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Risk Factors and Surgical Treatment Options for Intracranial Infections

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ABSTRACT

AIM: To present our experience on intracranial infections, and to determine the possible locations as well as the risk factors for surgical treatment.

MATERIAL and METHODS: Over 13 years, 103 patients with intracranial infection underwent surgical evacuation. Seventy-one (68.9%) patients were men, and the mean age was 38.57 years. For intracranial infections, direct and indirect microbiological identification methods were used. The clinical and radiological data of patients were retrospectively analyzed and compared statistically based on the type of infection, location, history of previous surgery, comorbid diseases, and demographic features of the patients.

RESULTS: Forty-six (44.7%) patients had intraparenchymal abscess, 25 (24.3%) had subdural empyema, and 32 (31.0%) had epidural empyema. Emergent surgical evacuation was performed in 60 (58.25%) patients. Microbiological agents were not isolated in 26 (25%) patients, while multiple microorganisms were isolated in 17 (16.5%) patients. Intraparenchymal abscesses are more common in the frontal lobe and cerebellum, while subdural empyemas are located more frequently in the frontoparietal region. There was no significant difference between intracranial infection and age, gender, history of surgery, and preoperative antibiotic use. However, a statistically significant relationship between intracranial infection, history of previous surgery, and the patient's comorbid disease was found. Specifically, intraparenchymal abscesses were more frequently detected in immunocompromised patients, and subdural empyemas were common in patients with previous tumor surgery.

CONCLUSION: Brain abscesses commonly develop in the frontal lobe and cerebellum. Patients who underwent previous cranial surgery and patients with comorbid diseases are more prone to intracranial infections. Large abscesses with significant edema are best candidates for emergent surgical evacuation.

KEYWORDS: Brain, Infection, Risk factor, Surgery

INTRODUCTION

Intracranial infection can be defined as an infection caused by viruses, bacteria, fungi, or parasites that affects the intracranial region, such as the brain parenchyma, ventricles, and meninges (20,33,38,54). These infections refer to diseases in a different spectrum, including intraparenchymal abscess, subdural/epidural empyema, meningitis, arachnoiditis, ventriculitis, and encephalitis (4,29,44). Ventricular rupture and ventriculitis can both lead to abscesses (29). These infections can be fatal when the diagnosis and treatment are delayed. Patients with intracranial infections may complain of fever, headache, altered consciousness, nausea and vomiting, seizures, loss of neurological function, and restlessness, depending on the age group (36).

If there are symptoms of intracranial infections, they should be examined by laboratory and radiological imaging methods.

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Brain computed tomography (CT) and magnetic resonance imaging (MRI) are the main methods used for radiological evaluation. In particular, MRI is the most effective diagnostic method of brain abscesses (4). Diffusion-weighted MRI is the gold standard for assessing of postoperative abscess recurrence (22). CT has an effective use in the rapid detection and evaluation of hydrocephalus, brain edema, intracranial hemorrhage, and intracranial mass lesions (12). Cultivating microorganisms or determining them molecularly is the gold standard in the diagnosis of infection. However, for the differential diagnosis and follow-up of intracranial infection, MRI is the most sensitive radiological technique (20).

Depending on age, the frequency of factors that may cause intracranial infections varies. While ear infections are at the forefront in pediatric and elderly groups, paranasal sinus infections are prominent in adult patients (9). However, they could also develop in immunocompetent patients (11,50). Adjacent organ infections, previous trauma, previous cranial surgeries, hematogenous spread of distant organ, and systemic infections are the main predisposing factors. Fibroma in the paranasal sinuses may be a risk factor for frontal lobe abscesses (23), and isoniazid-resistant *M. tuberculosis* may cause brain abscess in immunocompetent patients (21). In addition, the risk of developing an intracranial infection is increased by the presence of chronic diseases, such as immunodeficiency, diabetes, kidney failure, and cardiopulmonary diseases. Today, with the widespread use of vaccines, the risk of exposure to intracranial infections, such as meningitis and encephalitis, has decreased (6,45).

Intraparenchymal abscesses are focal suppurative infections in the brain parenchyma tissue (7,13,33,49). The lesions that are confined to the capsule and contents of the capsule are purulent fluid. It can be unifocal or observed simultaneously in many foci (19). The frontal, temporal, parietal, and occipital lobes are the most common supratentorial locations, whereas the cerebellar parenchyma is the infratentorial location (9,21). It is more common in the adult age group than in the pediatric age group (17,19,38,54). The annual incidence of pediatric brain abscesses has been estimated as 0.5 per 100,000 children (54). Pediatric abscesses are rare but frequently observed in patients with specific risk factors (38). Their treatment includes surgically disrupting the integrity of the abscess capsule, drainage of the abscess contents and appropriate antibiotic therapy for a sufficient period are required. Hyperbaric oxygen therapy can also be added, if necessary (20,40).

Subdural or epidural empyema is a pyogenic infection with intracranial extra-axial location (24,31). It represents 15%–20% of intracranial infections (31). Previous cranial surgery is the most common cause in the etiology of empyemas. In addition, otitis, sinusitis, and meningitis are among the factors that cause empyema development (24). Their treatment includes surgical drainage and irrigation of the surgical site, and appropriate antibiotic therapy should be administered for a sufficient period. If necessary, hyperbaric oxygen therapy can also be added (33).

Successful management of a brain abscess usually requires a combination of antibiotics and surgical drainage for both diagnostic and therapeutic purposes (5,10,13,29). A patient's life depends on the timing of surgical evacuation. In addition, surgical techniques are important to achieve better clinical and radiological outcomes (33). Once the abscess material has been obtained during the surgery for microbiological analysis, empirical antibiotics should be initiated based on the patient's clinical status and the possible microbiological agent for abscess development. Once the causative microorganism is isolated, relevant antibiotherapy (AB) is performed for better clinical achievement. Antibiotics, which can be effective against the causative agent and can penetrate the abscess cavity, should be used in the medical treatment of brain abscesses (4,25,42,51).

The prognosis of patients with intracranial infections has continuously advanced with contemporary neurosurgical methods, such as improved culture techniques, to isolate the microorganisms, stereotactic surgical interventions, brand-new antibiotics, and state-of-the-art neuroimaging techniques (25,42,51).

This study aimed to present our series of 103 patients with intracranial infection, to determine the possible risk factors for intracranial infections, and to identify the best technique that may provide an excellent clinical outcome.

MATERIAL and METHODS

We retrospectively reviewed the data of patients who underwent surgical treatment for intracranial infection over a 13-year period. Ethical approval of this retrospective study was obtained from our institutional ethics board (University of Health Sciences, Non-Interventional Researches Ethics Committee, Approval date: 08.01.2019, Approval no: 18/347). Between 2008 and 2021, 103 patients who underwent surgical and medical treatment with the diagnosis of intracranial abscess, epidural empyemas, or subdural empyemas were included in the study. MRI and CT scans were used in the radiological diagnosis of infections. Direct (sampling of foci of infection, blood, and/or abscess material culture) and indirect (serology) microbiological identification methods were used for detecting intracranial infections. For culturing microorganisms, selective and unselective enrichment methods were preferred. The microorganism can be recognized by its visual appearance on a standard agar. However, this technique is usually unreliable. As a result, serological tests, such as ELISA, agglutination, direct and indirect immunofluorescence, and Western blotting, were used to detect bacterial antigens and antibodies (IgG and IgM) as the indirect microbiological identification methods. Etiology, complaint at admission, use of antibiotics in the last month before surgery, presence of concomitant chronic disease, time elapsed between surgeries, and isolated factor were recorded for all patients. Some blood test results such, as C-reactive protein (CRP), sedimentation rate, and white blood cell (WBC) count were analyzed and compared preoperatively and postoperatively. Seventy-one (68.9%) patients were men, and 32 (31.1%) were women. The mean age of the patients was 38.57 ± 2.21(0.5–95) years. The surgical treatment of the patients was performed using craniotomy. In epidural and subdural empyemas, the infected parts of the

dura were cleaned after the empyema contents were evacuated. A rifampicin solution was used to clean the surgical area. In intraparenchymal abscesses, the contents of the abscess were evacuated with neuronavigation, microsurgery, or endoscopic method suitable to the location of abscess. Abscess capsule was excised completely or partially, and its integrity was broken. The surgical area was irrigated by washing with plenty of saline.

Following the surgical procedure, empiric antibiotic therapy containing a combination of ceftriaxone and metronidazole was initiated. Empirical treatment was continued until the infectious agent was isolated. Following identification of the causative microorganism, the appropriate antibiotic therapy—to which the microorganism was sensitive—was initiated. AB was continued for at least 3 weeks after surgery. In the postoperative period, the patient's clinical picture, WBC count, sedimentation rate, and CPR level were followed up. After surgery, patients underwent radiological follow-up using MRI. Treatment duration was guided by regression of infection as verified by MRI, clinical, and laboratory findings. If the clinical picture and laboratory findings did not reach the normal level, AB was extended up to 4–6 weeks. Hyperbaric oxygen (HBO) therapy was applied to patients who were unresponsive or resistant to AB.

The data of patients, including demographic features, infection types (abscess and empyema), locations, associated diseases, and surgical technique, are recorded and compared statistically. Statistical analysis was performed using IBM SPSS Version 25.0 (IBM Corp Armonk, NY).

RESULTS

The characteristics of 103 patients are summarized in Table I. Forty-six (44.7%) patients had intraparenchymal abscess, 25 (24.3%) had subdural empyema, and 32 (31.0%) had epidural empyema. In our series, 93 (90.3%) patients had a history of previous surgery (Figure 1A-C). In the etiology of 29 (28.2%) patients, there was a history of trauma that disrupted the skin integrity, such as cranial gunshot injury. Sixty-four (62.1%) patients had a history of surgery due to conditions, such as intracranial mass or intracranial hematoma, but their skin integrity was still intact, and skin cleansing and antisepsis–aseptic could be applied. Ten (9.7%) patients had no history of surgery. Emergent surgical evacuation was performed in 60 (58.25%) patients. Thirty-two of them had intraparenchymal abscess, 16 had subdural empyema, and 12 had epidural empyema. No microbiological agent was detected in 26 (25%) patients despite the use of convenient microbiological identification methods. *Streptococcus spp.* and *Staphylococcus spp.* were the most common causes of infection identified in our study (Table I). Systemic infection was found in five patients, whereas 98 patients had local infection. During the first surgery of the patients, 1 g of cefazolin was initiated for prophylaxis; 1 g of cefazolin was administered every 8 h for 48 h postoperatively. Twenty-three (23.3%) patients had a history of antibiotic use due to an extracranial infection in the last month before intracranial surgery. In patients with a history of previous surgery in the etiology, the interval between the last two surgeries was 7.3 ± 0.75 (0.2–33) months. A frontal lesion was detected in 29 (28.2%) patients. Results of microbiological identification methods are shown in Table I. AB was continued for 3 weeks in 76 (73.8%) patients in whom the radiological findings of infection were regressed, and clinical condition was improved. Despite the appropriate AB, radiological markers were persistent, and clinical condition was not improved in 27 patients. In these patients, the duration of AB was prolonged to 4–6 weeks. Five (4.8%) patients died from septic shock within the first postoperative month. They had systemic infections and positive blood cultures during the follow-up period. Three of them had intraparenchymal abscess, and two had subdural empyema. Six (5.8%) patients died in the first postoperative year due to malignancy. None of them had a systemic infection. Ceftriaxone, metronidazole, vancomycine, cefepime, aztreonam, and ciprofloxacin are the most commonly used antibiotics in our patients, and amphotericine-B and voriconazole were preferred as antifungal agents. HBO therapy was administered to five (4.9%) patients for 4–6 weeks due to resistance to AB. Four (8.7%) patients who were operated with the diagnosis of intraparenchymal abscess underwent recurrent surgeries due to abscess recurrence in the follow-up period. The mean follow-up period

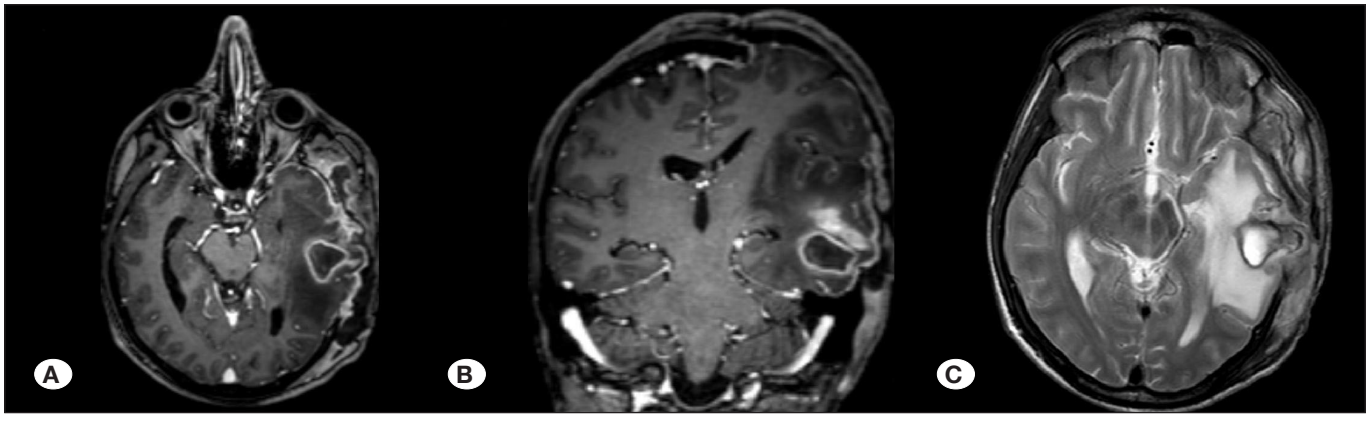

Figure 1: Axial T1W **(A)**, coronal T1W **(B)** contrast-enhanced, and axial T2W **(C)** magnetic resonance imaging scans of a patient who underwent previous surgery for intracranial tumor and developed intraparenchymal abscess and meningitis. The lesion and the dura were contrast enhancing and causes significant brain edema.

Table I: Clinical Characteristics of Patients with Intracranial Infections

	Number (%)
Gender	
Male	71 (68.9)
Female	32 (31.1)
Complaints at Admission	
Headache	37 (35.9)
Change of Consciousness	23 (22.3)
Neurological Deficit	18 (17.5)
Seizure	14 (%13.6)
Loss of Balance	11 (10.7)
Type of Infection	
Intraparenchymal Abscess	46 (44.7)
Subdural Empyema	25 (24.3)
Epidural Empyema	32 (31.0)
Location	
Frontal	29 (28.2)
Temporal	12 (11.7)
Parietal	17 (16.5)
Occipital	3 (2.9)
Frontotemporal	21 (20.5)
Frontoparietal	16 (15.5)
Cerebellum	5 (4.9)
Side	
Right	48 (46.6)
Left	46 (44.7)
Bilateral	9 (8.7)
Etiology	
Intracranial Lesion	64 (62.1)
Trauma	29 (28.2)
No Surgery	10 (9.7)
Use of Preoperative Antibiotics	
Yes	23 (22.3)
No	80 (77.7)
Comorbid Disease	
None	68 (66.0)
Diabetes	20 (19.3)
Organ Failure	5 (4.9)
Immunodeficiency	5 (4.9)
Cardiopulmonary Disease	5 (4.9)
Previous Surgery	
Yes	93 (90.3)
No	10 (9.7)
Microbiological Factor	
Not Isolated	26 (25)
Streptococcus Spp	24 (23.3)
Staphylococcus Spp	20 (19.4)
Klebsiella Spp	10 (9.7)
Acinetobacter Spp	9 (8.7)
Pseudomonas Aeruginosa	3 (2.9)
Serratia Marcescens	3 (2.9)
Proteus Spp	2 (1.9)
Prevotella Spp	5 (4.9)
Peptostreptococcus Spp	4 (3.9)
Micrococcus Luteus	3 (2.9)
Cutibacterium Acnes	4 (3.9)
Enterococcus Faecalis	3 (2.9)
Aspergillus Spp	3 (2.9)
Mucormycosis	1 (0.9)
Microbiological Agent's Group	
Gram Negative Bacilli	27 (26.2)
Gram Positive Cocci	47 (45.6)
Anaerobic Bacteria	16 (15.5)
Fungi	4 (3.9)

was 14.2 months (ranged from 1 to 42 months). Ninety-two (89.3%) patients improved clinically and radiologically 1 year after the surgery and AB. Septic shock was the most common cause of mortality in the early postoperative period, while malignant disease caused death in the later follow-up period.

The relationship between intracranial infection and location of intracranial infection was statistically significant ($p \leq 0.05$). Intraparenchymal abscesses are more commonly located in the frontal lobe and cerebellum, whereas subdural empyemas are frequently located in the frontoparietal region (Table II).

The relationship between intracranial infection and the patient's comorbid disease was statistically significant ($p \leq 0.05$). Intraparenchymal abscesses were detected more frequently in immunocompromised patients (Table III).

In addition, there was also a statistically significant relationship between the presence of previous surgery and intracranial infection ($p \leq 0.05$). Infection was more commonly detected in patients who underwent previous surgery for trauma or mass lesions, such as tumor. Previous history of surgery for mass lesions is an important risk factor for subdural empyema (Table IV).

There was no statistically significant difference between the intracranial infection and microbiological agent's group ($p > 0.05$) (Table V). There was no statistically significant

Table II: Relationship with Intracranial Infection and Its Location

Location	Epidural Empyema n(%)	Subdural Empyeman(%)	Intraparenchymal Abscessn (%)	Total
Frontal	6 (20.0)	4 (13.3)	20 (66.7)*	30
Temporal	5 (41.7)	2 (16.7)	5 (41.7)	12
Parietal	7 (41.2)	4 (23.5)	6 (35.3)	17
Frontotemporal	9 (42.9)	5 (23.8)	7 (33.3)	21
Frontoparietal	3 (18.8)	10 (62.5)*	3 (18.8)	16
Occipital	2 (66.7)	0	1 (33.3)	3
Cerebellum	0	0	5 (100.0)*	5
Total	32 (30.8)	25 (24.0)	47 (45.2)	104

*Data are expressed as number and ratio (%). Pearson Chi-Square test p=0.143 *p<0.05.*

Table III: Relationship with Intracranial Infection and Patient's Comorbid Disease

Comorbid Disease	Epidural Empyeman n(%)	Subdural Empyema n(%)	Intraparenchymal Abscess n(%)	Total
None	26 (38.2%)	12 (17.6%)	30 (44.1%)	68
Diabetes	5 (25.0%)	7 (35.0%)	8 (40.0%)	20
Organ Failure	1 (20.0%)	2 (40.0%)	2 (40.0%)	5
Immunodeficiency	0	0	5 (100.0%)*	5
Cardiopulmonary Disease	0	4 (80.0%)	1 (20.0%)	5
Total	32	25	46	103

*Data are expressed as number and ratio (%). PearsonChi-Square test. p=0.014 *p<0.05.*

Table IV: Relationship with Intracranial Infection and Previous History of Surgery

Previous surgery	Epidural Empyema n(%)	Subdural Empyema n(%)	Intraparenchymal Abscess n(%)	Total
Yes	31	24	38	93
For trauma	11	2	16	29 (28.2)
For tumor or hematoma	20	22	22	64 (62.1)
No	1	1	8	10
Total	32	25	46	103

*Data are expressed as number and ratio (%). Pearson Chi-Square test. p=0.011 *p<0.05.*

Table V: Relationship with Intracranial İnfection and Microorganisms

Microorganism	Epidural Empyeman (%)	Subdural Empyema n(%)	Intraparenchymal Abscessn (%)
Not Isolated	9 (24.3)	7 (24.1)	10 (18.5)
Gram Negative	11 (29.7)	7 (24.1)	9 (16.7)
Gram Positive	12 (32.4)	11 (37.9)	24 (44.4)
Anaerobic bacteria	5 (13.5)	4 (13.8)	7 (13.0)
Fungus	0	0	4 (17.4)
Total	37	29	54

Data are expressed as number and ratio (%). Pearson Chi-Square test. p=0.445.

Table VI: Comparison of Mean CRP, WBC Count and Sedimentation Rate Based on Pre- and Postoperative Test Results

	Epidural Empyema (n=32)		Subdural Empyema (n=25)		Intraparenchymal Abscess (n=46)		p
	Preop.	Postop.	Preop.	Postop.	Preop.	Postop.	
Mean CRP (mg/L)	22	12	33	15	16	9	0.063
Mean Sedimentation rate (mm/h)	53	24	88	26	45	22	0.075
Mean WBC count (cell/ml)	12100	10500	13180	9800	11300	10320	0.065

Postop.= *One month after surgery. p≥0.05 for each parameter.*

Table VII: Comparison of Infection Types Based on the Treatment Duration

	Epidural Empyema (n=32)			Subdural Empyema (n=25)			Intraparenchymal Abscess (n=46)			Total
	Surgery +3 weeks AB	Surgery +4-6 weeks AB	Surgery +4-6 weeks AB+HBO	Surgery +3 weeks AB	Surgery +4-6 weeks AB	Surgery +4-6 weeks AB+HBO	Surgery +3 weeks AB	Surgery +4-6 weeks AB	Surgery +4-6 weeks AB+HBO	
Improved	27	4	1	16	2	2	33	7	0	92
Death	0	0	0	2	3	0	3	1	2	11
Total	27	4	1	18	5	2	36	8	2	103

AB: *Antibiotherapy,* ***HBO:*** *Hyperbaric oxygene therapy.*

difference between intracranial infection and microbiological agents (p>0.05).

Serum CRP level, sedimentation rate, and WBC count decreased in postoperative period in all infection groups (Table VI), but the changes were not statistically significant (p>0.05).

Mortality was observed in patients with intraparenchymal abscess and subdural empyema. With the appropriate treatment methods, all patients with epidural empyema were improved (Table VII).

There was no statistically significant difference between intracranial infection and age, gender, history of surgery, and use of antibiotic in the last month preoperatively (p>0.05).

DISCUSSION

Surgical treatment and AB are the most effective methods for the treatment of intracranial infections. In surgical treatment, craniotomy is essential for abscesses and empyemas near the cortical surface (14,20,28). The evaluation of a wider area in intracranial infections is made possible by craniotomy (14,40,47). Emergent surgical evacuation is reserved for patients with intracranial hypertension. In deep-seated abscesses, endoscopic approaches and stereotactic techniques provide significant benefits. The use of ports, particularly in the endoscopic approach, reduces both tissue damage by retraction of cortical tissue and the spread of infected material to surrounding tissues (40). The disadvantage of stereotactic techniques is that while the abscess contents can be evacuated, the abscess's capsule formation cannot be disrupted (41). In our series, we performed craniotomy in all surgeries, including smaller sizes in endoscopic techniques in surgical treatment. For abscesses close to the cortical surface, we preferred microsurgery, whereas for deeply located abscesses, we preferred endoscopic methods with port. The aim of our surgical treatment was to remove completely the contents and capsule of the abscess. However, partial excision of the capsule could be performed in most cases because of the relationship of the capsule with the surrounding brain parenchyma and vascular structures. In addition, it is not easy to remove a capsule in emergent cases because there is not much time to save a patient's life. In intracranial empyema, drainage of the empyema material and AB is required (31). It is difficult to distinguish epidural and subdural empyemas from epidural and subdural hematomas in non-contrast CT and MRI examinations. As a result, series with contrast agent administration should be included (31). It is also thought to cause cerebral inflammation, vasculitis, septic venous thrombosis, edema, and venous infarction (1). Emergency surgical evacuation was performed on 60 patients with abscess, epidural, and subdural empyema in our study. All of them had significant brain edema, midline shift in MRI and worsening neurological condition at admission. Two (3.3%) of 60 patients died within the first postoperative month, while others are still alive after AB.

The distribution of causative microorganisms of intracranial infections did not substantially change over the years (1). Although the organisms would differ based on the site of

origin, *Streptococci* were isolated from abscesses of all types and at all sites, and they are frequently isolated in mixed infections (10,12,25,42,51). In a recent review including 123 studies and 9,699 patients, reported between 1935 and 2012, the most common causative microorganisms were *Streptococci* and *Staphylococci*, in which 23% of cases were polymicrobial (8). *Haemophilus aphrophilus* and *Entamoeba histolytica* may also be detected in brain abscesses (3,4,46). *Streptococci* and *Staphylococci* were the leading causative microorganisms in our study, concordant with the literature. Blood cultures were positive, but pus cultures of 9.3% cases yielded no bacteria. Both pus and blood culture were negative in only 25% cases by the improved microbiological culture techniques. In one patient, urine and pus cultures yielded the same bacteria (*E.coli*). Therefore, it is extremely important to perform microbiological studies on both pus and other presumed infected sources. Consistently with the previous reports, polymicrobial infections were common in our study. This shows the importance of aerobic and anaerobic cultures in the diagnosis of infection. *Streptococci* are frequently isolated in mixed infections (30%–60% of cases) (8,12,15,18).

The most crucial step in the treating intracranial infections, as with all infectious diseases, is AB (4). Although it varies depending on the agent, it takes time for the infectious agent to be isolated and grown in the culture medium (7-9). In this process, empirical AB appropriate for the etiology should be initiated (37). There are no randomized controlled clinical studies on the assessment of the activity of different antibiotics in the bacterial brain abscess management. Combined metronidazole and third-generation cephalosporin regimen is commonly preferred in recent series (25,52). If an *S.aureus*-related brain abscess is suspected, vancomycin should be initiated. If meticilline-resistant *S. aureus* is suspected, cefotaxime and metronidazole with the addition of vancomycin may be preferred (5,31). If the *Pseudomonas spp* is the possible agent for abscess or infection, the first choice should be ceftazidime or cefepime. When the causative agent is not identified yet, empirical treatment, including metronidazole, vancomycin, and a third-generation or fourth-generation cephalosporin, is recommended until the culture result is obtained (25,51). We waited 3–7 days for the culture results of our patients. We used the combination of ceftriaxone and metronidazole as empirical treatment in AB during this process. When the culture was concluded, we arranged AB according to the sensitivity of the microorganisms.

Treatment of fungal brain abscess is associated with a high risk of mortality despite the surgical interventions (abscess drainage or excision) and antifungal agents (2,25). Previously until recently, amphotericin-B and voriconazole have been preferred antifungal agents for brain abscess secondary to aspergillosis. Amphotericin-B should also be used for the treatment of mucormycosis-related brain abscesses (12). Besides amphotericin, it should also be applied topically in the cranial cavities or intrathecally (25,34,35,51). Orbital manifestations of intracranial infections are not rare, and they are usually secondary to orbital traumas or retained orbital foreign bodies secondary to penetrating injuries (6,27,30). Ptosis and mydriasis are frequently observed in these patients due to the ciliary ganglion involvement (30). In our series, bone marrow transplantation was performed in three of our patients due to leukemia. Aspergillus was isolated in the intracranial abscess of these patients who were immunosuppressed due to the chemotherapy. Amphotericin-B was applied to the abscess cavity of the patients during surgery. Intravenous and intrathecal amphotericin-B was administered to two of these patients. These patients died of malignancy-related causes in the third postoperative month. Intravenous voriconazole and intrathecal amphotericin-B were administered to the other patient. He died in the first month due to septic shock.

As intracranial infections are space-occupying lesions, complications, such as edema and hydrocephalus, may develop in the surrounding brain parenchyma (7). Corticosteroids have an important role in reducing parenchymal edema, but they may increase the severity of the infection or reduce the effectiveness of antibiotic therapy (32). Therefore, it should not be used if the corticosteroid administration is completed in a short time, and there is no increase in intracranial pressure (16). In the presence of acute hydrocephalus, external ventricular drainage is an effective treatment method (26).

Surgical aspiration or the resection of entire abscess wall combined with a 6-week or longer IV antimicrobial therapy results in higher cure rates (5). The patients, in our study, received 6 weeks of AB. The clinical status of the patients was evaluated by laboratory and radiological imaging. AB was continued when the signs of infection were detected.

Neuroradiological imaging techniques should be used in the follow-up of patients until the abscess has entirely disappeared in the MRI scans. Surgical excision should be performed when the abscess continues to enlarge after 2 weeks of AB or not to resolve after 4-week period. When the abscess is totally removed during the surgery, shorter courses of AB may be performed with close radiological follow-up (25).

In some cases, intravenous administration of antibiotics cannot improve the clinical course of the infection (2). The main reason for this is the negative effect of the blood-brain barrier on antibiotics. This situation can be overcome with intrathecal AB. However, the focus of infection must be connected to the circulation of the cerebrospinal fluid for intrathecal AB to be effective (43). Antibiotic or silver impregnated catheter may be used for intrathecal AB (48). These materials prevent the colonization of microorganisms on the surface of the catheter. Intraventricular irrigation and antibiotics should be used in abscess with ventricular rupture (29). Intrathecal AB was applied in 10 patients included in our study. Intrathecal AB was administered as an adjunct to intravenous antibiotic therapy, and intravenous AB was not interrupted. In addition, HBO therapy was applied in five different patients because the clinical course did not improve despite AB.

Surgical interventions for intracranial infections are not free of risks (19,20). The common complications of surgical evacuations of intracranial infections are hemorrhage, cerebrospinal fluid fistula, subdural effusion, recurrence of infection, seizure, and brain edema (19,20,28,53). Meticulous surgical drainage of infections associated with microsurgical techniques and

modern surgical equipment provide excellent clinical outcomes. In addition, neurosurgeons should be aware of these complications and perform close follow-ups with radiological studies. Intracranial tumors, such as glioblastoma, may develop after the treatment of brain abscess, and these lesions should be carefully followed up with serial MRI scans after surgery and AB (39).

In our study, the presence of intracranial infections is associated with location and accompanying diseases, which is in accordance with the literature. Patients with immunodeficiency were treated with the diagnosis of leukemia, and the abscess developed after the bone marrow transplantation. Emergent surgical evacuation was mostly performed in large brain abscesses with significant mass effect. Subdural and epidural empyemas also underwent emergent drainage, especially in case of midline shift and brain edema. Otherwise, they were operated under elective conditions.

This study has some limitations. We could not reach the full clinical and radiological outcomes of some patients because they were operated at different centers. Because of the retrospective nature of our study, documentation of patients' long-term follow-up outcomes is limited.

CONCLUSION

Patients with comorbid diseases or a history of surgery are more prone to intracranial infections. The frontal lobe and cerebellum are the frequent locations for intracranial abscesses. The main indications for emergent surgical evacuation of intracranial infections include increased intracranial pressure and the presence of significant edema. Craniotomy and capsule resection in association with abscess drainage are the gold standard techniques for better clinical outcome. Mortality is more frequent in patients with intraparenchymal abscess and subdural empyema. For the detection of recurrences, close follow-up with radiological studies is crucial.

AUTHORSHIP CONTRIBUTION

Study conception and design: GYT

Data collection: SK, MCE

Analysis and interpretation of results: SK, GYT

Draft manuscript preparation: GYT, MOD

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