INFLAMATORY DISEASES OF THE BRAIN

Inflammation of the brain (encephalitis) is usually secondary to viral infection. Other brain infections include brain abscesses, helminthic infections, prion diseases, and subdural empyema. Meningitis (inflammation of the brain and spinal cord—see Meningitis), cytomegalovirus infection, and HIV infection can also affect the brain. Slow virus infections, such as progressive multifocal leukoencephalopathy, are characterized by long incubations and a prolonged course. They may be caused by the JC virus, the measles virus, or the rubella virus.

Meningitis is inflammation of the meninges of the brain or spinal cord. It is often infectious and is one of the most common CNS infections. Sometimes inflammation involves both the meninges and brain parenchyma (meningoencephalitis). Meningitis may become evident over hours or days (acute) or a longer period (subacute or chronic).

The most common types of acute meningitis are acute bacterial meningitis and aseptic meningitis. Acute bacterial meningitis is a severe illness characterized by purulent CSF. It is rapidly progressive and, without treatment, fatal. Aseptic meningitis is milder and typically self-limited; it is usually caused by viruses but sometimes by bacteria, fungi, parasites, or noninfectious inflammation.

Symptoms and Signs

Many cases of infectious meningitis begin with a vague prodrome of viral symptoms. The classic meningitis triad of fever, headache, and nuchal rigidity develops over hours or days. Passive flexion of the neck is restricted and painful, but rotation and extension are typically not as painful. In severe cases, attempts at neck flexion may induce flexion of the hip or knee (Brudzinski's sign), and there may be resistance to passive extension of the knee while the hip is flexed (Kernig's sign). Neck stiffness and Brudzinski's and Kernig's signs are termed meningeal signs or meningismus; they occur because tension on nerve roots passing through inflamed meninges causes irritation.

Although brain parenchyma is not typically involved early in meningitis, lethargy, confusion, seizures, and focal deficits may develop, particularly in untreated bacterial meningitis.

Diagnosis and Treatment

Acute meningitis is a medical emergency that requires rapid diagnosis and treatment. After IV access and blood cultures are obtained, lumbar puncture is done to obtain CSF for Gram stain, culture, cell count and differential, and glucose and protein content. These tests must be done as rapidly as possible. However, patients with signs compatible with a mass lesion (eg, focal deficits, papilledema, deterioration in consciousness, seizures) require head CT before lumbar puncture because there is a small possibility that lumbar puncture can cause cerebral herniation if a brain abscess or other mass lesion is present.

CSF findings aid in the diagnosis of meningitis. Presence of bacteria on Gram stain or growth of bacteria in culture is diagnostic of bacterial meningitis. Gram stain is positive about 80% of the time in bacterial meningitis and usually differentiates among the common causative pathogens. CSF lymphocytosis and absence of pathogens suggest aseptic meningitis but may represent partially treated bacterial meningitis.

If patients appear ill and have findings of meningitis, antibiotics are started as soon as blood cultures are drawn. If patients do not appear very ill and the diagnosis is less certain, antibiotics can await CSF results.

Acute bacterial meningitis is fulminant, often fatal pyogenic infection beginning in the meninges. Symptoms include headache, fever, and stiff neck. Without rapid treatment, obtundation and coma follow. Diagnosis is by CSF tests. Treatment requires antibiotics, often beginning empirically with a 3rd- or 4th-generation cephalosporin, vancomycin, and ampicillin; corticosteroids are usually given. Residual morbidity is common.

Etiology

Many bacteria can cause meningitis, but most common are group B streptococci during the 1st 2 mo of life and, thereafter, *Neisseria meningitidis* (meningococci) and *Streptococcus pneumoniae* (pneumococci). Meningococci exist in the nasopharynx of about 5% of people and spread by respiratory droplets and close contact. Only a small fraction of carriers develop meningitis; what makes them susceptible is unknown. Meningococcal meningitis occurs most often in the 1st year of life. It also tends to occur in epidemics among closed populations (eg, in military barracks, college dormitories, boarding schools).

Pneumococci are the most common cause of meningitis in adults. Especially at risk are alcoholics and people with chronic otitis, sinusitis, mastoiditis, CSF leaks, recurrent meningitis, pneumococcal pneumonia, sickle cell disease, or asplenia. Incidence of pneumococcal meningitis is decreasing because of routine vaccination.

Gram-negative meningitis (most often due to *Escherichia coli, Klebsiella* sp, or *Enterobacter* sp) can occur in immunocompromised patients or after CNS surgery, CNS trauma, bacteremia (eg, due to GU manipulation), or hospital-acquired infections. *Pseudomonas* sp occasionally causes meningitis in immunocompromised or colonized patients. *Haemophilus influenzae* type b meningitis, now uncommon because of widespread vaccination, can occur in immunocompromised patients or after head trauma in unvaccinated people.

Staphylococcal meningitis can occur after penetrating head wounds or neurosurgical procedures (often as part of a mixed infection) or after bacteremia (eg, due to endocarditis). Listerial meningitis can occur at all ages and is particularly common among patients immunocompromised because of chronic renal failure, hepatic disorders, or corticosteroid or cytotoxic therapy after organ transplantation.

Bacteria typically reach the meninges by hematogenous spread from sites of colonization in the nasopharynx or other foci of infection (eg, pneumonia). Why some bacteria are more prone to colonize CSF is not clear, but binding pili and encapsulation appear to play a role. Receptors for pili and other bacterial surface components in the choroid plexus facilitate penetration into CSF.

Bacteria can also enter CSF by direct extension from nearby infections (eg, sinusitis, mastoiditis) or through exterior openings in normally closed CSF pathways (eg, due to meningomyelocele, spinal dermal sinus, penetrating injuries, neurosurgical procedures).

Pathophysiology

Bacterial surface components, complement, and inflammatory cytokines (eg, tumor necrosis factor, IL-1) draw neutrophils into the CSF space. The neutrophils release metabolites that damage cell membranes including those of the vascular endothelium. The result is vasculitis and thrombophlebitis, causing focal ischemia or infarction, and brain edema. Vasculitis also disrupts the blood-brain barrier, further increasing brain edema. The purulent exudate in the CSF blocks CSF reabsorption by the arachnoid villi, causing hydrocephalus. Brain edema and hydrocephalus increase intracranial pressure.

Systemic complications include hyponatremia due to the syndrome of inappropriate antidiuretic hormone (SIADH), disseminated intravascular coagulation (DIC), and septic shock. Occasionally, bilateral adrenal hemorrhagic infarction (Waterhouse-Friderichsen syndrome) results.

Symptoms and Signs

A respiratory illness or sore throat often precedes the more characteristic symptoms of fever, headache, stiff neck, and vomiting. Kernig's and Brudzinski's signs appear in about ½ of patients. Adults may become desperately ill within 24 h, and children even sooner. Seizures occur in about 30%. Cranial nerve abnormalities (eg, 3rd [oculomotor] or 7th [facial] cranial nerve palsy; occasionally, deafness) and other focal deficits occur in 10 to 20%. In patients > 2 yr, changes in consciousness progress through irritability, confusion, drowsiness, stupor, and coma. Opisthotonic posturing may occur.

Dehydration is common, and vascular collapse produces shock. Infection, particularly meningococcal, may be disseminated widely, to the joints, lungs, sinuses, and elsewhere. A petechial or purpuric rash commonly occurs in meningococcal meningitis. Examination of the head, ears, spine, and skin may reveal a source or route of infection. Spinal dimples, sinuses, nevi, or tufts of hair suggest a meningomyelocele.

In children < 2 yr, meningeal signs may be absent. In those < 2 mo, symptoms and signs are often nonspecific, particularly in early disease. Fever, hypothermia, poor feeding, lethargy, vomiting, and irritability are common presenting symptoms. Seizures, a high-pitched cry, and bulging or tight fontanelles are possible but often occur late. Subdural effusions may develop after several days; typical signs are seizures, persistent fever, and enlarging head size.

The elderly may have nonspecific symptoms (eg, confusion with or occasionally without fever). Meningeal signs may be absent or mild. Arthritis may restrict neck motion, often in multiple directions, and should not be mistaken for meningismus.

Partially treated meningitis

Patients seen early in the disease, before typical findings of meningitis appear, are sometimes diagnosed with otitis media or sinusitis and given oral antibiotics. Depending on the drug, the infection may be partially (but temporarily) suppressed. Patients may not appear as ill and have milder meningeal signs and slower disease progression. This situation can significantly hamper recognition of meningitis.

Diagnosis

Acute bacterial meningitis is suspected in children < 2 yr with lethargy, progressive irritability, a high-pitched cry, a bulging fontanelle, meningeal signs, or hypothermia. It is suspected in patients > 2 yr with meningeal signs or unexplained alterations in consciousness, particularly in those with fever or risk factors.

Because acute bacterial meningitis, especially meningococcal, can be lethal within hours, it must be diagnosed and treated rapidly. Prompt lumbar puncture is required but should not delay immediate treatment with antibiotics and corticosteroids.

CSF pressure may be elevated. Gram stain shows organisms in CSF in 80% of patients. CSF neutrophil count usually exceeds 2000/μL. Glucose is usually < 40 mg/dL because of impaired CNS glucose transport and glucose consumption by neutrophils and bacteria. Protein is typically > 100 mg/dL. Cultures are positive in 90%; they may be falsely negative in patients who are

partially treated. Latex agglutination tests can be used to detect antigens of meningococci, *H. influenzae* type b, pneumococci, group B streptococci, and *E. coli* K1 strains. However, these tests are not always routinely done because they probably add little to other routine CSF tests. The limulus amebocyte lysate test can detect endotoxin in gram-negative meningitis. This test and the latex agglutination tests may be helpful when patients have received prior antibiotics (partial treatment), when patients are immunocompromised, or when other CSF tests do not identify the causative organism. PCR can occasionally be useful if CSF cultures reveal no organisms.

CT may be normal or show small ventricles, effacement of the sulci, and contrast enhancement over the convexities. MRI with gadolinium is more sensitive for subarachnoid inflammation but is not commonly used. Scans should be scrutinized for evidence of brain abscess, sinusitis, mastoiditis, skull fracture, and congenital malformations. Evidence of venous infarctions or communicating hydrocephalus may appear after days or weeks.

Disorders that resemble bacterial meningitis can usually be differentiated by clinical presentation, neuroimaging, and routine CSF tests. Viral meningitis can cause fever, headache, and stiff neck, but patients do not appear as ill and CSF test results are different. Subarachnoid hemorrhage causes severe headache and a stiff neck, but onset is explosive and fever is usually absent; CT shows hemorrhage, or the CSF contains RBCs or is xanthochromic. Brain abscess can cause fever, headache, and impaired consciousness, but the neck is typically supple unless abscess contents have ruptured into the CSF space, producing a fulminant secondary meningitis. Severe systemic infections (eg, sepsis, infective endocarditis) can impair cognition or consciousness by producing fever and compromising tissue perfusion; CSF is normal or contains a small number of WBCs, and the neck is supple. Cerebellar tonsillar herniation can cause impaired consciousness (secondary to obstructive hydrocephalus) and neck stiffness but usually not fever, and it can be differentiated by CT or MRI. Cerebral vasculitis (eg, due to SLE) and cerebral venous thrombosis can cause mild fever, headache, altered mental status, and mild to moderate meningeal inflammation, typically producing CSF test results similar to those of viral encephalitis.

Occasionally, fungal meningitis or amebic (*Naegleria*) meningoencephalitis can cause acute, fulminant meningitis with clinical findings and routine CSF test results similar to those of bacterial meningitis. Gram stain and routine cultures show no bacteria. Microscopic examination or culture of CSF can detect fungi (see Meningitis: Diagnosis and Treatment). In amebic meningoencephalitis, ameboid movement can be detected in unspun wet mounts of CSF, and the ameba can be cultured. TB meningitis is usually subacute or chronic but is occasionally acute; CSF characteristics are usually intermediate between those of acute bacterial and aseptic meningitis and special stains (eg, acid-fast, immunofluorescent) are needed to identify TB.

Peripheral blood tests include blood cultures (positive in 50%), cell count with differential, electrolytes, glucose, renal function, and coagulation tests. Serum Na is monitored for evidence of SIADH, and coagulation results are monitored for evidence of DIC. Urine and any nasopharyngeal or respiratory secretions and skin lesions are cultured.

Waterhouse-Friderichsen syndrome should be suspected in any febrile patient who remains in shock despite adequate volume replacement and who has rapidly evolving purpura and evidence of DIC. Serum cortisol level is measured, and CT, MRI, or ultrasonography of the adrenal glands is done.

Prognosis and Treatment

Early antibiotics and supportive care have reduced the mortality rate of acute bacterial meningitis to < 10%. However, if meningitis is treated late or occurs in neonates, the elderly, or immunocompromised patients, death is common. A poor outcome is predicted by persistent leukopenia or development of Waterhouse-Friderichsen syndrome. Survivors occasionally have deafness, other cranial nerve deficits, cerebral infarction, recurrent seizures, or mental retardation.

If acute bacterial meningitis is suspected, antibiotics and corticosteroids are given as soon as blood cultures are drawn. If the diagnosis is unclear and the patient is not very ill, antibiotics may be withheld pending CSF test results. Giving antibiotics before lumbar puncture slightly increases the probability of false-negative cultures, particularly with pneumococci, but does not affect other test results.

Dexamethasone 0.15 mg/kg every 6 h in children and 10 mg every 6 h in adults should be given 15 min before the 1st dose of antibiotics and continued for 4 days. Dexamethasone may prevent hearing loss and other neurologic sequelae, possibly by inhibiting release of proinflammatory cytokines triggered by antibiotic-induced bacterial lysis. Dexamethasone should not be given to patients with immunodeficiency because it may impair host defenses against nonbacterial meningitis.

If no pathogen is identified in the CSF, addition of antibiotics for TB should be considered. If no bacteria grow in culture or are otherwise identified after 24 to 48 h, corticosteroids are stopped; corticosteroids continued for > 1 day without appropriate antibiotic coverage could worsen the infection. Corticosteroids impede vancomycin's penetration of CSF, so the vancomycin dose may have to be increased.

When initial CSF tests are inconclusive, a repeat lumbar puncture in 8 to 24 h (or sooner if the patient deteriorates) may help. If clinical and CSF findings continue to suggest aseptic meningitis, antibiotics are withheld. If the patient's condition is serious, especially if antibiotics have been given (possibly producing falsely sterile cultures), antibiotics should be continued.

Choice of antibiotics depends on pathogen and patient age. Third-generation cephalosporins (eg, ceftriaxone, cefotaxime) are effective against pathogens common in patients of all ages. Cefepime, a 4th-generation cephalosporin, can be substituted for a 3rd-generation cephalosporin in children and can be useful for *Pseudomonas* infection. However, because cephalosporin-resistant pneumococci are becoming increasingly prevalent, vancomycin, with or without rifampin, is usually added. Ampicillin is added to cover *Listeria* sp. Aminoglycosides penetrate the CNS poorly but are still used empirically to cover gram-negative bacteria in neonates. When CSF Gram stain and culture results become available, antibiotics are adjusted.

Lumbar puncture should be repeated 24 to 48 h after starting antibiotics to confirm CSF sterility and conversion to lymphocytic predominance. Generally, antibiotics are continued for ≥ 1 wk after fever subsides and CSF is nearly normal (complete normalization may take weeks). Drug doses are not reduced when clinical improvement occurs because drug penetration commonly decreases as meningeal inflammation decreases.

Supportive therapy includes treatment of fever, dehydration, electrolyte disorders, seizures, and shock. If Waterhouse-Friderichsen syndrome is suspected, high-dose hydrocortisone (eg, 100 to 200 mg every 4 to 6 h or as a continuous infusion after an initial bolus) is given; treatment should not be delayed pending hormone levels.

Cerebral edema can be minimized by avoiding overhydration. If brain herniation is suspected, hyperventilation ($Paco_2$, 25 to 30 mm Hg), mannitol (0.25 to 1.0 g/kg), and additional dexamethasone (4 mg every 4 h) can be used; monitoring intracranial pressure may be helpful. If ventricles are enlarged, intracranial pressure may be monitored and CSF drained, but outcome is usually poor.

For infants up to 1 yr of age with subdural effusion, daily subdural taps through the cranial sutures usually help. *No more than 20 mL/day of CSF should be removed from one side* to avoid

sudden shifts in intracranial contents. If effusion persists after 3 to 4 wk of taps, surgical exploration for possible excision of a subdural membrane is indicated.

Patients with severe meningococcal meningitis may benefit from drotrecogin alfa (activated protein C), which downregulates the inflammatory response. A greater frequency of intracranial bleeding occurs with or without drotrecogin alfa treatment in patients septic due to meningitis.

Prevention

A conjugated pneumococcal vaccine effective against 7 serotypes, including > 80% of organisms that cause meningitis, is recommended for all children. Routine vaccination for *H. influenzae* type b is highly effective and begins at age 2 mo. A quadrivalent meningococcal vaccine is given to children ≥ 2 yr with immunodeficiencies or functional asplenia, travelers to endemic areas, and laboratory personnel who routinely handle meningococcal specimens. Meningococcal vaccine should also be considered for students living in dormitories and for military recruits.

Spread of meningitis is prevented by keeping patients in respiratory isolation (droplet precautions) for the 1st 24 h of therapy. Gloves, masks, and gowns are used. Anyone who has face-to-face contact with the patient (eg, family and medical staff members) should receive postexposure prophylaxis. For meningococcal meningitis, it consists of meningococcal vaccine and chemoprophylaxis. Vaccination is especially important for containing epidemics. Chemoprophylaxis against meningococci is oral rifampin for 48 h (adults, 600 mg every 12 h; children, 10 mg/kg every 12 h; infants < 1 mo, 5 mg/kg every 12 h). Alternatives include a single dose of IM ceftriaxone (adults, 250 mg; children, 125 mg) or a single dose of ciprofloxacin 500 mg po (adults only). Chemoprophylaxis against *H. influenzae* type b is rifampin 20 mg/kg po once/day (maximum 600 mg) for 4 days. There is no consensus on whether children < 2 yr require prophylaxis for exposure at day care. Chemoprophylaxis is not usually needed for contacts of patients with pneumococcal meningitis.

Encephalitis is inflammation of the parenchyma of the brain, resulting from direct viral invasion or hypersensitivity initiated by a virus or another foreign protein. Encephalomyelitis is the same process but involves the brain and spinal cord. These disorders can be caused by many viruses. Symptoms include fever, headache, and altered mental status, often accompanied by seizures or focal neurologic deficits. Diagnosis requires CSF analysis and neuroimaging. Treatment is supportive and, for certain causes, includes antiviral drugs.

Etiology and Pathophysiology

Encephalitis may be a primary manifestation or a secondary complication of viral infection. Viruses causing primary encephalitis may be epidemic (eg, arbovirus, poliovirus, echovirus, coxsackievirus) or sporadic (eg, herpes simplex, rabies, varicella-zoster, or mumps virus). Mosquito-borne arboviral encephalitides infect people during the summer and early fall when the weather is warm. Incidence in the US varies from 150 to > 4000 cases yearly, mostly in children. Most cases occur during epidemics. Among arboviruses, La Crosse virus (California virus) is identified as a cause primarily in the north central US. However, the virus is geographically widespread, and La Crosse encephalitis probably is underrecognized and accounts for most cases of arbovirus encephalitis in children. Mortality rate is probably < 1%. Until 1975, St. Louis encephalitis occurred every 10 yr, mostly in the central and eastern US; it is now rare. As of 2003, West Nile encephalitis has spread from the East Coast, where it first appeared in 1999, to all but a few western states. Mortality rate is about 9%. Small epidemics of eastern equine encephalitis occur every 10 to 20 yr in the eastern US, mainly among young children and people > 55. Mortality rate is about 50 to 70%. For unknown reasons, western equine encephalitis has largely disappeared from the US since 1988.

In the US, the most common sporadic encephalitis is caused by herpes simplex virus (HSV); hundreds to several thousand cases occur yearly. Most are due to HSV type 1, but HSV type 2 may be more common among immunocompromised patients. HSV encephalitis occurs at any time of the year, tends to affect patients < 20 or > 40 yr, and is often fatal if untreated.

Primary encephalitis can occur as a late consequence of a viral infection. The best known types are HIV encephalopathy, which causes dementia, which occurs years after a measles infection. The mechanism is probably reactivation of the original infection.

Encephalitis can occur as a secondary immunologic complication of certain viral infections or vaccinations. Inflammatory demyelination of the brain and spinal cord can occur 1 to 3 wk later (as acute disseminated encephalomyelitis); the immune system attacks one or more CNS antigens that resemble proteins of the infectious agent. The most common causes used to be measles, rubella, chickenpox, and mumps (all now uncommon because childhood vaccination is widespread); smallpox vaccine; and live-virus vaccines (eg, the older rabies vaccines prepared from sheep or goat brain). In the US, most cases now result from influenza A or B virus, enteroviruses, Epstein-Barr virus, hepatitis A or B virus, or HIV.

In acute encephalitis, cerebral edema and petechial hemorrhages occur throughout the hemispheres, brain stem, cerebellum, and, occasionally, spinal cord. Direct viral invasion of the brain usually damages neurons, sometimes with visible inclusion bodies. Severe infection, particularly untreated HSV encephalitis, can produce brain hemorrhagic necrosis. Acute disseminated encephalomyelitis is characterized by perivenous demyelination and absence of virus in the brain.

Symptoms and Signs

Symptoms include fever, headache, and altered mental status, often accompanied by seizures and focal neurologic deficits. A GI or respiratory prodrome may precede these symptoms. Meningeal signs are typically mild and less prominent than other manifestations. Status epilepticus, particularly convulsive status epilepticus, or coma suggests severe brain inflammation and a poor prognosis.

Diagnosis

Encephalitis is suspected in patients with unexplained alterations in mental status. Clinical presentation and differential diagnoses may suggest certain diagnostic tests, but MRI and CSF analysis (including PCR for HSV) are usually done, sometimes with other tests to identify the causative virus. MRI is sensitive for early HSV encephalitis, showing edema in the orbitofrontal and temporal areas, which HSV typically infects. MRI can also exclude lesions that mimic viral encephalitis (eg, brain abscess, sagittal sinus thrombosis). CT is much less sensitive than MRI for HSV but can help because it is rapidly available and can exclude disorders that make lumbar puncture risky (eg, mass lesions, hydrocephalus, cerebral edema). If encephalitis is present, CSF is characterized by lymphocytic pleocytosis, normal glucose, mildly elevated protein, and an absence of pathogens using Gram stain and culture (similar to CSF in aseptic meningitis). CSF abnormalities may not develop until 8 to 24 h after onset of symptoms.

PCR for HSV in CSF is sensitive and specific. However, results may not be available rapidly. CSF viral cultures grow enteroviruses but not most other viruses. Paired acute and convalescent serologic tests of CSF and blood must be drawn several weeks apart; they can detect an increase in viral titers specific for certain viral infections. Despite extensive testing, the cause of most cases of encephalitis remains unknown. Brain biopsy may be indicated for patients who are worsening, who are responding poorly to treatment with acyclovir or another antimicrobial, or who have a lesion that is still undiagnosed.

Prognosis and Treatment

Mortality rate varies with cause, but severity of epidemics due to the same virus varies during different years. Permanent neurologic deficits are more likely to occur in infants.

If HSV encephalitis is suspected, acyclovir 10 mg/kg every 8 h is started promptly and continued usually for 14 days. Acyclovir is relatively nontoxic but can cause liver function abnormalities, bone marrow suppression, and transient renal failure. Giving acyclovir IV slowly over 1 h helps prevent nephrotoxicity.

Supportive therapy includes treatment of fever, dehydration, electrolyte disorders, and seizures. Euvolemia should be maintained.

BRAIN ABSCESS

A brain abscess is an intracerebral collection of pus. Symptoms may include headache, lethargy, fever, and focal neurologic deficits. Diagnosis is by contrast-enhanced CT or MRI and sometimes culture. Treatment is with antibiotics and usually surgical drainage.

A brain abscess can result from direct extension of cranial infections (eg, osteomyelitis, mastoiditis, sinusitis, subdural empyema), penetrating head wounds (including neurosurgical procedures), hematogenous spread (eg, in bacterial endocarditis, congenital heart disease with right-to-left shunt), or unknown causes.

The bacteria involved are usually anaerobic and sometimes mixed, often including anaerobic streptococci or *Bacteroides.* Staphylococci are common after cranial trauma, neurosurgery, or endocarditis.Enterobacteriaceae are common with an ear source. Fungi (eg, *Aspergillus*) and protozoa (eg, *Toxoplasma gondii,* particularly in HIV-infected patients) can cause abscesses.

An abscess forms when an area of cerebral inflammation becomes necrotic and encapsulated by glial cells and fibroblasts. Edema around the abscess may increase intracranial pressure.

Symptoms, Signs, and Diagnosis

Symptoms result from increased intracranial pressure and mass effect. Headache, nausea, vomiting, lethargy, seizures, personality changes, papilledema, and focal neurologic deficits develop over days to weeks. Fever, chills, and leukocytosis may develop before the infection is encapsulated, then subside.

When symptoms suggest an abscess, contrast-enhanced CT or MRI is done. An abscess appears as an edematous mass with ring enhancement, which may be difficult to distinguish from a tumor or occasionally infarction; culture and drainage may be necessary. Lumbar puncture is not done because it may precipitate transtentorial herniation and because CSF findings are nonspecific (see

Treatment

All patients receive antibiotics for ≥ 4 to 8 wk. Initial empiric antibiotics include cefotaxime 2 g every 4 h or ceftriaxone 2 g every 12 h; both are effective against streptococci, Enterobacteriaceae, and most anaerobes but not against *Bacteroides fragilis,* which requires metronidazole 7.5 mg/kg every 6 h. If *Staphylococcus aureus* is suspected, vancomycin 1 g every 12 h is used until sensitivity to nafcillin (2 g every 4 h) is determined. Response to antibiotics is best monitored by serial CT or MRI. Drainage, stereotactic or open, provides optimal therapy and is necessary for most abscesses that are solitary and surgically accessible, particularly those > 2 cm in diameter. Patients with increased intracranial pressure may benefit from a short course of high-dose corticosteroids. Anticonvulsants are sometimes recommended to prevent seizures.