Brain Abscess

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Opinion statement

Optimal treatment of a brain abscess requires early clinical suspicion, and the diagnosis is usually made by identification of the abscess on contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI). The immediate first step is to reduce the potentially life-threatening brain mass (abscess and surrounding cerebral edema) and secure the diagnosis with culture specimens. This is usually accomplished by reducing the increased intracranial pressure (ICP) through surgical aspiration with or without drainage of the abscess pus. The surgical procedure chosen depends on several factors, including the location and type of abscess, multiplicity, and the medical condition of the patient. In addition, dexamethasone and hyperventilation may be required if brain herniation is imminent. The dexamethasone dose should be reduced as soon as the ICP is reduced because steroid administration may retard abscess capsule formation and decrease antibiotic concentrations within the abscess cavity. Antibiotic therapy should be started as soon as the diagnosis is made. Penicillin G or third-generation cephalosporins plus metronidazole are commonly given to treat both anaerobic and aerobic bacteria. The initial choice of antibiotic will vary on the basis of the suspected source of the brain organisms, which is most often either contiguous spread from a sinus or mastoid infection or hematogenous spread from a pulmonary, gastrointestinal, cardiac, or dental infection. Isolation and determination of the antibiotic sensitivities of the organism from abscess pus allow definitive antibiotic therapy. Patients should be managed in an intensive care unit. Phenytoin is often given to prevent seizures, which could further elevate the ICP. The duration of antimicrobial treatment is 4 to 8 weeks, during which time the patient should be monitored clinically and with repeated neuroimaging studies to ensure abscess resolution.

Introduction

Brain abscesses date back to antiquity; Hippocrates, in 460 BC, described a probable case following mastoiditis. Currently, in the United States, brain abscesses are uncommon, with an incidence of about 1 case per 100,000 persons per year [1, Class III]. Cases occur in people of both sexes and all ages [2•,3–5,6••, all Class III]. Although we now have much better methods with which to diagnose and treat cerebral infections, brain abscesses can still be difficult to diagnose, can be a challenge to treat, and currently kill in 10% to 20% of cases [7, Class III]. Of the survivors, 20% to 60% are left with neurologic sequelae, including epilepsy and focal neurologic deficits [7,8, both Class III].

Understanding the pathophysiology of a brain abscess is useful in determining the best methods with which to diagnose the condition and manage the patient. The brain has no normal flora of bacteria or fungi. Microorganisms that cause abscesses reach the brain primarily through the blood stream or directly from adjacent sinuses or mastoid air cells that have become infected [2•,6••, both Class III]. Less common routes of entry include depressed skull fractures or surgical procedures involving the sinuses, calvarium, or brain. Common sources of blood stream infection include intravenous drug abuse and infections of the lungs (bronchiectasis, empyema, and lung abscess), the gastrointestinal tract, the urinary system, the mouth (dental abscess), and the heart (acute bacterial endocarditis and cyanotic congenital heart disease [9, Class III]). In about 15% of patients, no initial source for the brain abscess can be identified.

The location of the abscess depends on the source. Abscesses from sinusitis occur in the frontal lobe, adja-

Table 1. Predisposing conditions, common pathogens, and empirical antibiotics

Predisposing condition	Common pathogens	Empirical antibiotics
Sinusitis or mastoiditis	Streptococci, *Bacteroides fragilis, Haemophilus* species, *Staphylococcus aureus*	Ceftriaxone, cefotaxime, or penicillin G and metronidazole
Dental infections	Streptococci, *B. fragilis*	Penicillin G and metronidazole
Chronic ear infection	Pseudomonas, protei, *Klebsiella species, B. fragilis,* streptococci, staphylococci	Cefotaxime or ceftriaxone and metronidazole. If pseudomonads are suspected, use ceftazidime
Pulmonary infections	Mixed flora, fusobacteria, *B. fragilis,* streptococci, *Nocardia* species, actinomycetes	Cefotaxime, ceftriaxone, or penicillin G plus metronidazole. If *Nocardia* species is suspected, use sulfadiazine and pyrimethamine
Head trauma or postcranial surgery	Staphylococci, pseudomonads, *Enterobacter* species, streptococci	Ceftriaxone or cefotaxime plus metronidazole and nafcillin or vancomycin
Endocarditis or parenteral drug use	Mixed flora, streptococci, *S. aureus*	Ceftriaxone or cefotaxime plus metronidazole and nafcillin or vancomycin
Cyanotic congenital heart disease	Streptococci, *Haemophilus* species	Penicillin G, cefotaxime, or ceftriaxone plus metronidazole
Gastrointestinal or abdominal infection	Mixed flora, gram-negative bacteria, pseudomonads	Ceftriaxone or cefotaxime plus metronidazole. If pseudomonads are suspected, use ceftazidime
Immunodeficiency	Above depending on site, plus *Nocardia* species, *Toxoplasma gondii,* aspergilli, *Candida* species	Amphotericin B, fluconazole, sulfadiazine, or pyrimethamine plus above regimens

cent to the infected sinus [2•, Class III]. Abscesses from mastoiditis develop in the temporal lobe (from upward extension) or, occasionally, in the cerebellum (from medial extension). The locations of abscesses from a hematogenous route are generally distributed proportionally to cerebral blood flow. Whatever the cause, brain abscesses are located in the frontal lobe in 33% of cases, the temporal lobe in 33%, the parietal lobe in 20%, the cerebellum in 10%, the occipital lobe in 2%, and the brain stem or basal ganglia in 2% [3,8,10, all Class III]. About three quarters of brain abscesses are solitary. Multiplicity of abscesses at different locations usually implies a hematogenous origin.

The majority of patients have bacterial infection, but 10% of cases are due to fungi or protozoa [2•,3,10, all Class III]. Sixty percent of the bacteria are anaerobic or microaerobic. Table 1 lists the most common organisms based on the predisposing condition. Most abscesses contain a single organism, but 15% to 20% are polymicrobial. If the patient is immunocompromised, brain abscesses are more likely to contain fungi, protozoa (toxoplasmosis or amoeba), or unusual bacteria. In Latin America, the most common cause of a brain abscess is *Taenia solium,* but this parasite is atypical because it tightly controls its eventual size, limits the extent of surrounding cerebral edema, and causes few symptoms until the cyst dies [11, Class III].

The brain abscess begins as a small, localized area of cerebritis, often at the gray-white matter junction of the cerebral cortex [12,13••, both Class III]. Growth of the organism soon results in expansion of the cerebritis, and increasing numbers of neutrophils and mononuclear cells enter the infected site. Necrosis with liquefaction of the center of the abscess then occurs. A fibrotic and gliotic response surrounds the abscess, forming a capsule. Surrounding the abscess is a varying amount of cerebral edema, which contributes to the mass of the abscess [3,12, both Class III]. The capsule wall is inadequate to control medial expansion of the abscess. If untreated, the abscess continues to expand until the mass is large enough to cause transtentorial herniation (cerebral hemisphere abscess), foramen magnum herniation (cerebellar abscess), or rupture of the abscess contents into the ventricles.

The signs and symptoms of a brain abscess are those of a rapidly expanding brain mass that usually occurs over 1 to 2 weeks. Common symptoms at presentation are those related to increased ICP and focal neurologic signs. Signs of increased ICP include headache (75%), lethargy and confusion (50%), nausea and vomiting (50%), and cranial nerve palsies (30%). Less common signs include papilledema (10% to 25%) and stiff neck (25%) [3,10,14•, all Class III]. Focal neurologic signs (40%) depend on the abscess location. Focal or generalized seizures occur in 33% of cases [10, Class III]. Systemic signs are uncommon. Fever is present in fewer than half of cases, and the body temperature is usually less than 39°C. The leukocyte count is elevated in 60%

of cases, but the total count is elevated above 20,000 cells/mm^3 in only 10% of cases. The majority of patients have an elevated erythrocyte sedimentation rate and an elevated serum C-reactive protein level [13••, Class III].

A brain abscess should be suspected in someone who presents with a subacute course of these signs and symptoms. Predisposing infections in the mouth or in the respiratory, gastrointestinal, or urinary systems should heighten suspicion. The clinical diagnosis is usually made by neuroimaging with cranial CT [12, Class III] with and without contrast or MRI with and without gadolinium [14•, Class III]. The neuroimaging differential diagnosis includes necrotic or cystic primary and metastatic brain neoplasms, granulomas, subdural empyema, and atypical cerebral infarctions and hematomas. CT has the advantages of being widely available, requiring less patient cooperation, and visualizing the sinuses and mastoids well, and it is required for CT-guided stereotactic aspiration of the abscess. MRI is slightly more sensitive in establishing the diagnosis and is especially useful for identifying early cerebritis, multiple abscesses, abscesses located adjacent to bone, and tumors from abscesses. Stereotactic aspiration of brain abscesses can also be done with MRI guidance. Brain abscesses tend to have a thinner, more uniform thickness and a more homogeneous appearance to their contrast-enhancing rims than do most, but not all, brain neoplasms. A thorough examination should be made for the site of primary infection and should include examination of the mouth, lungs, heart, and abdomen plus chest radiography and urine culture.

Treatment

- Optimal management of the patient involves six steps: 1) Prompt reduction of the size of the life-threatening mass (abscess and surrounding cerebral edema); 2) collection of appropriate culture specimens; 3) definitive treatment of brain abscess with antibiotics and, usually, neurosurgical aspiration of the abscess cavity or expiration of the abscess and capsule; 4) elimination of any identifiable source of the brain abscess; 5) prevention of seizures; and 6) neurorehabilitation.

Pharmacologic treatment

- Intravenous antibiotic treatment should begin as soon as possible after the diagnosis is made.
- Initial antibiotic treatment should be against a wide variety of anaerobic and aerobic gram-positive and gram-negative bacteria (*see* Table 1).
- If the source of the abscess can be identified and the infected material can be Gram stained and cultured, the expected range of bacteria and the choice of antibiotics can be narrowed.
- Determination of sensitivities to antibiotics after the organism is isolated from abscess pus enables definitive therapy.
- The antibiotics chosen should penetrate the blood-brain barrier, should penetrate the abscess wall, should not be inactivated by brain abscess pus, and should (ideally) be bactericidal. Antibiotics reported to reach therapeutic concentrations inside brain abscesses include metronidazole, chloramphenicol, penicillin G, ampicillin, methicillin, nafcillin, vancomycin, trimethoprim-sulfamethoxazole, and cefotaxime [10,13••, both Class III]. The abscess penetration of many widely used antibiotics has not been studied.
- If the patient is immunocompromised or has existing chronic sinusitis or mastoiditis in which a fungal infection is suspected, the addition of antifungal drugs should be considered.
- Because of the infrequent occurrence of brain abscesses and the varying etiologic agents of these abscesses, no comparative antibiotic studies have been performed. Thus, the recommendations given below have come from the empirical experience of many neurologists, neurosurgeons, and infectious disease experts.

- Initial antibiotic therapy for a brain abscess in an adult depends on the degree of suspicion about the source of the abscess and whether the patient is immunocompromised (*see* Table 1). Standard dosages are listed in Table 2.

Table 2. Antibiotics commonly used for brain abscess

Antibiotic	Usual adult intravenous dosage
Penicillin G	20 to 24 million U/d in 4 divided doses
Nafcillin	12 g/d in 6 divided doses
Cefotaxime	6 to 9 g/d in 3 divided doses
Ceftriaxone	4 g/d in 2 divided doses
Ceftazidime	6 g/d in 3 divided doses
Chloramphenicol	3 to 4 g/d in 4 divided doses
Metronidazole	2 g/d in 4 divided doses
Vancomycin	2 to 3 g/d in 2 divided doses
Fluconazole	400 to 600 mg/d in 2 divided doses
Sulfadiazine and pyrimethamine	4 g/d in 4 divided doses 75 mg/d in 3 divided doses

- The most common initial therapy is cefotaxime, ceftriaxone, or penicillin G plus metronidazole or chloramphenicol.
- The choice of a third-generation cephalosporin or penicillin G depends on the suspected location of the source of the abscess. Ceftriaxone or cefotaxime is usually given, particularly if gram-negative Enterobacteriaceae are suspected. Penicillin is often given if the source is likely to be dental. Both metronidazole and chloramphenicol penetrate the abscess cavity well, and their concentrations are not reduced by concomitant administration of steroids. Metronidazole is bactericidal, however, whereas chloramphenicol is bacteriostatic.
- Nafcillin should replace penicillin if *Staphylococcus* is suspected, especially in the setting of head trauma or after cranial surgery. Vancomycin should be used if the *Staphylococcus* is suspected to be methicillin-resistant.
- If *Enterobacter* species are isolated, piperacillin or ciprofloxacin should be considered.
- Anaerobic bacteria may be difficult to isolate from abscess pus. If anaerobic bacteria are not isolated, therapy with metronidazole or chloramphenicol should be discontinued only after careful consideration, particularly if mixed flora are seen on Gram staining.
- The treatments just discussed are likely to change as new antibiotics come on the market and more resistance to commonly used antibiotics emerges. The *Medical Letter*, which frequently issues new antibiotic recommendations, should be consulted.
- The duration of antibiotic therapy is usually 4 to 8 weeks [3,10,13••, all Class III].

Cefotaxime and ceftriaxone

Both cefotaxime and ceftriaxone are third-generation cephalosporin antibiotics [15,16, both Class III]. Both are bactericidal against a broad range of gram-positive and gram-negative bacteria that cause brain abscesses. Neither is effective against methicillin-resistant *S. aureus* or enterococci. Cefotaxime has been shown to penetrate effectively into brain abscesses [17, Class III]. Cefotaxime has a half-life of 0.8 to 1.4 hours, while ceftriaxone has a longer half-life of 6 to 9 hours. About 35% to 50% of cefotaxime and 83% to 93% of ceftriaxone is bound to proteins. Cefotaxime is metabolized by the liver to active metabolites. Both cefo-

taxime and its metabolites are excreted by the kidney. Renal disease may alter the kinetics of cefotaxime, requiring dosage adjustment. Ceftriaxone is minimally metabolized and is eliminated by biliary and renal excretion. Hepatic and renal disease alter the kinetics of ceftriaxone only minimally, and dosage adjustments are seldom needed unless the patient has both hepatic and renal insufficiency. Cefotaxime and metronidazole together have been shown to be very effective in the treatment of brain abscesses [18, Class III].

Standard dosage For severe infections in adults (*eg*, brain abscess), cefotaxime is usually given intravenously as 6 to 9 g/d divided into three doses, but it has also been given at 9 to 12 g/d divided into three to four doses [17–19, all Class III]. Ceftriaxone is given intravenously to adults as 4 g/d divided into two doses. The pediatric dosage for cefotaxime is 100 mg/kg/day; for ceftriaxone, it is is 100 mg/kg/day. The duration of drug administration is usually 4 to 8 weeks.

Contraindictions Allergy to cephalosporins. Caution should be used when the patient has a known allergy to penicillin.

Main drug interactions Coadministration of aminoglycoside antibiotics and cephalosporins could produce additive nephrotoxic effects, particularly in a patient with pre-existing renal disease.

Main side effects Both drugs have mild and minimal side effects (5%). Cefotaxime can produce local reactions, including pain at the injection site and phlebitis, skin rash, diarrhea, nausea, vomiting, and, rarely, colitis. Ceftriaxone can produce diarrhea, leukopenia, headache, depression, injection site pain and phlebitis, and transient elevations of renal and hepatic function test results. In less than 1% of patients, the side effects are severe enough to change antibiotics.

Cost effectiveness Both drugs are moderately expensive and about equal in price (cefotaxime, $64/d; ceftriaxone, $141/d). Given the life-threatening nature of a brain abscess, however, administration of one or the other is usually required.

Metronidazole

Metronidazole is currently the best drug with which to treat most anaerobic bacteria that cause brain abscess [20, Class III]. It may be given intravenously or orally and has excellent absorption in the gut. Metronidazole has an 8-hour half-life; is metabolized by the liver and excreted by the kidneys; and has excellent tissue penetration into cerebrospinal fluid, the brain, and brain abscesses. It is bactericidal, rapidly killing most gram-negative anaerobic bacilli (*Bacteroides, Prevotella, Prophyromonas*, and *Fusobacterium* species) and many species of gram-positive anaerobic cocci (*Peptostreptococcus* species) [20, Class III]. Metronidazole does not kill most gram-positive aerobic cocci, such as microaerophilic streptococci.

Standard dosage The standard dosage is 2 g/d in four divided doses. A loading dose of 1 g may be given. For children, the dose is 7.5 mg/kg of body weight per day in four divided doses [20, Class III]. The drug is initially administered intravenously but may be given orally in the later stages of the course if the patient responds clinically and radiologically. The duration of therapy is usually 4 to 8 weeks.

Contraindications Allergy to the drug.

Main drug interactions When the drug is taken with ethanol, patients may get a disulfiram-like reaction with nausea, abdominal cramps, vomiting, headache, and psychosis [20, Class III]. Metronidazole does not interfere with the administration of other antibiotics.

Main side effects The drug is generally well tolerated. Rare serious reactions include seizures, encephalopathy, and ataxia [20, Class III]. Gastrointestinal adverse effects may include nausea, anorexia, vomiting, glossitis, and a metallic taste in the mouth. Reversible leukopenia, thrombocytopenia, rash, and pruritus may occur.

Special points Because the drug is metabolized by the liver, patients with severe liver disease are usually given 50% of the dosage listed above [20, Class III]. Patients with marked renal failure may also require a dosage reduction.

Cost effectiveness A generic drug formulation, which is reasonable in cost, is available at $131/d.

Corticosteroids: dexamethasone

The use of corticosteroids is somewhat controversial but is often necessary if the abscess is producing a severe elevation of ICP. Intravenous dexamethasone is effective in reducing the volume of surrounding cerebral edema but not the abscess volume. Dexamethasone usually produces a noticeable benefit within 8 hours of administration.

Standard dosage Intravenous dexamethasone (16 to 20 mg per day in four divided doses) is given to the patient with evidence of a markedly increased ICP before surgery, and the dose is tapered 1 to 2 days after surgery when the ICP is reduced. To date, no prospective studies have compared treatment with and without corticosteroids in patients with brain abscess.

Contraindications There are no absolute contraindications, but corticosteroids may retard the process of encapsulation of the abscess, allowing more rapid expansion of the abscess [21•, Class III]. In addition, some antibiotics may have decreased penetration in the brain and possibly in the abscess when corticosteroids are given. The resulting lower antibiotic concentration in the brain and abscess could theoretically lead to an antibiotic concentration that is inadequate to kill the bacteria. Corticosteroids are known to reduce the seizure threshold, which may increase the likelihood of seizures. Finally, patients with severe diabetes mellitus, known gastric or duodenal ulcers, or severe underlying infections are at higher risk for complications. Thus, dexamethasone should be reserved for patients with marked ICP who are semicomatose or have neuroimaging evidence of severe cerebral edema. The dexamethasone dose should be tapered as soon as possible.

Main drug interactions This drug may reduce concentrations of antibiotics in the brain abscess to levels that are insufficient to kill the organisms. Data on this theoretical possibility are minimal, however.

Cost effectiveness Generic formulations of dexamethasone are available and are relatively inexpensive ($2.00/d).

Surgery

- Surgical intervention for patients with brain abscess is done for two indications: to collect proper specimens for culture and sensitivity determinations and to reduce mass effect.
- In some cases, the pathogen causing the abscess can be determined from cultures of suspected source sites, but the finding of a potential source infection elsewhere in the body does not definitively identify the organism causing the abscess. An analogy to this situation is the use of sputum cultures to identify the responsible organism in cases of lung abscess. The potential for error in these settings is high.
- The early surgical collection of aspirated material from an abscess provides the highest likelihood of definitively diagnosing the pathogen and determining the antibiotic sensitivity of the organisms.

Stereotactic aspiration/craniotomy

Standard procedure The choice of surgical procedures depends on several factors (Table 3). For most patients with abscess, the current intervention of choice is stereotactic aspiration of the abscess or abscesses. This can be done with either framed or frameless instrumentation [22•, Class III]. Stereotactic surgery offers minimally invasive treatment for the lesion while providing pinpoint accuracy for the aspiration of selected sites and a low incidence of serious complications. The minimal invasiveness clearly makes this treatment the procedure of choice for patients with multiple abscesses.

Surgery should be timed to coincide with the earliest evidence of cavitation of the lesion. Abscesses remain in the early cerebritis stage for 1 to 3 days [12, Class III]. During this time, disruption of the blood-brain barrier is already considerable [23, Class III]. Although the edema that occurs during this stage is seldom life threatening, the potential for rapid development of life-threatening edema exists. For patients who present in the early cerebritis stage, the best therapy may be the search for a source infection and empirical broad-spectrum antibiotic treatment with meticulous follow-up imaging [24, Class III].

The late cerebritis stage of abscess formation (days 4 to 9) is identified by the beginning of ring enhancement on imaging studies [12, Class III]. This stage is characterized by the infusion of contrast material into the center of the ringed area. At this stage, the abscess usually shows early central softening, allowing aspiration of the lesion. Encapsulation of the abscess has not occurred; thus, excision of the abscess is not easily done. In patients who present at stages beyond the late cerebritis stage, encapsulation is well underway. Surgical excision of the entire lesion can be considered, provided that the abscess is located in noneloquent brain.

In the patient with multiple abscesses, surgical intervention should be aimed predominantly toward reducing the lesions that are causing the majority of symptoms. This usually means aspirating the largest lesion. In addition, the site of multiple abscesses must sometimes be considered, and surgical interventions aimed toward reducing mass by removing lesions in noneloquent brain may be preferred. When more than one of the abscesses is of considerable size, a combined medical-surgical approach has been shown to be effective in reducing morbidity and mortality [25, Class III]. This approach involves initially aspirating, with stereotactic guidance, lesions greater than 2.5 cm in diameter. If any abscess fails to resolve or expands, a reoperation is performed [25,26, both Class III].

Craniotomy for the treatment of brain abscess also remains a viable alternative in some circumstances. It allows a more definitive approach to relief of the mass effect because the abscess can be completely resected. The open operation also allows definitive treatment of potential sources of reinfection, such as the closing off of a communicating tract to a sinus. Open operation is often favored in the patient who has persistent disease with an expanding abscess despite previous aspiration and antibiotic therapy. Patients with recurrent abscesses should undergo craniotomy if they can withstand general anesthesia. Recurrence of brain abscess may indicate persistent communication with an infectious source or an organism resistant to the antibiotics being administered. In the critically ill patient, craniotomy may be dangerous, and a stereotactic aspiration done under local anesthesia is probably the procedure of choice.

Occasionally, cerebrospinal fluid diversion through an external ventricular drain is a concomitant part of the treatment and will reduce mortality and morbidity, especially in patients with cerebellar abscesses [27, Class III].

Contraindications Presence of a coagulopathy.

Complications Hemorrhage, wound infection, recurrent abscess formation, and seizures.

Special points Handling of abscess material involves the following: 1) Do not place abscess material into formalin fixative until microbiological cultures have been done. 2) Take abscess material to the microbiology laboratory promptly because anaerobic bacteria may die under prolonged aerobic conditions. 3) Tell the microbiology laboratory what antibiotics were received by the patient before surgery. 4) Stain abscess material with Gram, Giemsa, and fungal stains. 5) Culture abscess material for anaerobic and aerobic bacteria and fungi. 6) Culture abscess material for *Mycobacterium tuberculosis* or protozoa if the clinical history warrants. 7) If solid material is present, process the tissue for histologic examination to identify neoplasms, bacteria, fungi, and protozoa.

Table 3. Types of surgical procedures for brain abscess

Procedure	Indications
Stereotactic aspiration*	Obtain pus for culture Accurate location of small deep abscesses Patients too ill to tolerate craniotomy and general anesthesia Placement of drainage tube, if desired
Abscess and capsule excision	Solitary abscess recurrence in noneloquent cerebral cortex with mature capsule Possible cystic or necrotic neoplasm Abscess with possible sinus tract from adjacent sinusitis, mastoiditis, osteomyelitis, or skull fracture
No surgery, only antibiotics	Cerebritis without encapsulation Multiple small abscesses in patient in whom likely bacteria can be isolated from site of infection source Abscess deep in brain stem or basal ganglia Initial treatment for patient with AIDS and abscess, especially multiple abscesses

* If abscess is multiloculated or large, complete removal of pus may be difficult.

General medical management

- Most patients, particularly those with evidence of markedly increased ICP with obtundation, seizures, or major neurologic signs, should be placed in an intensive care unit for careful observation and management.
- If signs of brain herniation develop, the fastest way to reduce the ICP is with hyperventilation. The patient should receive endotracheal intubation, should be placed on a ventilator, and should be hyperventilated so that the arterial PCO_2 is between 25 and 30 torr [28, Class III]. If dexamethasone has not been given, it should be given intravenously in a bolus of 10 mg. Surgical drainage of the abscess should be done as soon as the patient is a surgical candidate. If the abscess has caused obstructive hydrocephalus, a ventricular drain should be placed to reduce the cerebrospinal fluid pressure.
- Seizures occur in up to 50% of patients. If the patient has markedly increased ICP, a seizure may cause a further dramatic increase in ICP, possibly triggering a brain herniation. Thus, phenytoin or fosphenytoin (1 g of phenytoin equivalent given over 20 to 60 minutes) is often given intravenously on admission or after the abscess is diagnosed.
- A diligent search for the source of the brain abscess should be undertaken. Once identified, the source should be appropriately treated with surgical drainage, antibiotics, or dental care.
- It is important to monitor the patient carefully both clinically and with repeated neuroimaging studies during treatment. It is recognized that the abscess may continue to expand despite surgical aspiration or drainage and appropriate antibiotic therapy. The reasons for this are unclear, but it is possible that a second bacterium or fungus is present or that the antibiotics may not penetrate the abscess cavity sufficiently to reach killing concentrations. In addition, pus is acidic and may impair the killing ability of some antibiotics [13••, Class III]. Generally, CT or MRI should be repeated three

times during the first week after initiation of therapy and then once or twice a week depending on the patient's clinical condition. Careful follow-up neuroimaging is essential if the brain abscess is not drained and the causes and antibiotic sensitivities of the organisms remain unknown. If the abscess continues to expand, surgical drainage of the abscess contents, expiration of the entire abscess (including capsule), and the addition of a wider spectrum of antibiotics may be necessary.

- Rehabilitation of the patient after the abscess is cured is important to minimize neurologic sequelae. Seizures as sequelae of brain abscess are common (30% to 60%). They may be focal or generalized and may be difficult to suppress with anticonvulsant agents.

Emerging therapies/diagnostic strategies

- On some occasions, a firm preoperative diagnosis of brain abscess is difficult to make. Two situations in which diagnosis is difficult are known systemic cancer, particularly a lung tumor, and a very necrotic primary glioma. Neuroimaging may not always distinguish between the two conditions [29, Class III]. In these circumstances, using diffusion-weighted echo planar imaging, it has been reported that compared with necrotic or cystic tumors, brain abscesses have high signal intensity in the abscess center with an associated low apparent diffusion coefficient [30, Class III]. Brain spectroscopy of the mass may allow distinction of the abscess from a tumor [29,31, both Class III].
- Trovafloxacin is an antibiotic newly approved by the U.S. Food and Drug Administration that has a broad spectrum of activity against many bacteria that cause brain abscesses. Currently, the drug's usefulness in the treatment of brain infections has not been determined.

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:
- • Of special interest
- •• Of outstanding interest

1. Nicolosi A, Hauser WA, Musicco M, Kurland LT: **Incidence and prognosis of brain abscess in a defined population: Olmsted County, Minnesota, 1935-1981.** *Neuroepidemiology* 1991, **10(3):**122–131.
2. • Yen PT, Chan ST, Huang TS: **Brain abscess: with special reference to otolaryngologic sources of infection.** *Otolaryngol Head Neck Surg* 1995, **113:**15–22.

This is a careful review of brain abscesses of sinus, ear, mastoid, and dental origin.

3. Wong TT, Lee LS, Wang HS, *et al.*: **Brain abscesses in children—a cooperative study of 83 cases.** *Child Nerv Syst* 1989, **5:**19–24.
4. Renier D, Hirsch E, Hirsch JF: **Brain abscesses in neonates. A study of 30 cases.** *J Neurosurg* 1988, **69:**877–882.
5. Schliamser SE, Backman K, Norrby SR: **Intracranial abscesses in adults: an analysis of 54 consecutive cases.** *Scand J Infect Dis* 1988, **20:**1–9.
6. •• Mathisen GE, Johnson JP: **Brain abscess.** *Clin Infect Dis* 1997, **25:**763–781.

Current review of clinical, neuroimaging, and therapeutic aspects of brain abscesses.

7. Seydoux CH, Francioli P: **Bacterial brain abscesses: factors influencing mortality and sequelae.** *Clin Infect Dis* 1992, **15:**394–401.
8. Nielsen H, Harmsen A, Gyldensted C: **Cerebral abscess: a long-term follow-up.** *Acta Neurol Scand* 1983, **67:**330–337.
9. Kagawa M, Takeshita M, Yato S, Kitamura K: **Brain abscess in congenital cyanotic heart disease.** *J Neurosurg* 1983, **58:**913–917.
10. Chun CH, Johnson JD, Hofstetter M, Raff MJ: **Brain abscess: a study of 45 consecutive cases.** *Medicine* 1986, **65:**415–431.
11. Davis LE, Kornfeld M: **Neurocysticercosis: neurologic, pathogenic, diagnostic and therapeutic aspects.** *Eur Neurol* 1991, **31:**229–240.
12. Britt RH, Enzmann DR: **Clinical stages of human brain abscesses on serial CT scans after contrast infusion.** *J Neurosurg* 1983, **59:**972–989.

13.•• Wispelwey B, Scheld WM: **Brain abscess.** In *Principles and Practice of Infectious Diseases, edn 4*. Edited by Mandell GL, Bennett JE, Dolin R. New York: Churchill Livingstone; 1995:887–897.

An excellent current review of the pathogenesis, etiologic agents, and clinical manifestations of a brain abscess.

14.• Yang SY, Zhao CS: **Review of 140 patients with brain abscess.** *Surg Neurol* 1993, **39:**290–296.

Current review of cases occurring in the People's Republic of China.

15. Brogden RN, Spencer CM: **Cefotaxime: a reappraisal of its antibacterial activity and pharmacokinetic properties, and a review of its therapeutic efficacy when administered twice daily for the treatment of mild to moderate infections.** *Drugs* 1997, **53:**483–510.

16. Brogden RN, Ward A: **Ceftriaxone: a reappraisal of its antibacterial activity and pharmacokinetic properties, and an update on its therapeutic use with particular reference to once-daily administration.** *Drugs* 1988, **35:**604–645.

17. Sjolin J, Erikksson N, Arneborn P, *et al.*: **Penetration of cefotaxime and desacetylcefotaxime into brain abscesses in humans.** *Antimicrob Agents Chemother* 1991, **35:**2606–2610.

18. Sjolin J, Lija A, Eriksson N, *et al.*: **Treatment of brain abscess with cefotaxime and metronidazole: prospective study on 15 consecutive patients.** *Clin Infect Dis* 1993, **17:**857–863.

19. Todd PA, Brogden RN: **Cefotaxime: an update of its pharmacology and therapeutic use.** *Drugs* 1990, **40:**608–651.

20. Falagas ME, Gorbach SL: **Clindamycin and metronidazole.** *Med Clin North Am* 1995, **79:**845–867.

21.• Rosenblum ML, Mampalam TJ, Pons VG: **Controversies in management of brain abscesses.** *Clin Neurosurg* 1986, **33:**603–632.

A good review of the controversies regarding surgical therapy plus antibiotics compared with antibiotics alone. Also considers the pros and cons of corticosteroid use.

22.• Laborde G, Klimek L, Harders A, Gilsbach J: **Frameless stereotactic drainage of intracranial abscess.** *Surg Neurol* 1993, **40:**16–21.

A good review of CT-guided sterotaxy for brain abscess.

23. Lo WD, Wolny A, Boesel C: **Blood-brain barrier permeability in staphylococcal cerebritis and early abscess.** *J Neurosurg* 1994, **80:**897–905.

24. Weisberg LA: **Nonsurgical management of focal intracranial infection.** *Neurology* 1981, **31:**575–580.

25. Mamelak AN, Mampalam TJ, Obana WG, Rosenblum ML: **Improved management of multiple brain abscesses: a combined surgical and medical approach.** *Neurosurgery* 1995, **36:**76–86.

26. Chacko AG, Chandy MJ: **Diagnostic and staged stereotactic aspiration of multiple bihemispheric pyogenic brain abscesses.** *Surg Neurol* 1997, **48:**278–283.

27. Nadvi SS, Parboosing R, Rikus van Dellen J: **Cerebellar abscess: the significance of cerebrospinal fluid diversion.** *Neurosurgery* 1997, **41:**61–67.

28. Katz RW, Davis LE: **Reye's syndrome.** In *Neurocritical Care.* Edited by Hacke W, Hanley DR, Einhaupl K, *et al.* Berlin: Springer-Verlag; 1994:860–865.

29. Kim SH, Chang KH, Song IC, *et al.*: **Brain abscess and brain tumor: discrimination with in vivo H-1 MR spectroscopy.** *Radiology* 1997, **204:**239–245.

30. 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:**1113–1116.

31. 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.