abscess has also been reported[9,15]. According to prior studies, immunostatus is thought to be the biological parameter responsible for diverse patterns of contrast enhancement in fungal abscess[3,15]. The authors believe that different immune status and aggressive pattern of infection might contribute to formation and organization of wall in Aspergillus abscess, more specifically at the level of granulation tissue, which might lead to the presence of dual-rim sign in 2 cases of the present study.

For tuberculous abscess, the present study is the first to demonstrate the presence of dual rim sign in tuberculous abscess. According to prior histopathologic study of the tuberculous abscess, four zones were

recognized along the wall, similar to pyogenic abscesses[13]. Therefore, when considering histological, we can hypothesize that the presence of the dual-rim sign in tuberculous abscesses could be related to well forming of the granulation tissue along the wall.

The present study has some limitations. First, small sample size have been included. Secondly, the pathological analysis or definite offending organism was not available in some cases, especially those with atypical imaging findings.

Conclusion

Fungal abscesses can be differentiated from pyogenic and tuberculous abscesses by a combination of the conventional, DWI, and SWMRS features. An irregular ring-enhancing wall, with heterogeneous DWI cavity, presence of intracavitary projection, and irregular LSIR with presence of CLSI favor fungal abscess. Dual rim sign, originally described as a specific sign for pyogenic abscess, can also be seen in fungal and tuberculous abscesses in the present study. This sign can be seen in both SWI and SWAN.

What is already known on this topic?

The typical features of brain abscess on conventional MRI include hypointense T2-weighted signal in the wall, thin and smooth rim enhancement. However, there is still lacking of specificity on conventional MRI to identify the causative microorganisms. DWI and SWI have been increasingly used in differentiating among pyogenic, fungal and tuberculous abscess. Pyogenic and tubercular abscess typically shows restricted diffusion in the cavity. Dual rim sign in SWMRS is a distinctive feature of pyogenic abscess. Whereas, intracavitary projection is previously found only in fungal abscess.

What this study adds?

"Dual-rim sign", previously described in pyogenic brain abscess, is not specific for pyogenic. This sign can be found in tuberculous and fungal abscess in the present study. Intracavitary projection, originally described only in fungal abscess, was observed in the 1 case of pyogenic abscess in the present study. On DWI, fungal and tuberculous abscess had a higher proportion of non-restricted portion within the cavity. In addition, there is a higher proportion of fungal abscesses with incomplete LSIR on SWI.

Potential conflicts of interest

The authors declare no conflict of interest.

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