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Clinical characteristics, complications, and outcome of brain abscess treated by stereotactic aspiration: a retrospective analysis

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Abstract

Background The aim of this study was to investigate the clinical presentation, imaging features, and outcome of patients diagnosed with brain abscess and treated by stereotactic aspiration.

Methods We retrospectively analyzed the medical data of all consecutive patients diagnosed with brain abscess who underwent stereotactic aspiration in our department from 2015 to 2022. The demographic characteristics, clinical presentation, radiological data, microbial aetiology, and outcome were collected and analyzed using t-test or χ^2 tests.

Results Overall, 120 patients were identified. The mean age was 49.7 years (range: 5–81); 59.2% were male. Seventy-nine patients (65.8%) had comorbidities, of which cardiovascular diseases was the most common. Most of the abscesses were solitary frontal or temporal lesions. A microbiological diagnosis was secured in 70 (58.3%) of cases, among which the majority were of the *Streptococcus* spp. Outcome was favorable in 107 (89.2%) of cases. The mortality rate during the initial hospital stay was 2.5%. A total of 10 individuals (8.3%) presented with preoperative delirium or coma, which was associated with an inferior clinical outcome compared to those who exhibited clear consciousness. ($p=0.01$).

Conclusions Stereotactic aspiration was a safe intervention with a low incidence of complications. The combination of stereotactic aspiration and antibiotic therapy was an effective treatment strategy for brain abscess. Patients who underwent stereotactic aspiration while in a state of disturbance of consciousness demonstrated a poorer outcome compared to those who were conscious.

Clinical trial number Not applicable.

Keywords Brain abscess, Stereotactic, Outcome

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Background

The presence of a brain abscess presents a significant and potentially fatal intracerebral infectious condition, resulting in mortality rates of approximately 10–20% [1–3]. The incidence has been estimated to range from 0.3 to 0.9 per 100,000 population [2, 4]. Pathogens infiltrate the central nervous system through various routes to establish colonization. Subsequently, they disrupt the normal brain tissue architecture, leading to the formation of a necrotic abscess cavity and triggering peripheral inflammation as well as extensive cerebral edema, resulting in pronounced mass effect [5]. The suggestion for surgical intervention arises when the abscess diameter reaches or exceeds 2.5 cm [6, 7]. With the advancement of imaging techniques and stereotactic biopsy, coupled with the introduction of novel antibiotics, the integrated approach of medical and surgical aspiration has emerged as a pivotal therapeutic modality for managing brain abscesses [7–9]. In comparison to patients receiving medical therapy alone, those undergoing combined therapy exhibited a reduced mortality rate and fewer neurological sequelae [5, 10]. However, limited research has been conducted to investigate the related factors influencing the complications and outcome of stereotactic aspiration in brain abscess.

In this retrospective study, we collected and analyzed data from patients diagnosed with primary brain abscess and treated by stereotactic aspiration at our hospital over the past eight years. Our objective was to investigate and quantify potential related factors associated with complications and unfavorable outcome subsequent to stereotactic aspiration.

Methods

Study design and patient population

We retrospectively analyzed the medical data of all consecutive patients diagnosed with brain abscess who underwent stereotactic aspiration in our department from 2015 to 2022. Subdural empyema and epidural abscesses were excluded from the analysis. The data were obtained from the HIS electronic medical record system, and radiologic images acquired before and after the stereotactic aspiration procedure underwent thorough review. In addition to demographic variables such as age and sex, predisposing factors, microbial aetiology results, stereotactic techniques, conscious state, mortality, and outcome after the procedure were collected. Imaging data, such as the brain abscess location and volume were also evaluated. In our department, patients underwent stereotactic aspiration with three different types of stereotactic system: Leksell stereotactic system, Brainlab VarioGuide, and Remebot robot. The selection of the system was based on the individual preference of the responsible neurosurgeon. All patients received antibiotic therapy for a minimum of 4 weeks following stereotactic aspiration. During this period, patients were transferred to either the infection department of our hospital or a rehabilitation hospital for further management. The Glasgow Outcome Scale score (GOS) at discharge was utilized to assess the final outcome. A poor outcome was defined as a GOS score of 1–3, while a good outcome was defined as a GOS score of 4–5. After data collection, various variables were analyzed to identify the related factors associated with unfavorable outcome following the procedure. This study was approved by the ethics committee of the Xiangya Hospital of Central South University (No. 2023030736).

Statistical analysis

The continuous data were presented as means ± standard deviations and analyzed using either the independent t-test or Mann–Whitney U test. Categorical variables, expressed as number (%), were compared using χ^2 tests or Fisher's exact test. Statistical significance was defined as $P < 0.05$. All analyses were performed using IBM SPSS Statistics v22.0 software (IBM Corp, Armonk, NY).

Results

Demographic characteristics and clinical presentation

During the study period, a total of 120 patients diagnosed with brain abscess underwent stereotactic aspiration at our institution. Seventy-one patients (59.2%) were male, and 49 patients (40.8%) were female. The mean age on surgery day was 49.7 ± 16.9 years ranged from 5 to 81 years. Predisposing factors were identified in 79 out of 120 (65.8%) patients. with one predisposing factor observed in 63 (52.5%) patients and two predisposing factors observed in 16 (13.3%) patients. The patients' predisposing factors included diseases in different systems, such as cardiovascular diseases (24 patients, 20%), endocrine diseases (15 patients, 12.5%), nervous system diseases (11 patients, 9.2%), digestive system diseases (3 patients, 2.5%), and skin diseases (1 patients, 0.8%). Adjacent site infection such as otitis or sinusitis (12 patients, 10%), pulmonary infection (4 patients, 3.3%), and dental infection (2 patient, 1.7%) were also predisposing factors. Besides, 15 patients (12.5%) previously underwent head surgery, 11 patients (9.2%) had congenital heart disease. Among the patients who underwent the operation, a total of 10 individuals (8.3%) were observed to be in a state of delirium or coma. The demographic characteristics and clinical presentation are shown in Table 1.

Radiological data

All patients underwent computed tomography (CT), with enhanced brain magnetic resonance imaging (MRI) performed in 105 patients (87.5%). Thirty patients(25%) had more than 1 abscess. The frontal lobe was the most

Table 1 Demographic and clinical characteristics of patients with brain abscess

Characteristics	Total ($n=120$)
Male, n (%)	71 (59.2)
Age, mean ± SD	49.7 ± 16.9
Comorbidities, n (%)	
Cardiovascular diseases	24 (20)
Head trauma/neurosurgery	15 (12.5)
Endocrine diseases	12 (10)
ENT infection	12 (10)
Congenital heart disease	11 (9.2)
Nervous system diseases	11 (9.2)
Respiratory diseases	4 (3.3)
Digestive system diseases	3 (2.5)
Dental infection	2 (1.7)
Skin diseases	1 (0.8)
Number of abscess, n (%)	
Single	90 (75)
Multiple	30 (25)
Location of abscess, n (%)	
Frontal lobe	41 (34.2)
Temporal lobe	28 (23.3)
Basal ganglia	16 (13.3)
Parietal lobe	12 (10)
Occipital lobe	12 (10)
Cerebellum	4 (3.3)
Ventricles	4 (3.3)
Brainstem	3 (2.5)
Lesion volume (cm^3), mean ± SD	12.4 ± 11.0
Conscious state, n (%)	
Conscious	110 (91.7)
Delirium or coma	10 (8.3)
Stereotactic techniques, n (%)	
Leksell stereotactic system	89 (74.2)
VarioGuide	27 (22.5)
Frameless robot	4 (3.3)

frequently affected anatomical site, with 41 patients (34.2%) demonstrating involvement, followed by the temporal lobe (28 patients, 23.3%), basal ganglia (16 patients, 13.3%), parietal lobe (12 patients, 10%), occipital lobe (12 patients, 10%), and cerebellum (4 patients, 3.3%). Brain abscesses were also found in the ventricles (4 patients, 3.3%) and brainstem (3 patients, 2.5%). The mean abscess volume was 12.4 ± 11.0 cm^3. The radiological data was shown in Table 1.

Microbiology

After surgical intervention, brain abscess fluid culture was performed on, with 70 (58.3%) yielding positive results. In a few patients, next-generation sequencing (NGS) also facilitated pathogen identification; however, these specific data were not collected. The most common pathogens identified were *Streptococcus* spp. in 50%, followed by *Escherichia coli*. (12.9%), *Fusobacteria* (11.4%), *Klebsiella pneumoniae* (5.71%), *Enterococcus* (4.29%), *Pseudomonas aeruginosa* (2.86%), and *Staphylococcus* spp. (2.86%; Table 2).

Table 2 Brain abscess culture isolates

Bacteriological data	Total ($n=70$), n (%)
Streptococcus	35 (50.0)
Escherichia coli	9 (12.9)
Fusobacteria	8 (11.4)
Klebsiella pneumoniae	4 (5.71)
Enterococcus	3 (4.29)
Pseudomonas aeruginosa	2 (2.86)
Staphylococcus	2 (2.86)
Proteus mirabilis	1 (1.43)
Corynebacterium	1 (1.43)
Nocardia farcinica	1 (1.43)
Propionibacterium acnes	1 (1.43)
Mycobacterium tuberculosis	1 (1.43)
Scedosporium apiospermum	1 (1.43)
Aspergillus fumigatus	1 (1.43)

Outcomes

Eighty-nine patients (74.2%) underwent stereotactic aspiration using the Leksell stereotactic system, while twenty-seven patients using Brainlab VarioGuide. Additionally, four patients stereotactic aspiration performed by Remebot robot. The comparison of patients with favorable and unfavorable outcome is shown in Table 3. One hundred and seven patients (89.2%) achieved a favorable outcome, most of them had resolution of initial symptoms without any neurological deficits. A few individuals had transient event that did not require treatment or complication visible only on post-aspiration CT scan (asymptomatic hemorrhage). An additional five patients underwent a second operation (stereotactic aspiration) due to abscess recurrence, ultimately achieving a good outcome. Thirteen patients (10.8%) experienced an unfavorable outcome, with three patients succumbing to postoperative hemorrhage or brain edema, and the family declining further surgical intervention. Other ten patients exhibited a persistent vegetative state or severe disability. Compared with those who had favorable outcome, patients with unfavorable outcome had no significant differences in gender, age, location of abscess, lesion volume, and stereotactic techniques. However, the patients who underwent the operation while in a state of delirium or coma exhibited a poorer outcome compared to conscious patients. ($p=0.01$).

Discussion

In our cohort, the mean age at surgery was 49.7 years, ranged from 5 to 81 years. The majority of patients (59.2%) were men. These result are consistent with

Table 3 Comparison of patients with favorable and unfavorable outcome

Characteristics	unfavorable outcome ($n=13$)	favorable outcome ($n=107$)	X^2	p
Male, n (%)	5 (41.7)	66 (61.1)	2.587	0.108
Age, mean ± SD	44.3 ± 17.0	50.3 ± 16.8		0.247
Location of abscess, n (%)			1.772	0.981
Frontal lobe	6 (46.2)	34 (31.8)		
Temporal lobe	3 (23.1)	25 (23.4)		
Parietal lobe	1 (7.7)	11 (10.3)		
Occipital lobe	1 (7.7)	11 (10.3)		
Basal ganglia	1 (7.7)	16 (15.0)		
Cerebellum	0	4 (3.7)		
Brainstem	0	3 (2.8)		
Ventricles	1 (7.7)	3 (2.8)		
Lesion volume (cm^3), mean ± SD	12.6 ± 11.2	11.1 ± 9.4		0.657
Conscious state, n (%)			6.596	0.010
Conscious	9 (69.2)	101 (94.4)		
Delirium or coma	4 (30.8)	6 (5.6)		
Stereotactic techniques, n (%)			4.135	0.125
Leksell stereotactic system	7 (53.8)	82 (76.6)		
VarioGuide	6 (46.2)	21 (19.6)		
Frameless robot	0	4 (3.7)		

previous studies [3, 11, 12]. A previous study found an increasing incidence of brain abscess that was most pronounced among those older than 40 and in patients with dental infection or immuno-compromise [2]. However, it should be noted that the higher morbidity in the older than 40 age group cannot be inferred. Underlying predisposing factors for brain abscess were observed across all age groups. Historically, important risk factors for the development of brain abscess include contiguous infections, head trauma and neurosurgery without age difference [2, 13, 14]. Additionally, diabetes, cardiac valve and pulmonary infections in adults have been implicated [11, 15, 16]. Congenital heart disease is frequently observed in children and adolescents with brain abscess [17]. This is the reason why patients with brain abscess exhibit a wide age. Predisposing factors were present in 65.8% patients. Proper identification and treatment of primary sources of infection in patients with brain abscess is crucial to prevent further bacterial dissemination. Additionally, the contribution of noninfectious diseases, such as stroke, diabetes, and liver cirrhosis, should not be disregarded in the pathogenesis of brain abscess. A previous study reported that brain abscess may occur in a previous hemorrhage or infarction area as a complication of systemic infection [18]. Diabetes mellitus can potentially impair host defense mechanisms, thereby increasing susceptibility to infections and subsequently elevating the risk of brain abscess formation [19].

The most commonly identified pathogens in our study was *Streptococcus* spp. (50%), followed by Escherichia coli (12.9%) and Fusobacteria (11.4%). The distribution pattern of bacteria exhibited similarities to a previous systematic review and meta-analysis involving 9699 patients with abscess [20]. However, the rate of brain abscess fluid culture positivity in our study was 58.3%, which is significantly lower than the previously reported rate of 76% [20]. As a national referral center for neurological diseases, the majority of patients were referred to our department from other hospitals. These patients had previously received prolonged courses of potent antibiotics prior to their arrival at our department. Some patients may have received effective antibiotic therapy prior to obtaining brain abscess fluid for culture, which could have resulted in a decreased rate of pathogen culture positivity [20, 21]. NGS has the potential to provide unbiased sequencing and rapid diagnosis of causative pathogens, enabling identification of both common and rare. Moreover, NGS offers a novel platform for quantifying all detected microorganisms, while being less influenced by prior antibiotic [22, 23]. Therefore, NGS may be a promising strategy to explore the clinical causative pathogens in brain abscess.

In our study, MRI was performed in 87.5% of the patients included, a particular focus on diffusion-weighted imaging (DWI) due to its high sensitivity for abscess detection and potential to enhance specificity in contrast-enhanced T1W imaging of ring-enhancing fluid collections [24]. The frontal lobe exhibited the highest frequency of brain abscesses in our study, followed by the temporal lobe, basal ganglia, parietal lobe, and occipital lobe. These findings align closely with those reported in previous studies [5, 20].

The incidence of brain abscess is low but has been observed to be increasing, particularly among the elderly

population, accompanied by a rising proportion of brain abscess patients with compromised immune systems [2, 25, 26]. However, notable advancements have been documented in the outcomes of individuals afflicted with brain abscess [27]. After performing stereotactic aspiration, a prolonged course of antibiotic therapy (lasting 4–8 weeks) was administered in our study. At discharge, 10.8% of the patients experienced an unfavorable outcome, with 2.5% of them succumbing to postoperative hemorrhage or brain edema. In fact, the mortality rate has witnessed a remarkable decline from 40 to 10% over the past 6 decades, and the rate of patients with full recovery increased from 33–70% [20]. Notably, in the year 2020, the mortality rate was reported as low as 6% at discharge [28]. Most patients with brain abscess undergo surgical treatment and antibiotic therapy to achieve cure rather than medical therapy alone [5]. The observed overall improvements in mortality are likely to be attributed to advancements in imaging techniques, microbiologic diagnostics, more precise aspiration methods, and contemporary antimicrobial therapy.

The surgical management of brain abscess has undergone significant advancements in the past two decades, with a shift towards aspiration as the predominant approach rather than excision. Stereotactic aspiration is a safe intervention with a low incidence of surgery-related intracranial hemorrhage [29]. The choice of stereotactic system was guided by the individual preference of the responsible neurosurgeon. Our statistical analysis revealed that neither frame-based nor frameless stereotactic systems significantly influenced patient prognosis. Relevant literature has yielded different findings regarding the factors associated with outcome. Immunosuppression, hematogenous dissemination, and advanced age were identified as prognostic indicators [30]. Mortality demonstrated a significant correlation with increasing age, the presence of multiple abscesses, immunosuppression, and the existence of an underlying cardiac anomaly [25]. The administration of adjunctive corticosteroids for symptomatic perifocal brain edema exhibit no association with elevated mortality [28]. However, another study demonstrated that the outcome was influenced by headache rather than factors such as confusion, patient age, adjacent site infection, or type of surgery [3]. In our study, no significant differences in gender, abscess location, lesion volume, and stereotactic techniques were observed between the favorable outcome group and the unfavorable outcome group. Patients who underwent the operation while in a state of delirium or coma exhibited a poorer outcome compared to conscious patients. The disturbance of consciousness in patients was correlated with disease severity, often accompanied by severe cytotoxic edema. This condition was prone to postoperative hemorrhage or exacerbation of cerebral edema, leading to patient mortality, impaired plant survival, or severe disability.

The retrospective nature of the study represents a significant potential limitation, which should be acknowledged. Additionally, it is important to note that this was a single-center study with a limited sample size. Therefore, caution should be exercised when generalizing our findings to patients in different regions and hospitals with varying levels of care. Furthermore, our study is limited by the absence of certain data, including levels of inflammatory markers, NGS results, and long-term follow-up. Future investigations should aim to incorporate more detailed data and encompass multicenter studies with larger sample sizes.

Conclusions

We retrospectively analyzed the medical data of 120 patients diagnosed with brain abscess who underwent stereotactic aspiration. Stereotactic aspiration was a safe intervention with a low incidence of complications. The combination of stereotactic aspiration and antibiotic therapy was an effective treatment strategy for brain abscess. Patients who underwent stereotactic aspiration while in a state of disturbance of consciousness demonstrated a poorer outcome compared to those who were conscious.

Abbreviations

CT	Computed tomography
DWI	Diffusion-weighted imaging
GOS	Glasgow Outcome Scale score
MRI	Magnetic resonance imaging
NGS	Next-generation sequencing

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-025-10770-4.

Supplementary Material 1

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Author contributions

Y.C. and Y. W. designed the study. Y. C., J. L., and G. J. collected and analysed the data. Y. C. and Y. W. wrote the manuscript. Y. W. and Y. H. provided clinical and statistical review. All authors interpreted the results and revised the manuscript. All authors read and approved the final version of the manuscript. The corresponding author Y. W. has final responsibility for the decision to submit for publication.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
This study was approved by the ethics committee of the Xiangya Hospital of Central South University (No. 2023030736). All methods were performed in accordance with the relevant guidelines and regulations. As per national legislation and institutional guidelines, it was not necessary to obtain written informed consent to participate from the participants of this study. And the ethics committee of the Xiangya Hospital of Central South University approved the waiver for the need of informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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