Infectious Diseases of the Nervous System

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Infectious diseases of the nervous system include bacterial, viral, fungal, spirochetal, and parasitic infections. Although the central nervous system (CNS) is protected from bacterial invasion by the intact blood-brain barrier, bacterial invasion is enhanced by the special surface properties of bacteria as well as host immune deficiencies. Similar to any type of infection of the nervous system, bacteria may involve any of the nervous system compartments: the epidural space (epidural abscess), the dura (pachymeningitis), the subdural space (subdural empyema), the leptomeninges and the subarachnoid space containing cerebrospinal fluid (meningitis or leptomeningitis), and the brain parenchyma (brain abscess). This chapter presents the clinical manifestations, pathogenesis, pathology, etiology, epidemiology, diagnosis, differential diagnosis, and treatment of these syndromes.

The list of viruses capable of causing neurologic disease is extensive. Most viral infections of the nervous system represent unusual complications of common systemic infections. After replication in extraneural tissue, viruses reach the CNS by the bloodstream or spread along nerve fibers. Although rabies and poliomyelitis have been known since antiquity, only in the early part of the twentieth century were they demonstrated to be caused by "filterable agents" (viruses). In the 1930s, arboviruses were isolated from the brains of patients dying of encephalitides (Eastern and Western equine, St. Louis, and Japanese encephalitis), and lymphocytic choriomeningitis virus was isolated from the spinal fluid of patients with aseptic meningitis, being the first virus demonstrated to cause this syndrome. The coxsackievirus and echoviruses were isolated and recognized to cause viral meningitis in the 1950s. Slow virus infections were recognized during the 1960s and 1970s, with conventional viruses and atypical agents (prions) isolated from chronic neurologic diseases. The 1980s ushered in the identification of the retroviruses with the AIDS epidemic and tropical spastic paraparesis. In the late 1990s, West Nile virus began to cause disease in North America and enterovirus 71 (EV 71) began to cause epidemics of rhombencephalitis in Asia Pacific regions. In the late 2000s, the cases of progressive multifocal leukoencephalopathy (PML) began to increase, especially in multiple sclerosis patients treated with immunomodulators. We have yet to discover what other viruses are unrecognized as causes of unusual neurologic diseases.

The past 30 years have seen a steady increase in the frequency of fungal infections of the CNS, primarily due to the increased use of immunosuppressive drugs and the AIDS epidemic. Most fungal infections are caused by opportunistic organisms, except those caused by the pathogenic fungi (histoplasmosis, blastomycosis, coccidioidomycosis, and paracoccidioidomycosis). In most fungal infections, spread to the CNS occurs after obvious extraneural primary infection of the lungs, skin, and hair, the main exception being cryptococcosis.

The spirochetal diseases that involve the nervous system include syphilis, Lyme disease, and leptospirosis. Syphilis and Lyme disease regularly cause both meningeal and parenchymal disease; humans are the only host in syphilis and an important dead-end host in Lyme disease. Both of these diseases can be chronic and are relatively common, so they are discussed in detail. Leptospirosis, in contrast, is a disease of both wild and domestic animals, with humans being incidental hosts. Human infection occurs through contact with infected animal tissue or urine or from exposure to contaminated ground water, soil, or vegetation. Leptospirosis is a self-limited illness that primarily manifests as aseptic meningitis. Rarely, encephalitis, myelitis, optic neuritis, and peripheral neuropathy have been reported. Penicillin (or tetracycline as an alternative therapy) is the antibiotic of choice; fewer than 100 cases of leptospirosis are reported per year.

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R. N. Rosenberg (ed.), *Atlas of Clinical Neurology*, https://doi.org/10.1007/978-3-030-03283-8_12

Parasitic infections can be divided into two major categories: protozoan and helminthic (worms). Helminths include nematodes (roundworms), trematodes (flukes), and cestodes (tapeworms). Parasitic diseases occur worldwide but are most common in tropical and underdeveloped areas of the world, where poverty and poor housing conditions contribute to their pathogenesis and spread. Tropical climates are also ideal for the vectors that spread these infections. In these areas, parasitic infections are the most common infectious disease, and they exact a heavy toll on the human population.

Bacterial Infections

Acute Bacterial Meningitis

The clinical manifestations of acute bacterial meningitis differ by age group (Table 1). The symptoms and signs of bacterial meningitis in infants are nonspecific and typical of a severe systemic infection including sepsis. In children and adults, the classic signs of meningeal irritation are nuchal rigidity, Kernig's sign, and Brudzinski's sign. Nuchal rigidity is present when the patient has resistance to passive flexion of the neck. Kernig's sign is elicited by flexing the thigh and knee while the patient is in the supine position; in the presence of meningeal inflammation, there is resistance to passive extension of the leg at the knee with the thigh flexed. Brudzinski's sign is positive when passive flexion of the neck causes flexion of the hips and knees. Neurologic complications are frequently associated with bacterial meningitis. Seizures occur in 40% of cases. Generalized seizures usually occur early due to fever, metabolic derangements, or toxic factors (*eg*, alcohol withdrawal); focal seizures are more likely to occur after 4–10 days and are caused by arterial thrombosis, cortical vein thrombosis, or abscess formation. Cranial nerve (CN) palsies, especially of CN III, VI, VII, and VIII, are due to purulent exudates in the arachnoid sheaths of the specific cranial nerve. Sensorineural hearing loss is a major complication in infants and children, occurring in 30% of cases. Cerebral edema and increased intracranial pressure may be due to noncommunicating hydrocephalus caused by basilar exudates, or to exudates in the Virchow-Robin spaces invading the parenchyma. Focal cerebral signs are most likely to occur at the end of the first week of infection but may occur later as well; they are due to arterial thrombosis causing infarction, cortical vein thrombosis with secondary hemorrhagic infarction, or abscess formation.

Meningococcus is the only bacterium that frequently causes a rash, which is probably the most important clue to the diagnosis of meningococcal meningitis (Fig. 1). It usually begins as a diffuse erythematous maculopapular rash. As the rash evolves, petechiae and purpura appear primarily on the trunk and lower extremities.

Figure 2 illustrates the pathogenesis of meningitis. For bacterial meningitis to occur, the host usually acquires a new organism by colonization of the nasopharynx. This may lead to direct seeding of cerebral spinal fluid (CSF) spaces, but more likely causes local spread to the sinuses or the lungs (pneumonia) or bacteremia, which then results in meningeal invasion.

The neurologic complications of cranial nerve palsies and increased intracranial pressure are often caused by inflammation of the base of the brain (Fig. 3). The increased intra-

Table 1 Clinical manifestations of acute bacterial meningitis by age group

Age group	Symptoms	Signs
Infants (≤2 years)	Irritability	Fever
	Poor feeding	Lethargy
	Vomiting	Stupor, coma
	Unconsciousness	Bulging fontanel
	Respiratory symptoms	Seizures
	Apnea	Petechial or purpuric rash
Children and adults	Headache	Fever
	Neck stiffness or pain	Nuchal rigidity, Kernig's and Brudzinski's signs
	Unconsciousness	Lethargy, confusion, stupor, coma
	Nausea and vomiting	Seizures
	Photophobia	Focal neurologic deficits, including cranial nerve palsies
	Respiratory symptoms	Ataxia (in children)
		Petechial or purpuric rash

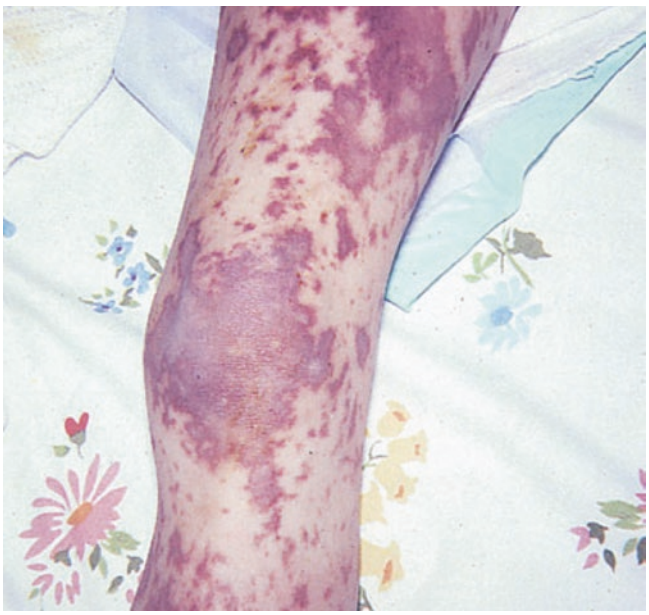

Fig. 1 Meningococcal rash. (From Roos et al. [1]; with permission)

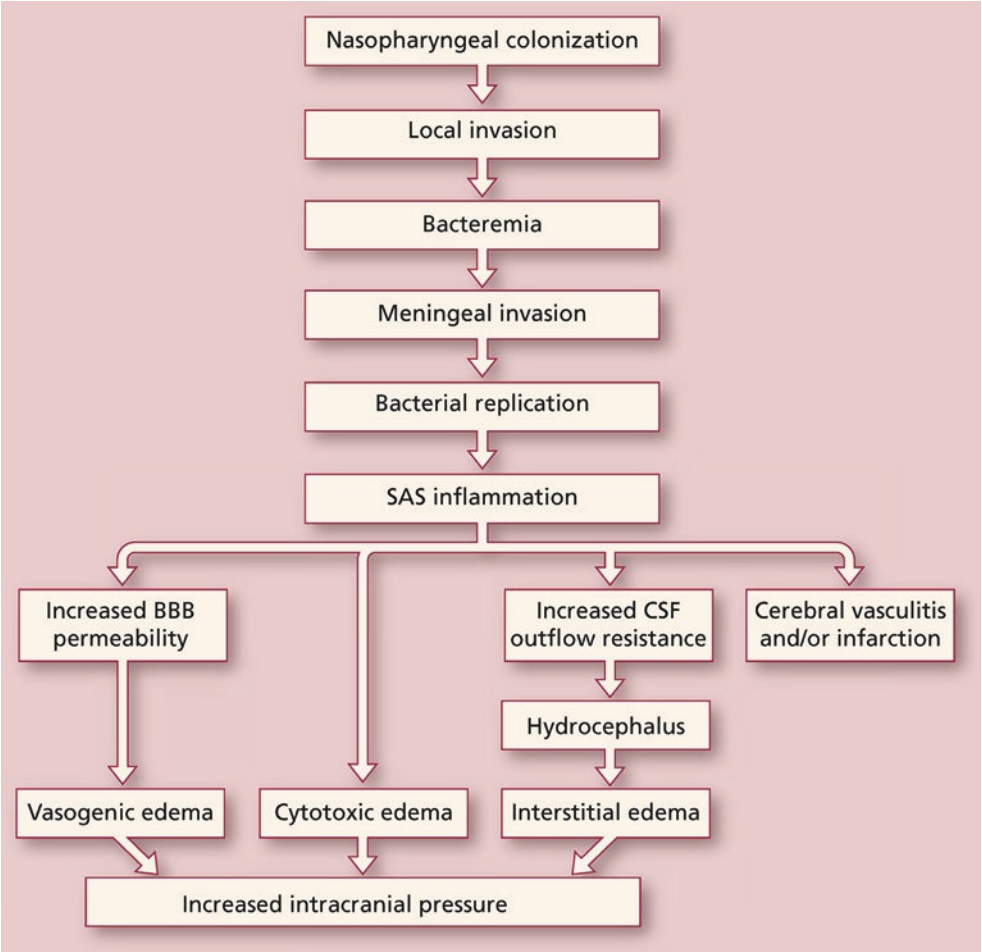

Fig. 2 Pathogenesis of meningitis. *BBB* blood-brain barrier, *SAS* subarachnoid space. (Adapted from Roos et al. [1])

cranial pressure occurs because cerebrospinal fluid pathways are blocked, resulting in obstructive hydrocephalus.

Purulent exudate of leptomeningitis (inflammation of pia and arachnoid spaces) over the convexities of the cerebral cortex (Fig. 4). The result may be additional complications of arterial or venous thrombosis with infarction and hemorrhage, both of which may lead to focal neurologic defects. Exudates over the convexity initially appear yellow, but later turn gray as they become thicker.

Microscopic examination in bacterial meningitis may show that the meninges are thickened by both polymorphonuclear and mononuclear inflammatory cells (Fig. 5a). Thickening of blood vessels may eventually lead to thrombotic occlusion, cerebral infarcts, and focal neurologic deficits. Inflammatory cells also may be seen in the Virchow-Robin spaces around penetrating parenchymal vessels (Fig. 5b). The Virchow-Robin spaces are an extension of the subarachnoid space. Occasionally, inflammation may extend into the perivascular parenchyma.

Predisposing factors for community-acquired meningitis are somewhat different than those seen in nosocomial infections. Predisposing factors for nosocomial infections are primarily caused by openings into the CNS.

The causative organisms of bacterial meningitis are somewhat different for community-acquired meningitis than for nosocomial meningitis. The causative organisms also differ among patients of different ages. *Haemophilus influenzae* type b was the leading cause of meningitis until widespread use of vaccine. Now *H. influenzae* is not a significant cause of bacterial meningitis in the vaccinated population [5]. Meningococcal meningitis caused by *Neisseria meningitidis* affects mostly children and young adults. As of 1995, *N. meningitidis* had replaced *H. influenzae* as the leading cause of bacterial meningitis in these age groups in the United States [6]. Congenital terminal complement deficiencies (C5–C8) predispose to meningococcemia. Pneumococcal meningitis caused by *Streptococcus pneumoniae* is the most common cause of bacterial meningitis in adults. Predisposing factors include pneumonia, otitis media, sinusitis, head trauma, cerebrospinal fluid leaks, sickle cell disease, splenectomy, diabetes and alcoholism.

Streptococcus pneumoniae is the most frequent cause of community-acquired recurrent meningitis. Gram-negative bacilli are the most frequent causes for nosocomial infections. The most frequent risk factors are head trauma, neurosurgical procedures, and cerebrospinal fluid leaks. Other

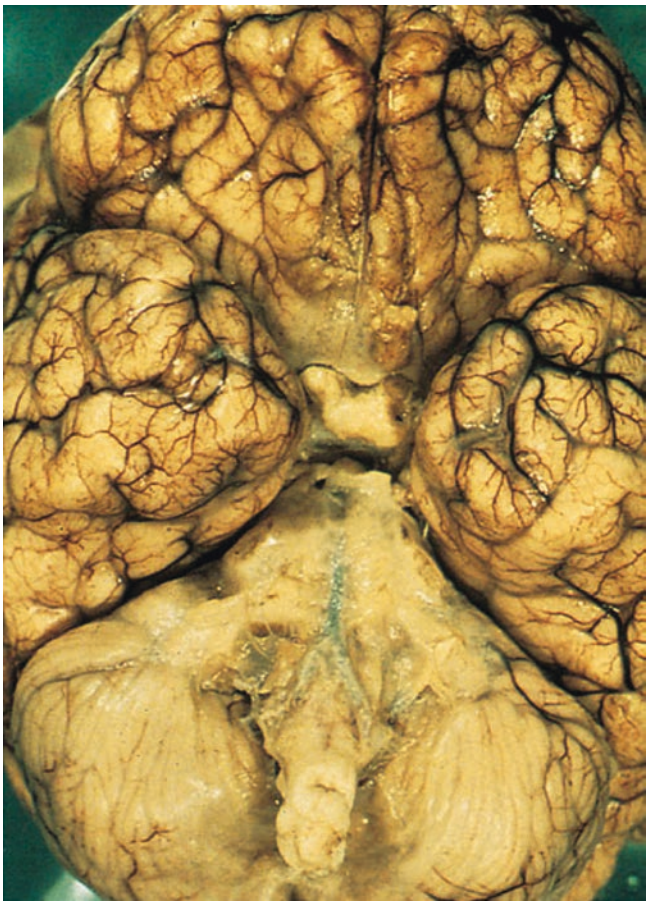

Fig. 3 Purulent exudate of bacterial meningitis at the base of the brain. (From Roos and Bonnin [2]; with permission)

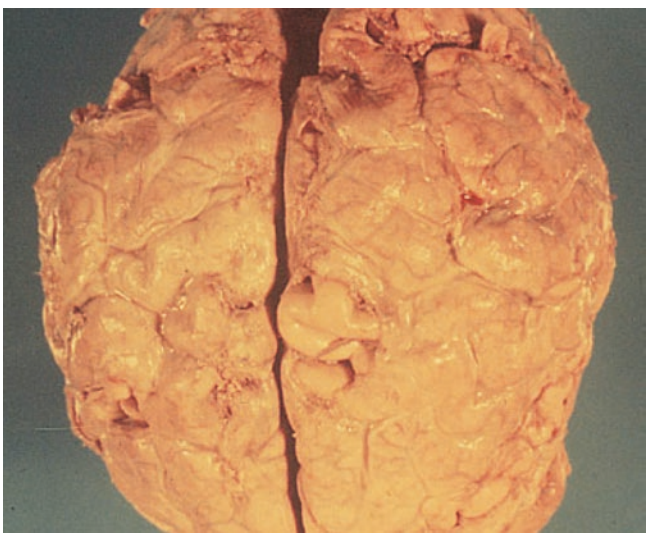

Fig. 4 Purulent exudate of leptomeningitis (inflammation of pia and arachnoid spaces) over the convexities of the cerebral cortex. (From Kaplan [3])

risk factors include immunodeficiencies, immunosuppressant therapy, splenectomy, and parameningeal infection (*eg*, sinusitis, otitis media).

The characteristic CSF picture in acute bacterial meningitis usually includes an increased opening pressure (>200 mm H_2O), an increased white cell count with a predominance of polymorphonuclear leukocytes or neutrophils, a decreased glucose level (<40 mg/dL) or decreased CSF to serum glucose ratio (<0.3), and an increased protein level (>45 mg/dL). Turbid CSF seen on visual inspection suggests more than 400 white cells per mm^3.

Diagnostic studies for acute bacterial meningitis include blood cultures (three sets) and CSF analysis. In addition to routine CSF studies, polymerase chain reaction (PCR) analysis should be performed in patients who have been partially treated, even with oral antibiotics. If the patient shows signs suggestive of increased intracranial pressure (impaired mental status, focal neurologic signs, papilledema, dilated nonreactive pupil, cranial nerve VI palsy), then a brain CT scan should be performed before lumbar puncture (LP). The CT scan may show diffuse cerebral edema (as in Fig. 6) or a focal lesion; these are contraindications to LP.

Table 2 outlines the differential diagnosis of acute bacterial meningitis. **Viral meningitis** is a diagnostic consideration of very early bacterial meningitis. In viral meningitis, fever is not as prominent, and CSF studies usually reveal normal glucose levels and mononuclear pleocytosis, although polymorphonuclear neutrophils may be seen in the first 12–24 h. In **viral encephalitis**, the CSF analysis is similar to that of viral meningitis, but mental status is altered. **Tuberculous meningitis** may be subacute or may have a rapid downhill course, but mononuclear cells predominate in the CSF and usually the glucose level is low. **Fungal meningitis** has a more chronic course. CSF studies reveal a mononuclear pleocytosis and low glucose. **Brain abscess** and **subdural empyema** usually present with focal abnormalities on examination, increased intracranial pressure, and a CSF pleocytosis with normal glucose. **Rocky Mountain spotted fever** may clinically resemble bacterial meningitis, with patients exhibiting fever, headache, altered mental status, and a petechial rash. The rash is usually different than that seen in meningococcemia (*see* Fig. 1), beginning on wrists and ankles, then spreading to the body and face; the mucous membranes are not involved. The CSF is usually normal, and a history of tick bite is elicited in 80% of patients. **Bacterial endocarditis** causes a new heart murmur; petechial lesions of the nailbeds, mucous membranes, and extremities; and hematuria, as well as altered mental status. **Subarachnoid hemorrhage** presents with sudden, excruciating headache, meningismus, fever at times, usually a normal mental status (unless intracerebral

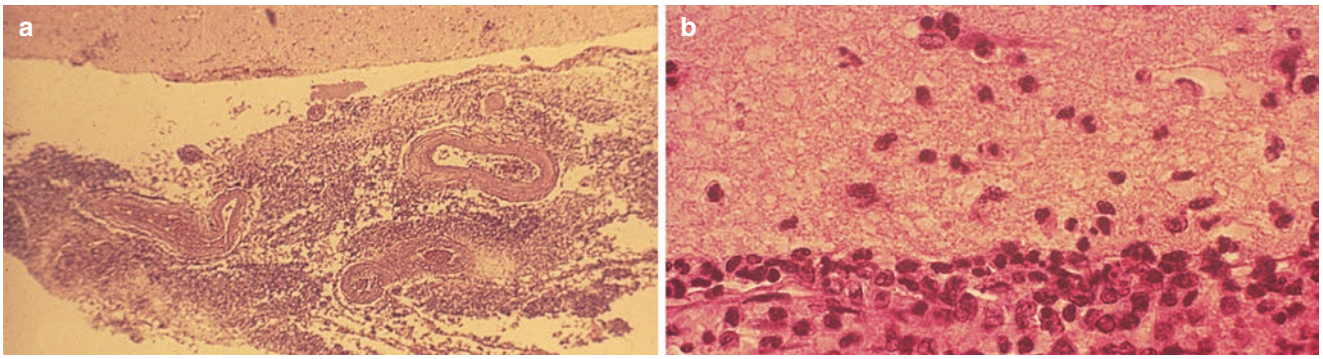

Fig. 5 Microscopic examination in bacterial meningitis. (**a**) The meninges are thickened by both polymorphonuclear and mononuclear inflammatory cells. (From Kaplan [3]). (**b**) Inflammatory cells in the Virchow-Robin spaces around penetrating parenchymal vessels. Occasionally, inflammation may extend into the perivascular parenchyma, as shown here. (From Wilson [4])

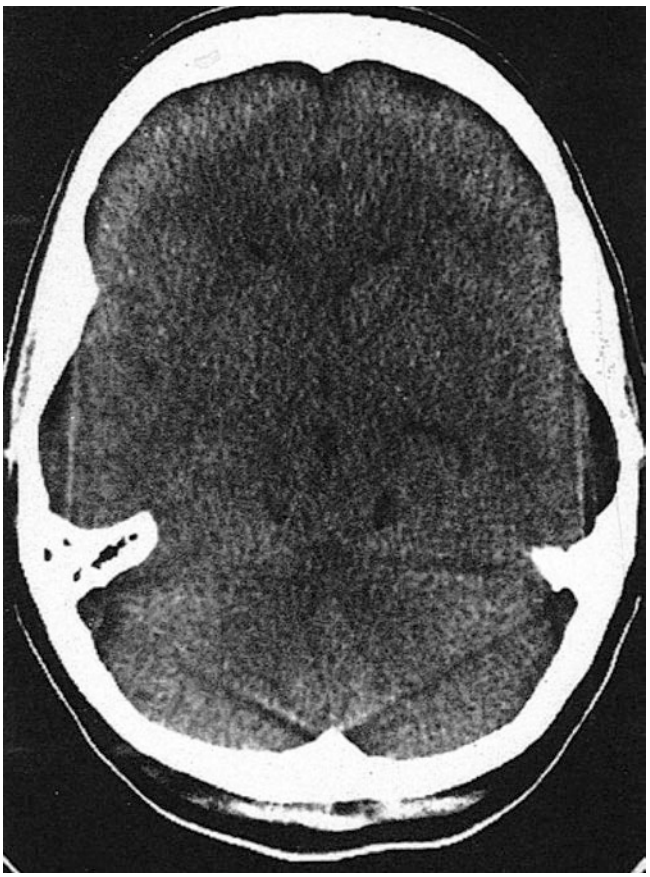

Fig. 6 CT scan done as part of a diagnostic work-up for acute bacterial meningitis, showing diffuse cerebral edema. (From Roos et al. [1]; with permission)

Table 2 Differential diagnosis of acute bacterial meningitis

Differential diagnosis	Diagnostic test
Viral meningitis	CSF
Viral encephalitis	CSF, EEG, MRI
Tuberculous meningitis	CSF
Fungal meningitis	CSF
Brain abscess	CT
Subdural empyema	CT
Rocky Mountain spotted fever	Rash biopsy with FA staining of specimen
Bacterial endocarditis	Cardiac murmur
Subarachnoid hemorrhage	CSF
Neoplastic meningitis	CSF

EEG electroencephalogram, *FA* fluorescent antibody

bleeding occurred), and CSF xanthochromia with a large number of red blood cells. **Neoplastic meningitis** (meningeal carcinomatosis) often causes cranial nerve palsies, mononuclear cells in the CSF, and low glucose levels; the cytologic appearance is diagnostic. A diffuse erythematous maculopapular rash is present in over 50% of patients with meningococcemia. This presents as petechiae and purpura on the trunk and lower extremities (*see* Fig. 1). The petechiae may appear on mucous membranes and conjunctivae but never in the nailbeds. Other organisms that cause meningitis less frequently cause similar rashes (*Staphylococcus aureus*, *Acinetobacter* species, *Streptococcus pneumoniae*, and *Haemophilus influenzae*). The rash of staphylococcal endocarditis involves the nailbeds in addition to the mucous membranes and the extremities. Echovirus type 9 infections often also cause a petechial or purpuric rash.

Table 3 lists the differential diagnosis of CSF abnormalities in acute bacterial meningitis. Rarely, monocytes (*Listeria monocytogenes* and especially brucellosis) may predominate in the CSF in bacterial meningitis. In viral meningitis, polymorphonuclear leukocytes (PMNs) may appear in the first 12–24 h, and then there is a shift to mononuclear cells. Most parameningeal foci of infection (*eg*, brain abscess, epidural abscess) cause a subacute to chronic condition of mononuclear cells in the CSF. Subdural empyema, however, may

Table 3 Differential diagnosis in acute bacterial meningitis based on typical cerebrospinal abnormalities

Type of infection	Predominant cells, *per mm*^{3}	Glucose, *mg/dL*	Stain for organisms	Diagnosis
Bacterial meningitis	PMNs	Very low (0–10)	Gram stain	Culture, CIE, LA, LLA, CoA
Tuberculous meningitis	Mononuclear leukocytes	Low to very low (10–20)	Ziehl-Nelson	Culture
Viral meningitis	Mononuclear leukocytes	Normal		Culture, some PCR assays
Fungal meningitis	Mononuclear leukocytes	Low (15–30)	Cryptococcus—India ink stain	Culture; various ab and ag tests
Parameningeal (serous) meningitis	Subacute and chronic mononuclear leukocytes (usual picture); acute: PMNs (uncommon)	Normal		CT, MRI; myelogram
Neoplastic meningitis	Mononuclear leukocytes	Low or normal (30–50)		Cytologic studies

Ab antibody, *Ag* antigen, *PCR* polymerase chain reaction, *PMN* polymorphonuclear leukocyte

Table 4 Empiric antimicrobial therapy for bacterial meningitis

Population	Antimicrobial agent
Neonates	Ampicillin plus cefotaxime
Infants and children	Vancomycin[a] plus cephalosporin, cefotaxime, or ceftriaxone
Adults (15–50 y)	Vancomycin[a] plus cephalosporin, cefotaxime, or ceftriaxone
Older adults (>50 y)	Vancomycin[a] plus cephalosporin, cefotaxime, or ceftriaxone plus ampicillin
Neurosurgical procedure or head trauma	Vancomycin[a] plus cephalosporin (ceftazidime), cefepime, or meropenem
Immunocompromised state	Vancomycin[a] plus cefepime or meropenem plus ampicillin
Neutropenic state	Cefepime
Recurrent meningitis	Vancomycin[a] plus cephalosporin, cefotaxime, or ceftriaxone

Adapted from van de Beek et al. [7]; with permission
[a]Until susceptibility testing available

Table 5 Specific antibiotic therapy for acute bacterial meningitis

Organism	Antibiotics
Streptococcus pneumoniae	
Sensitive to penicillin	Penicillin G or ampicillin
Relatively resistant to penicillin	Third-generation cephalosporin[a]
Resistant to penicillin	Vancomycin plus third-generation cephalosporin[abc]
Neisseria meningitis	Penicillin G or ampicillin[c]
Haemophilus influenzae	
β-Lactamase negative	Ampicillin[c]
β-Lactamase positive	Third- or fourth-generation cephalosporin[ac]
Enterobacteriaceae	Third- or fourth-generation cephalosporin[a]
Pseudomonas aeruginosa	Ceftazidime or meropenem
Streptococcus agalactiae	Ampicillin, penicillin G[d], or vancomycin
Listeria monocytogenes	Ampicillin or trimethoprim/sulfasoxazole
Staphylococcus aureus	
Methicillin sensitive	Nafcillin or oxacillin
Methicillin resistant	Vancomycin
Staphylococcus epidermidis	Vancomycin[b]

Adapted from Roos et al. [8]; with permission
[a]Cefotaxime or ceftriaxone
[b]Addition of rifampin should be considered
[c]Chloramphenicol is an option for penicillin-allergic patients
[d]Addition of an aminoglycoside should be considered

cause an acute parameningeal CSF appearance of a large number of PMNs.

Empiric antibiotic therapy must be given before the causative organism can be definitively identified. As shown on Table 4, the choice of the empiric agent depends on the patient's age and associated conditions (such as neurosurgical procedure, immunodeficiency), with modifications based on a positive Gram stain. To achieve adequate antibiotic levels in the CSF, antibiotics should be given intravenously.

Once the causative organism is cultured and sensitivities determined, therapy should be adjusted to be as narrow as possible (Table 5). The duration of treatment is somewhat empiric, with the following general recommendations: *Neisseria meningitidis*, 7 days; *Haemophilus influenzae*, 7–10 days; *Streptococcus pneumoniae*, 10–14 days; gram-negative bacilli, 21 days.

Adjunctive therapy and supportive care (Table 6) are also important for patients with acute bacterial meningitis. Several studies have demonstrated that dexamethasone decreases sensorineural hearing loss and improves neurologic outcome in children older than 2 months of age [8] as well as in adults [7, 9]. The dexamethasone should be started shortly before giving the first dose of antibiotics because the drug inhibits the production of inflammatory cytokines. It appears to be most useful for patients with pneumococcal or meningococcal meningitis.

The mortality rate for treated cases of acute bacterial meningitis remains significant because of the numerous potential complications (increased intracranial pressure, hydrocephalus, focal neurologic deficits, seizures, brain abscess, subdu-

Table 6 Adjunctive therapy and supportive care for bacterial meningitis

Adjunctive dexamethasone: 0.15 mg/kg every 6 h for 4 days for children; 12 mg every 12 h for adults
Supportive care
Fluid and electrolyte balance: Monitor for syndrome of inappropriate antidiuretic hormone
Maintenance of normal systemic blood pressure because of loss of autoregulation
Intracranial pressure (ICP) monitoring for critically ill patients
Treatment for increased ICP
Elevate head of bed to 30 degrees
Hyperventilation to $PaCO_2$ to 27–30 mm hg
Hyperosmolar agents: Mannitol, glycerol
Glucocorticoids: Dexamethasone
Monitor and treat obstructive hydrocephalus
Seizure control: levetiracetam, lacosamide, midazolam, pentobarbital

$PaCO_2$ arterial carbon dioxide pressure

ral empyema, sepsis). Factors associated with significantly higher overall mortality rates were age of 60 years or older, obtundation on admission, and seizures occurring within 24 h of admission.

Vaccines are now available for *Haemophilus influenzae* type b (Hib), *Neisseria meningitides*, and *Streptococcus pneumoniae* (Table 7). The routine use of Hib vaccine has greatly decreased the incidence of meningitis due to this agent [10]. Meningococcal and pneumococcal vaccines are used for specific circumstances or "at risk" populations. Meningococcal vaccine is available for serogroups A, C, W, Y, and B, but the response is poor in young children. Two serogroup B vaccines were approved between October 2014 and January 2015 [11]. Pneumococcal vaccine is indicated for all infants in addition to high-risk groups older than 2 years of age [12]. It is recommended that close contacts of patients with meningococcal or *H. influenzae* meningitis in the household, day care center, or medical facilities be treated prophylactically with rifampin.

Table 7 Vaccination for acute bacterial meningitis

Hib vaccine recommendations	Indicators for meningococcal and pneumococcal vaccines
Vaccinate all infants at 2, 4, and 6 months of age	Meningococcal quadrivalent vaccine
One booster dose is usually given at 12–15 months	Primary 11–12 years, 1 dose booster 1 dose if primary before age 16
Unvaccinated infants 7–11 months of age receive two doses 2 months apart	Vaccination during epidemic outbreaks due to represented serogroup
	Travel to hyperepidemic areas
Unvaccinated children 12–14 months of age receive one dose plus booster at 15 months	High-risk immunodeficient groups
	Terminal coagulant deficiency
Unvaccinated children 15–60 months of age receive one dose	Properdin deficiency
Children older than 5 years are vaccinated if increased disease risk (asplenia, sickle cell disease, immunodeficiency, or immunosuppression)	Pneumococcal vaccine
	Vaccinate all infants at 2, 4, and 6 months of age
	Booster dose 12–15 months
Children with history of invasive Hib disease or vaccinated at greater than 2 years with polyribosylribitol phosphate vaccine do not need revaccination	Elderly over 65 years of age
	Those with chronic cardiorespiratory conditions
	Chronic alcoholics
	Those with asplenic states, multiple myelemia, Wiskott-Aldrich syndrome
	HIV infection
	Those with diabetes mellitus or significant hepatic or renal disease

Chronic Bacterial Meningitis

Chronic meningitis accounts for about 10% of all meningitis cases. Clinical features include a subacute to chronic onset of various combinations of fever, headache, and stiff neck, often with signs of encephalitis (parenchymal involvement), mental status changes, seizures, and focal deficits. Therefore, chronic meningitis is often referred to as a meningoencephalitis. The CSF is abnormal, with a pleocytosis (usually mononuclear), elevated protein levels, and a moderately decreased glucose level (*see* Table 3 for comparison). Some require that these manifestations persist for 4 weeks as a criterion for the diagnosis of chronic meningitis but the differential diagnosis is usually considered before this period on the basis of the suggestive CSF profile. The differential diagnosis is quite extensive and includes both infectious and noninfectious causes (Table 8). The most common infectious causes of chronic meningitis are tuberculosis, cryptococcosis, and toxoplasmosis; the common noninfectious causes are neoplasms and vasculitis.

Exploring the history may reveal clues to an etiologic diagnosis (Table 9). The history can be explored in four major areas: exposure history, travel and geographic history, extraneural or systemic diseases, and immunologic deficiency. Such a clue is not found in most cases, but unfortunately

Table 8 Differential diagnosis of chronic meningitis

Infectious causes		Noninfectious causes
Bacterial infections	Parasitic diseases	Neoplasm
Tuberculosis	Cysticercosis	Sarcoidosis
Spirochetal (syphilis, Lyme disease, Leptospira infection)	Granulomatous amebic meningoencephalitis (acanthamoeba)	Vasculitis
		Primary central nervous system angiitis
Agents that form sinus tracts *(Actinomyces, Arachnia, Nocardia)*	Eosinophilic meningitis (angiostrongylus)	Systemic giant cell arteritis, systemic lupus erythematosus, Sjögren's syndrome, rheumatoid arthritis, lymphamatoid granulomatosis, polyarteritis nodosa, Wegener's granulomatosis)
	Toxoplasmosis	
Brucellosis	*Coenurus cerebralis*	
Listeria monocytogenes (rare cause)	Viral infections	
Nocardiosis	Retrovirus (HIV-1, HTLV-1)	Behçet's disease
Fungal infections	Enterovirus (in hypogammaglobulinemia)	Chemical meningitis
Common *(Candida, Coccidioides, Cryptococcus, Histoplasma)*	Parameningeal infections (epidural abscess, subdural empyema, brain abscess)	Endogenous
Uncommon *(Aspergillus, Blastomyces, Dematiaceous Paracoccidioides, Pseudallescheria, Sporothrix, Mucormycetes)*		Exogenous
		Chronic benign lymphocytic meningitis idiopathic hypertrophic pachymeningitis Vogt-Koyanagi-Harada disease

Adapted from Roos and Bonnin [2]; with permission
HTLV human T-cell lymphotropic virus

Table 9 Historical and clinical clues to diagnosis of chronic meningitis

History	Examination
Exposure history	Dermatologic lesions
To patient with tuberculosis (TB)	Erythema chronicum migrans—Lyme disease
Ingestion of unpasteurized milk or dairy products (brucellosis)	Depigmentation of skin (vitiligo) and hair (poliosis)—VKH
To farm animals or swimming in farm ponds (leptospirosis)	Macular hyperpigmented lesions of trunk, palms, and soles—Secondary syphilis
To deer ticks (Lyme disease)	
Swimming in warm fresh water ponds (acanthamebiasis)	Subcutaneous nodules, abscesses, draining sinuses—Fungal aspergillosis
Sexual transmission (syphilis, retroviruses)	
Intravenous drug use (retroviruses)	Ophthalmologic disease
Travel and geographic history	Uveitis—Sarcoidosis, Behçet's syndrome, VKH
Mexico and Latin America (cysticercosis)	Choroidal tubercles—TB, sarcoidosis
Southeast Asia and Pacific (angiostrongylosis)	Organ disease
US northeast, north central (Lyme disease)	Primary disease—Sarcoidosis, TB, histoplasmosis, aspergillosis, blastomycosis
US Midwest (histoplasmosis, blastomycosis)	
US southwest (coccidioidomycosis)	Enlarged liver—Potential biopsy sites for TB, histoplasmosis
US southeast (acanthamebiasis)	Muscle nodules—Biopsy site for sarcoidosis, vasculitis
History of extraneural or systemic disease	Adenopathy—Biopsy site for TB, systemic fungi
Pulmonary disease (TB, histoplasmosis, sarcoidosis)	Neurologic features
Polyarthritis (Lyme disease, Behçet's syndrome, systemic lupus erythematosus, rheumatoid arthritis)	Cranial nerve involvement—Sarcoidosis, Lyme disease, TB, fungal meningitis
Uveitis (sarcoidosis, Behçet's syndrome, Vogt-Koyanagi-Harada [VKH], leptospirosis)	Focal lesions
	Abscess—TB, fungal meningitis, toxoplasmosis
Skin lesions (syphilis, Lyme disease, VKH)	Hydrocephalus—TB, fungal meningitis (especially cryptococcosis), cysticercosis

Table 9 (continued)

History	Examination
Prior diagnosed disease (diabetes, malignancy, TB, syphilis, AIDS)	
History of immunodeficiency	Cryptococcosis, cystinosis
Congenital	Peripheral neuropathy—Lyme disease, sarcoidosis, brucellosis, vasculitis
Agammaglobulinemia (enteroviruses)	
Acquired	Multiple levels—Carcinomatous meningitis
AIDS (toxoplasmosis, cryptococcosis, syphilis, TB, etc.)	
Organ transplant immunosuppression (toxoplasmosis, listeriosis, candidiasis, nocardiosis, aspergillosis)	
Chronic steroid use (TB, cryptococcosis, candidiasis)	
Malignancy and chemotherapy (TB, cryptococcosis, listeriosis)	

Adapted from Roos and Bonnin [2]; with permission

none of the possible diagnoses are excluded. The physical examination of patients with chronic meningitis is directed at finding extraneural signs that provide clues to the CNS disease, identifying potential sites for biopsy, and documenting the exact location and extent of neurologic involvement. For example, skin and eye involvement support specific diagnoses, and skin lesions, adenopathy, and organomegaly indicate potential biopsy sites.

Laboratory tests are important in the diagnosis of chronic meningitis (Table 10). A complete blood count (CBC) may reveal bone marrow disease (tuberculosis [TB], vasculitis, neoplasms). Abnormal results of serum chemistry tests may include a low sodium level (syndrome of inappropriate antidiuretic hormone from TB), a high sodium level from diabetes insipidus (sarcoid), high levels of calcium and angiotensin-converting enzyme (ACE) (sarcoid), elevated liver function tests (TB, sarcoid, histoplasmosis), and positive antinuclear antibodies (ANA) and antineutrophil cytoplasmic antibodies (ANCA) (systemic vasculitis). CSF examination is the most important test for the diagnosis of chronic meningitis. If several lumbar CSF studies have negative results, then cisternal or lateral cervical CSF studies are needed, because basilar meningitis commonly occurs with chronic meningeal processes. A ventricular tap for CSF may ultimately be necessary. Chest radiographs are needed to determine the presence of TB, sarcoid, histoplasmosis, or tumor. Brain imaging studies should be performed before a spinal tap to exclude focal brain lesions (abscess or stroke) and hydrocephalus. Enhancements help to localize abscesses as well as reveal chronic meningeal inflammation. MRI is needed for spinal disease. Angiography may be useful for diagnosing systemic or central nervous system vasculitis. If these tests are not diagnostic, then biopsies may be required, especially if the patient continues to deteriorate.

In the CSF, the cellular infiltrate is mononuclear for most causes of chronic meningitis (Table 11). The glucose is low or normal. However, there are a few chronic infections that predominately have a neutrophilic response, which is the type of response usually seen in acute infections. Also, a few organisms elicit allergic eosinophilic responses.

Table 10 Laboratory tests in chronic meningitis

Blood tests: CBC, serum chemistry studies, ANA, ANCA, ESR, VDRL, ACE
Cultures of draining skin lesions, sinuses, nodes, blood, sputum, urine, CSF
Multiple sites
Multiple times (≥3)
Skin testing
Intermediate PPD
Anergy battery
Antibody studies
Paired serum and CSF samples
CSF studies (×3 if needed)
Cells, protein, glucose, antigen assays (fungus only), antibody assays, culture, cytologic analyses (Gram stain, India ink preparations, acid-fast stains), PCR assays
Imaging
Chest radiography
Contrast-enhanced MRI preferred over CT
Angiography
Biopsy
Extraneural
Meningeal/cerebral

ACE angiotensin-converting enzyme, *ANA* antinuclear antibody, *ANCA* antineutrophil cytoplasmic antibody, *ESR* erythrocyte sedimentation rate, *PCR* polymerase chain reaction, *PPD* purified protein derivative, *VDRL* Venereal Disease Research Laboratory test

Central Nervous System Tuberculosis

Because the clinical picture of meningitis due to tuberculosis varies, especially by age at onset, a clinical staging system (Table 12) was introduced over 60 years ago. Stage I patients have only a nonspecific prodrome that includes headache, malaise, and low-grade fever, without neurologic manifestations, This stage usually lasts up to 2 weeks. Stage II is often referred to as the meningitic phase, as symptoms and signs of

Table 11 CSF finding in diagnosis of chronic meningitis

Type of pleocytosis	Noninfectious meningitis (usually <50 cells/mL)
Mononuclear cells with low glucose levels	Neoplastic meningitis
	Sarcoid
	Tuberculosis meningitis
	Fungal meningitis
	Syphilis
	Lyme disease
	Cysticercosis
	Toxoplasmosis
Mononuclear cells with normal glucose levels	Neoplastic meningitis
	Sarcoid
	Lyme disease
	Vasculitis
	Parameningeal infection
	Chronic benign lymphocytic meningitis
	Chemical meningitis
Neutrophilic predominance	Bacterial infection (*Actinomyces*, *Brucella*, *Nocardia*, early TB)
	Fungal infection (*Aspergillus*, *Blastomyces*, *Candida*, *Coccidioides*, *Histoplasma*, *Pseudallescheria*, *Mucormycetes*)
	Noninfectious meningitis (chemical, vasculitis)
Eosinophilic predominance	Parasitic infection (*Angiostrongylus*, cysticercus, *Gnathostoma*)
	Bacterial infection (*Coccidioides*)
	Noninfectious meningitis (vasculitis, chemical)
	Neoplastic meningitis (lymphomatous, Hodgkin's disease)

TB tuberculosis

Table 12 Clinical staging of tuberculous meningitis

Stage I (early)	Nonspecific symptoms and signs
	No clouding of consciousness
	No neurologic deficits
Stage II (intermediate)	Lethargy or alteration in behavior
	Meningeal irritation
	Minor neurologic deficits (such as cranial nerve palsies)
Stage III (advanced)	Abnormal movements
	Convulsions
	Stupor or coma
	Severe neurologic deficits (pareses)

Adapted from the British Medical Research Council [13]; with permission

Table 13 Symptoms and signs of TB meningitis

Manifestations	Children, %	Adults, %
Symptoms		
Headache	20–50	50–60
Nausea/vomiting	50–75	8–40
Apathy/behavioral changes	30–70	30–70
Seizures	10–20	0–13
Prior history of tuberculosis	55	8–12
Signs		
Fever	50–100	60–100
Meningismus	70–100	60–70
Cranial nerve palsy	15–30	15–40
Coma/altered consciousness	30–45	20–30
Purified protein derivative-positive	85–90	40–65

Adapted from Thwaites et al. [16]; with permission

meningitis occur along with cranial nerve palsies. Behavior alteration and lethargy may be seen. This stage progresses over days to weeks to stage III (advanced), in which seizures, stupor or coma, focal neurologic signs, and decorticate or decerebrate posturing occur. Without treatment, the course proceeds steadily downhill to death in 6–12 weeks. Disease progression tends to occur faster in adults. Rarely, other forms of tuberculous meningitis may be seen. It can present acutely, similar to acute bacterial meningitis, with a more rapid course. Infrequently, it has a more chronic course, with slowly developing hydrocephalus, similar to fungal meningitis. A stroke syndrome has also been associated with tuberculous meningitis.

The clinical presentation of tuberculous meningitis in children is somewhat different from the presentation in adults (Table 13). Nausea and vomiting as well as behavioral changes are more common in children, whereas headache is clearly more common in adults. Children also frequently complain of abdominal pain and constipation. In both groups, seizures increase in frequency with disease progression. On examination, fever and meningismus are the most common signs in both age groups, although the frequency varies greatly. Cranial nerve palsies are present in some patients at presentation but eventually occur in about half of all cases. The sixth cranial nerve is involved most commonly, followed by the third, fourth, and seventh cranial nerves. Examination of the optic fundus may reveal tubercles in a small percentage of patients. Funduscopic examination may also reveal papilledema due to increased intracranial pressure from hydrocephalus. Hydrocephalus correlates well with the duration of disease and eventually occurs in most cases.

CNS tuberculosis can have a number of additional manifestations. Caseating granulomas of epithelioid cells and macrophages containing mycobacteria may occur in the brain as single or multiple focal lesions. Infrequently, caseating necrosis occurs, forming a tuberculous (cold) abscess. Both lesions often occur without meningitis. Most often, the initial presentation of tuberculoma and abscess is similar to that of a brain tumor, with headaches from increased intracranial pressure, seizures, focal deficits, and altered mental status. Less frequently, seizure or focal deficits may be the first manifestations. The most common form of tuberculo-

sis of the spine is epidural compression of the thoracic cord from vertebral and disc destruction by caseating granulomas (tuberculous osteomyelitis). Less frequently, the lumbar or cervical spine may be affected. The clinical manifestations are those of chronic epidural cord compression, with back pain increased with weight bearing; percussion tenderness over the spine; a spastic paraparesis, often with a sensory level; and bowel and bladder dysfunction. Localized and severe percussion spine tenderness with painful limitation of spinal motility is referred to as a "spinal gibbus." Tuberculous meningomyelitis is the rare occurrence of infection of the spinal leptomeninges without spine involvement; it has also been referred to as spinal meningitis, spinal arachnoiditis, and spinal radiculomyelitis. Thick exudates and tubercles encase the nerve roots and spinal cord. This process presents as subacute to chronic radiculomyelitis or as cauda equina syndrome. It appears mainly in highly endemic areas but has been reported in AIDS patients in the United States. Intramedullary tuberculomas are rare and have clinical presentations similar to other spinal cord tumors.

In tuberculous basilar meningitis (Fig. 7), the tubercle bacillus enters the human host through inhalation. Airborne droplets reach the alveoli and multiply there or in alveolar and circulating macrophages. During this 2- to 4-week stage of infection, hematogenous dissemination occurs, and delayed secondary hematogenous dissemination may also occur. During dissemination, tubercles form in multiple organs, including the brain. Eventually, tubercles rupture into the subarachnoid space or ventricular system to cause meningitis.

The initial pathologic event after tubercle rupture is the formation of a thick exudate in the subarachnoid space. This exudate initially begins at the base of the brain, where it is especially thick, and envelops cranial nerves, causing cranial nerve palsies.

Another manifestation of CNS TB is tuberculous hydrocephalus (Fig. 8). With the thick basilar exudate of tuberculous meningitis, often the foramina of Luschka and Magendie become obstructed. Obstruction also may occur at the level of the aqueduct, causing noncommunicating hydrocephalus, increased intracranial pressure, and papilledema. Another possibility is communicating hydrocephalus caused by blockage of the basilar cisterns, interfering with the resorption of CSF. Either type of hydrocephalus may result in brain atrophy.

Table 14 shows the prevalence of TB of the CNS in AIDS patients. In the first half of the twentieth century, autopsy studies revealed that 5–10% of patients with TB had CNS involvement. TB in AIDS patients is thought to occur because

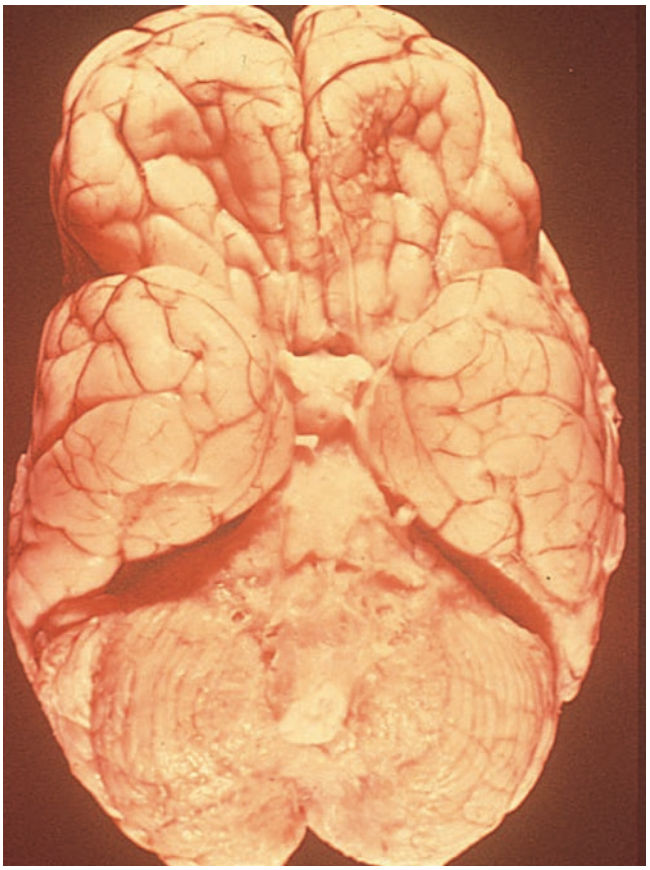

Fig. 7 Tuberculous basilar meningitis. (From Wilson [4])

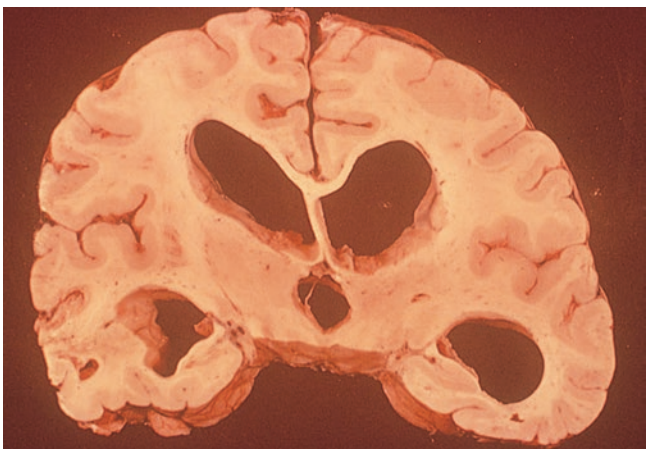

Fig. 8 Tuberculous hydrocephalus. (From Wilson [4])

Table 14 Prevalence of TB of the CNS in AIDS patients

Location	Year	Cases of active TB/ Cases of AIDS	Cases of TB with CNS disease
Florida	1984	27/45 (60%)	2 of 27 (7%)
New Jersey	1986	52/420 (12%)	10 of 52 (19%)
New York City	1986	24/280 (9%)	1 of 24 (4%)
San Francisco	1987	35/1705 (2%)	2 of 35 (6%)
Barcelona, Spain	1988	Not available	5 of 65 (8%)

Adapted from Zuger and Lowy [15]; with permission

of reactivation; most cases are pulmonary, but the incidence of extrapulmonary disease is much greater than that of the general population. Rates of tuberculin PPD reactivity range from 33% to 50% in AIDS patients, compared with 50–90% in the general population. The incidence of CNS involvement is similar to that of the general population, but mortality is much higher in HIV-infected individuals [14, 16].

The laboratory diagnosis of tuberculous meningitis (Table 15) is difficult. Routine CSF parameters (lymphocytic pleocytosis and low glucose), CSF adenosine deaminase, and CSF imaging [19] are nonspecific. Acid fast bacilli (AFB) staining, CSF culture, tuberculin skin test, and chest radiograph have low sensitivity. CSF culture is specific but takes too long for needed early diagnosis. PCR sequence amplification has the greatest sensitivity, depending on which sequence is amplified.

Chemotherapeutic options for tuberculous meningitis have been extrapolated from the treatment of other forms of TB (Table 16). Because of the rarity of tuberculous meningitis in developed countries, questions related to the optimal regimen, doses, routes of administration, and length of treatment have not been clarified. The number of drugs used depends on the probability of drug resistance. Recently, it has been found that ethambutol poorly penetrates even inflamed meninges. Thus, a fluoroquinolone (moxifloxacin or levofloxacin) or streptomycin may be substituted [21]. Most drug-resistant cases in the United States occur in AIDS patients and prisoners. Antituberculous chemotherapy must be initiated as soon as tuberculous meningitis is suspected based upon the CSF formula. Delays in treatment due to waiting for positive results from smears or cultures usually result in increased mortality and morbidity. Corticosteroids (dexamethasone) are now recommended as standard treatment [22]. Other adjunctive therapy includes ventricular drainage for hydrocephalus. Tuberculomas presenting with acute swelling and edema (TB brain abscess) should also be treated with steroids; surgical removal may be required [20].

Paradoxical responses to treatment—clinical or radiologic worsening of preexisting TB lesions (abscess formation or enlarging) or the development of new lesions—have been reported for up to 1 year during chemotherapy [23]. Treatment is with steroids with or without surgical intervention. AIDS patients who are naïve to antiretroviral therapy (ART) and commence ART treatment during treatment of TB meningitis may present with the immune reconstitution inflammatory syndrome (IRIS), which requires treatment with high-dose intravenous steroids [24].

Mortality and morbidity rates depend on several factors, including the patient's age, the duration of symptoms, and the stage of the disease.

Table 15 The laboratory diagnosis of tuberculous meningitis

Test	Positivity, %	Problems
CSF lymphocytic pleocytosis with decreased glucose	~75	Nonspecific
AFB CSF staining	~32	Low sensitivity
		Microscopic time dependent
CSF culture	~50	Low sensitivity
		Too long for early diagnosis
CSF adenosine deaminase	~75	Low specificity
		Not always available
PCR	50–98	Depends on sequence amplified
Tuberculin skin test	Adults 40–65	Low sensitivity in adults
	Children 85–90	
Chest radiograph	Adults 25–50	Low sensitivity
	Children 15–20	
CSF imaging (CT or MRI)	75–85	Nonspecific

Adapted from Rafi et al. [17] and Solomons et al. [18]; with permission

Intracranial Epidural Abscess

An intracranial epidural abscess is a localized area of infection between the skull and dura caused by the spread of infection from contiguous locations, such as the paranasal sinuses, the ear, and the orbit or because of skull defects (Table 17). Because the abscess grows by pushing the dura away from the skull, the process is slow and the lesion is well

Table 16 Recommended treatment regimen for tuberculous meningitis from The American Thoracic Society, Centers for Disease Control and Prevention, and The Infectious Diseases Society of America, 2003

	Initial regimen		Subsequent regimen	
	Drug	Duration	Drug	Duration
Low suspicion of drug resistance	Isoniazid	2 mo	Isoniazid	7–10 mo
	Rifampin	2 mo	Rifampin	7–10 mo
	Pyrazinamide	2 mo		
	Ethambutol[a]	2 mo		
	Dexamethasone[b]	6 wk		
High suspicion of drug resistance	In consultation with a specialist, begin treatment with at least three previously unused drugs to which in vitro susceptibility is likely. Depending on resistance pattern, treatment may have to continue for up to 24 mo			

Adapted from The American Thoracic Society [20]

[a]See Donald [21]

[b]Recommended does: 8 mg/d for children <25 kg and 12 mg/d for children >25 kg and adults for 3 wks, then tapered over the next 3 weeks

Table 17 Clinical manifestations and pathogenesis of intracranial epidural abscess

Clinical manifestations	Sources of infection
Early	Extension of contiguous infections
Fever	Paranasal sinusitis
Symptoms related to the source of infection	Orbital cellulitis
Sinusitis, otitis, etc.	Otitis
Headache	Mastoiditis
Localized skull tenderness from osteomyelitis	Cranial defects
Scalp and face cellulitis from osteomyelitis	Skull fracture
Cranial nerve palsies—rare	Neurosurgical procedures
Late	
Seizures	
Focal neurologic deficits	
Meningismus	
Nausea and vomiting from increased ICP	
Papilledema from increased ICP	
Altered mental status from increased ICP	
Cranial nerve palsies—rare	

circumscribed. Osteomyelitis of the skull may accompany the process, causing swelling and edema of the scalp and face, and skull tenderness. Fever, headache, lethargy, nausea, and vomiting are common. Because the abscess grows slowly, seizures, focal neurologic deficits, papilledema, and an altered level of consciousness with increased intracranial pressure occur late in the course. Cranial nerve palsies are uncommon, but may occur from increased intracranial pressure or when the abscess involves sites in which cranial nerves penetrate the dura. Infection of the apex of the petrous temporal bone may involve cranial nerves V and VI, causing facial pain, sensory loss, and lateral rectus palsy ("Gradenigo's syndrome"). Complications from the spread of infection include dural sinus or cortical vein thrombosis with infarction, subdural empyema, meningitis, and brain abscess.

The organisms responsible for intracranial epidural abscess are those commonly associated with the primary infectious process in the paranasal sinuses or ears (Table 18). Cranial epidural abscess is rare in young children; it occurs mainly in adolescents and adults. The exact incidence of intracranial abscess is not known, but it is much less common than subdural empyema and brain abscess.

Diagnosis of an intracranial epidural abscess is made by CT (Fig. 9) or MRI. Even if the initial CT scan is not diagnostic, contrast-enhanced MRI scanning should clarify the diagnosis. The CSF usually reveals a picture of a chronic parameningeal focus with mononuclear pleocytosis, normal glucose levels, and sterile cultures. Differential diagnoses include epidural tumor, epidural hematoma, subdural hemorrhage, subdural empyema, dural sinus or cortical vein thrombosis, and less frequently, brain abscess or brain tumor.

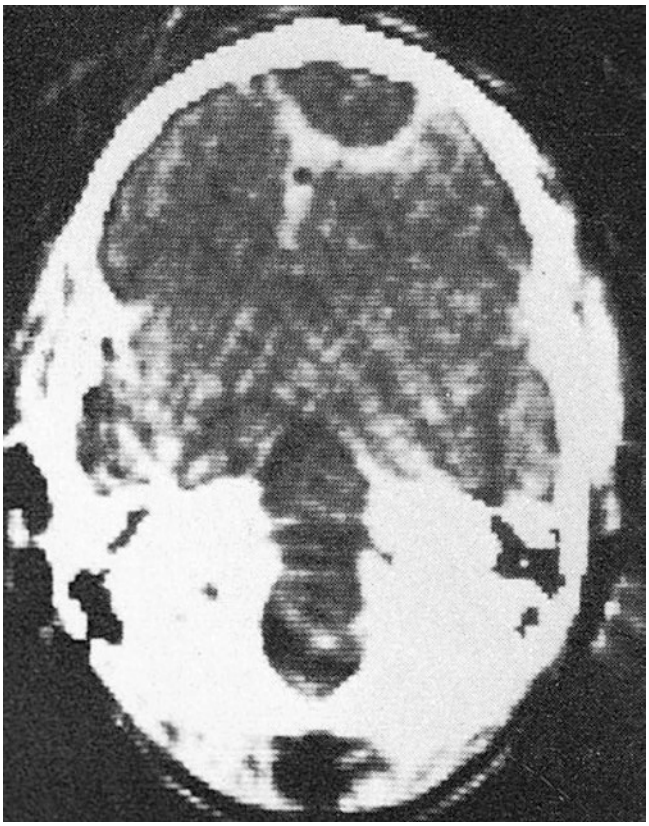

Fig. 9 CT scan of an epidural abscess revealing a lesion that is well-localized, extracerebral, hypodense, and lenticularly shaped, with a nonenhancing, hyperdense medial capsule. (From Weisberg et al. [25], with permission)

Table 18 Etiology of intracranial epidural abscess.

Organisms commonly causing intracranial epidural abscess (by location of primary infection)		
Paranasal sinuses	Otitis media	Cranial trauma or surgery
Hemolytic streptococci	*Streptococcus pneumoniae*	Staphylococci
Microaerophilic streptococci	*Haemophilus influenzae*	Streptococcal pneumonia
Gram-negative aerobes	Hemolytic streptococci	
Bacteroides or other anaerobes	Gram-negative aerobes	
Rhinocerebral mucormycosis (in diabetic or immunosuppressed patients)		

As outlined on Table 19, therapy for intracranial epidural abscess consists of antibiotic therapy combined with neurosurgical drainage and decompression. Antibiotic therapy should be continued for 4–6 weeks, and for 8 weeks with

Table 19 Treatment of intracranial epidural abscess

Empiric antibiotic therapy
Paranasal sinus or otitis source of infection
Vancomycin plus metronidazole plus ceftazidime
Cranial trauma or surgery
Vancomycin plus ceftazidime (or plus meropenem)
Surgical drainage and decompression
Gram stain and culture for bacteria and fungi
Craniectomy for osteomyelitis
Dural debridement; excision and grafting not usually required
Closure of any communication between sinus cavity and epidural space to prevent reaccumulation
Institute specific antibiotic therapy based on culture results

associated osteomyelitis. The prognosis for these epidural infections is excellent, with no mortality in recent series, probably because the process is usually subacute to chronic and CT and MRI are excellent diagnostic tools.

Spinal Epidural Abscess

The epidural space in the spinal cord is a true space, unlike the potential epidural intracranial space. In the spinal cord, the dura and arachnoid are closely approximated, so that the subdural space is only a potential space, and spinal subdural empyema or abscess is rare; spinal epidural abscess is much more common. Spinal epidural abscess is an emergency because spinal cord compression and paraplegia are possible complications that can occur rapidly, over hours. It can be acute (symptoms are present less than 2 weeks) or chronic (symptoms are present for more than 2 weeks); the acute form is more common. Four stages of progression of spinal epidural abscess have been recognized (Table 20). The acute form presents as an acute cord compression. Progression from stages I to II and from stages II to III usually takes 1–4 days each. Once stage III is reached, complete paralysis may occur in hours. In the acute form, fever, malaise, and a "flulike" prodrome may occur. The chronic form presents as an expanding tumor, usually without fever or other prodromal symptoms.

Table 21a, b demonstrates the pathogenesis and pathophysiology of spinal epidural abscess. Spinal epidural abscesses tend to occur most frequently in the thoracic and lumbar levels, posterior to the cord, where the epidural space is largest and contains more epidural fat. The most common source of infection is hematogenous or metastatic seeding occurring from cutaneous, respiratory, abdominal, pelvic, urinary, cardiac, or dental sites of infection, as well as from intravenous drug use. Hematogenous seeding is most likely to occur in the thoracic area owing to the end-anastomotic blood supply in this area. Contiguous sources of infection include vertebral body osteomyelitis and retroperitoneal and perinephric infections. Trauma and surgery (back surgery, epidural catheterization for anesthesia and pain control, dorsal column stimulators, lumbar puncture) play a lesser role. Medical conditions associated with spinal epidural abscess include diabetes, malignancy, cirrhosis, renal failure, and

Table 20 Clinical stages of progression of spinal epidural abscess

Stage I	Severe localized back pain
	Exquisite spinal percussion tenderness
	Paraspinal muscle spasm
Stage II	Nerve root irritation with radiating pain and paresthesia (radiculopathy)
	Focal weakness or reflex changes
Stage III	Spinal cord compression, with
	Progressive weakness
	Sensory loss
	Bowel and bladder dysfunction
Stage IV	Complete paralysis
	Sensation is impaired below sensory level at or near the cord segment of the lesion

Table 21a Pathogenesis and pathophysiology of spinal epidural abscess: location of spinal epidural abscess

Location	Patients, *n (%)*
Cervical	20 (14)
Thoracic	71 (51)
Lumbar	48 (35)
	Total: 139 (100)
Anterior	28 (21)
Posterior	105 (79)
	Total: 133 (100)

Adapted from Danner and Hartman [26]; with permission

Table 21b Pathogenesis and pathophysiology of spinal epidural abscess: source of infection of spinal epidural abscess

Source	Percentage of patients[a]
Hematogenous seeding	43
Skin and soft tissues	20
Abdomen and pelvis	7
Respiratory system	6
Intravenous drug use	5
Urinary tract	2
Cardiac system	2
Dental infection	1
Contiguous location	27
Vertebral osteomyelitis	8
Retroperitoneal or retromediastinal infection	7
Perinephric or psoas abscess	8
Decubitis ulcers	4
Surgery and trauma	5
No source identified	25
Total	100

Adapted from Danner and Hartman [26]; with permission
[a]Estimates compiled from various series

alcoholism. By far the most common etiologic agent is *Staphylococcus aureus*, although gram-negative aerobic bacilli (especially *Escherichia coli* and *Pseudomonas* species) have accounted for an increasing percentage of cases. In addition, TB has accounted for up to 25% of cases in recent series.

Patients with acute spinal epidural abscess have a high peripheral leukocyte count (12,000 to 15,000 cells per mm^3). If the process is chronic, the peripheral leukocyte count may be normal. CSF examination is consistent with parameningeal infection, with an elevated cell count, elevated protein level, normal glucose level, and negative cultures. When the process is acute, usually polymorphonuclear leukocytes predominate, with up to 100–200 cells per mm^3. In chronic cases, mononuclear cells predominate, usually with fewer than 50 cells per mm^3. CSF cultures are negative unless the organism has spread to the CSF and subsequently caused meningitis. Blood cultures are positive 60% to 70% of the time. The definitive diagnostic studies, however, are CT myelograms and MRI scans, with MRI the study of choice (Fig. 10). MRI scans directly visualize the extent of the abscess and should include T1-weighted images before and after contrast enhancement and T2-weighted images.

Treatment usually consists of surgical decompression, abscess drainage, and parenteral antibiotics. Empirical treatment is similar to the treatment for intracranial epidural abscess, with vancomycin plus a third- or fourth-generation cephalosporin. Once the etiologic bacteria have been identified, the antibiotic regimen should be adjusted based on sensitivities. Antibiotic treatment should continue for at least 4 weeks (8 weeks with osteomyelitis). Corticosteroids have been used for cord compression, but their benefit has not been subjected to controlled studies.

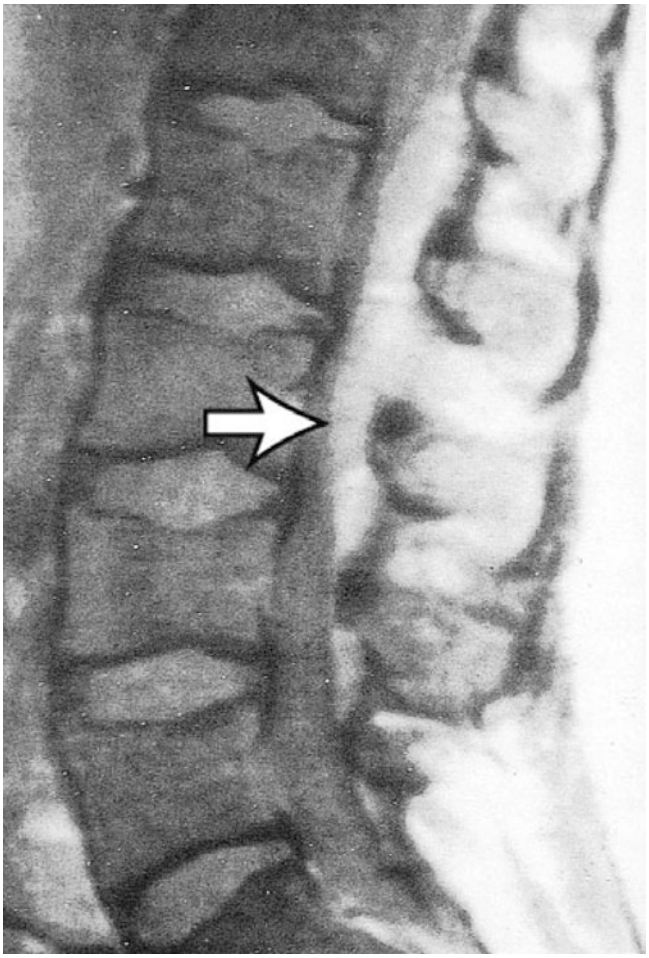

Fig. 10 Contrast-enhanced T1-weighted MRI done as part of a diagnostic workup for spinal epidural abscess. This scan reveals an epidural mass (*arrow*) extending from the lower part of the L1 vertebral body to the upper part of the L4 vertebral body. (From Gelfand et al. [27]; with permission)

Intracranial Subdural Empyema

Subdural empyema is a fulminant, purulent infection that spreads over the cerebral hemispheres in the existing subdural space. It is usually confined to one side of the brain by the anatomic barriers of the falx and tentorium. Undiagnosed and untreated, subdural empyema is rapidly fatal, and therefore it is a neurologic emergency. Usually patients have a nonspecific prodrome for several days to a week and then become acutely ill. After head trauma or surgery, the presentation may be milder and more subacute. The presenting manifestations usually include fever, headache, vomiting, and mild confusion (Table 22) [28]. These are shortly followed by hemiparesis, nuchal rigidity, and seizures. As the process continues, increased intracranial pressure causes papilledema and alteration of consciousness. At the end of the first week and into the second, cortical vein thrombosis begins to occur, causing infarcts and additional focal deficits.

Table 22 Clinical manifestations of subdural empyema

Signs/Symptoms	Patients, n^a	Percentage
Fever	451	78
Headache	467	74
Hemiparesis	389	71
Altered consciousness	544	69
Nuchal rigidity	416	60
Seizures	607	49
Papilledema	238	33
Altered speech	364	22
Other focal deficits	296	46

Adapted from Hartman and Helfgott [29]; with permission
[a]Total number of patients assessed for the specific manifestation

The exudate in acute subdural empyema is usually grey or yellowish (Fig. 11). The histologic findings in subdural empyema are typical of acute inflammatory processes: The exudate is composed primarily of polymorphonuclear leukocytes, although a few lymphocytes and plasma cells may be present.

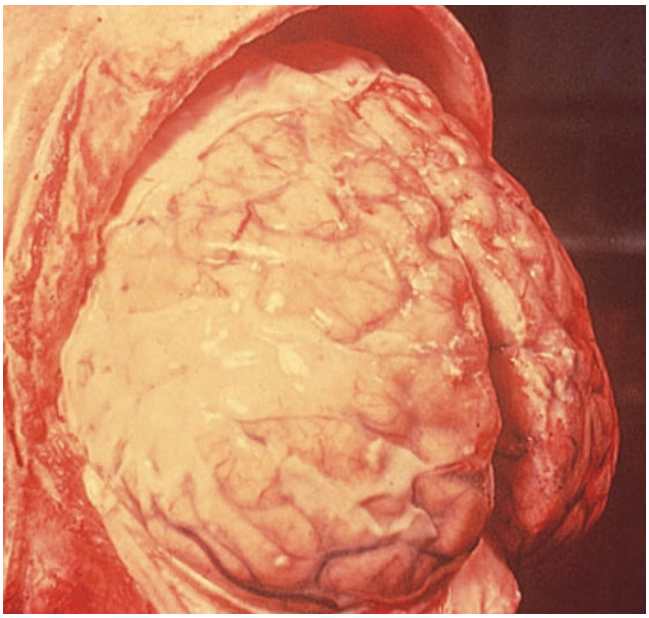

Fig. 11 Pathologic specimen showing acute subdural empyema with large amounts of exudate overlying parts of the left cerebral hemisphere. (From Wilson [4])

Table 23 Etiology of adult subdural empyema

Organism	Incidence[a], %
Streptococci	
Aerobic[b]	36
Anaerobic	10
Staphylococci	
Coagulase-positive	9
Coagulase-negative	3
Aerobic gram-negative bacilli[c]	10
Other anaerobes	6
Sterile	29

Adapted from Hartman and Helfgott [29]; with permission
[a]394 evaluated cases, total greater than 100% because of multiple isolates from single cases
[b]Includes α-hemolytic, β-hemolytic, and nonhemolytic
[c]Mostly enteric bacilli

Table 23 lists the predisposing causes, pathogenesis, and etiology of subdural empyema. About 75% of cases occur in males, perhaps owing to the growth of the frontal sinuses in boys during puberty. The most common predisposing cause of subdural empyema is sinusitis (54%). After infection has started in the sinuses, the middle ear, or other areas of the head, it spreads to the subdural space by means of venous drainage. Emissary veins connect the large veins of the scalp and face with the dural venous sinuses, and because the veins of the head and brain are valveless, retrograde spread of thrombophlebitis into the dural and cortical veins from infected venous sinuses may occur. The frontal sinus is probably the single most predisposing site of infection; the incidence of subdural empyema following frontal sinusitis is 1–2%. Another predisposing cause of subdural empyema is infection and trauma of the head (about 13%). This is followed by otogenic infections (otitis, mastoiditis—about 13%), which may also spread to the subdural space by erosion of bone. Otogenic infections usually cause a posterior fossa (infratentorial) subdural empyema; about 10% of all cases are infratentorial. A minor predisposing cause of subdural empyema is hematogenous spread (about 3%). About 40% of cases of subdural empyema occur during the second decade of life, followed by the third (about 15%), first (about 11%), fourth (about 10%), and fifth (about 9%) decades. Streptococci and staphylococci are the most common causative organisms. Sinus and ear infections usually result in streptococcal subdural empyema, whereas head trauma or surgery usually results in a staphylococcal subdural empyema. Meningitis is an important predisposing condition in infants but not in adults.

The diagnostic studies of choice for subdural empyema are CT scans with contrast and MRI scans (Fig. 12). Routine blood tests may reveal an elevated leukocyte count, especially in acute subdural empyema. Lumbar puncture is usually contraindicated because of focal deficits, increased intracranial pressure, and abnormalities on CT or MRI scans. When lumbar puncture is performed, the picture is one of parameningeal inflammatory response with an increased cell count; about 15% of cases have more than 1000 cells per mm^3. The response is acute with greater than 50% polymorphonuclear leukocytes in about 70% of cases. The glucose level is usually normal and cultures are negative in more than 90% of cases. The differential diagnosis includes epidural abscess, brain abscess, intracerebral thrombophlebitis, subdural hematoma, meningoencephalitis, pyogenic meningitis (especially after infarction has occurred), herpes simplex encephalitis, cysticercosis, and cerebral neoplasm.

Treatment consists of the immediate deployment of parenteral antibiotics, followed by surgical drainage. Empirical antibiotic therapy could include a third-generation cephalosporin (*eg*, ceftriaxone) for broad spectrum coverage, plus vancomycin for methicillin-resistant staphylococci and anaerobes (such as bacteroides [30]. Mortality remains high, at about 20% to 30%. Prognosis depends on the level of consciousness at the time of treatment.

Brain Abscess

The clinical manifestations of brain abscess (Table 24) depend upon the location of the lesion, whether the lesion is single (75% of cases) or multiple, and the duration of the process (fulminant or indolent, hours to several months—average 10–13 days). In most cases, the manifestations are those of an expanding intracerebral mass with few signs of infection. The headache may be focal, from a mass lesion,

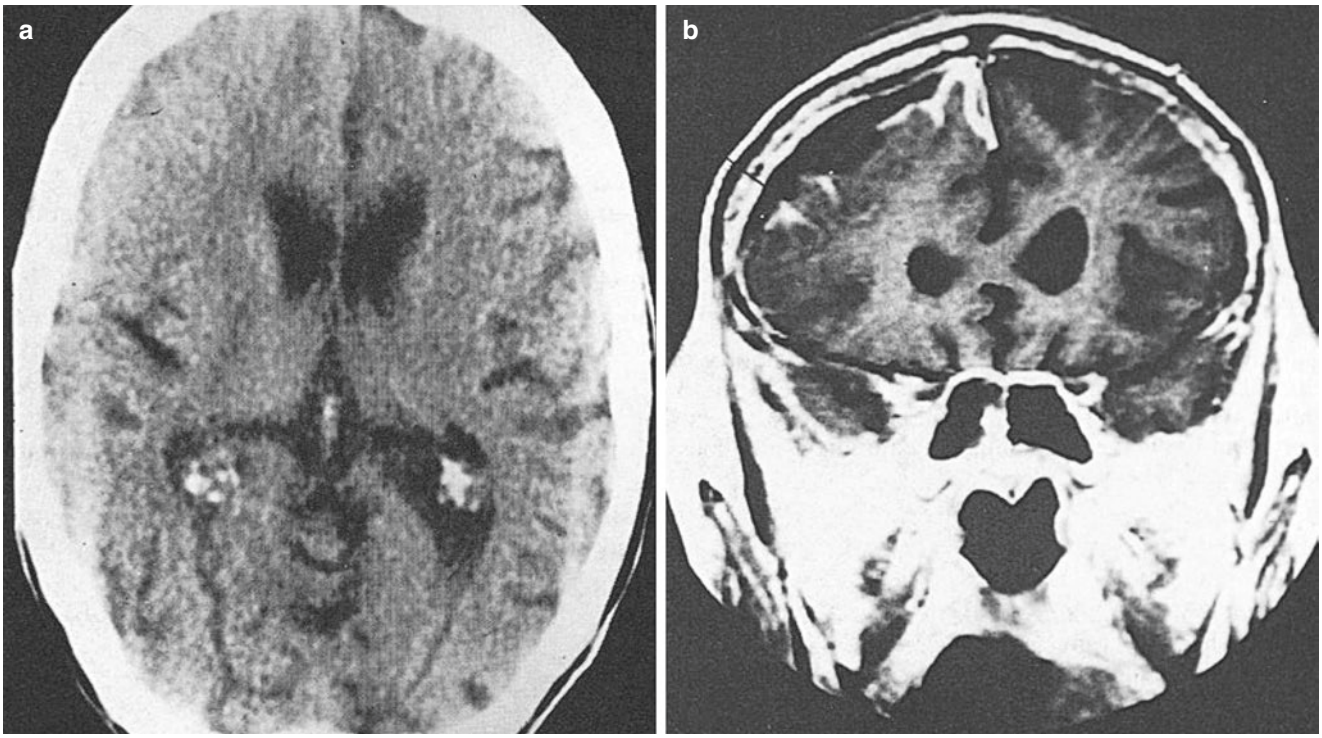

Fig. 12 CT scan with contrast and MRI scan of subdural empyema done as part of a diagnostic work-up. (**a**) CT scan reveals effaced sulci over the right hemisphere, with only minimal mass effect. (**b**) MRI scanning with contrast reveals the large subdural empyema with mass effect. (From Tunkel [30]; with permission)

Table 24 Clinical manifestations of brain abscess

Manifestation	Percent (approximations)
Headache	75
Fever	50
Nausea/vomiting	50
Focal neurologic deficits	50
Altered mental status	50
Seizures	30
Signs of systemic infection	30
Nuchal rigidity	25
Papilledema	25

or diffuse, suggesting increased intracranial pressure. Focal neurologic deficits and seizures are usually caused by the mass itself, while nausea or vomiting, papilledema, and altered mental status are due to increased intracranial pressure. Focal deficits include hemiparesis, hemianopsia, hemisensory loss, and aphasia. About 25% of abscesses involve the posterior fossa, primarily the cerebellum.

Brain abscesses are usually associated with a contiguous site of infection, head trauma, or surgery, and hematogenous spread from distant sites of infection. A contiguous site of infection usually accounts for about 40–50% of the cases; hematogenous spread, for about 25–35%; and head trauma or surgery, for about 10%. In about 15% of cases, there is no obvious predisposing factor. Unlike other age groups, brain abscess complicates meningitis in neonates. The predisposing condition plays a definite role regarding the site of the abscess in the brain and which organisms cause the abscess.

In the preantibiotic era, *Staphylococcus aureus*, streptococci, and coliform bacteria were the common isolates from brain abscess. In the past 20 years, however, anaerobes (*Streptococci intermedius* group, *Bacteroides* species) are probably the most common cause in patients who are not immunologically compromised.

Patients with AIDS, underlying malignancy, or those treated with immunosuppressive agents are at an increased risk for developing brain abscess. Fungi and parasites are also important diagnostic considerations in these patients (Table 25). Neutropenia and neutrophilic defects are most often due to chemotherapy.

The differential diagnosis of brain abscess in the immunologically uncompromised host (Table 26a) includes entities causing focal neurologic deficits, which are usually seen early in the course, and diffuse manifestations, which are seen later in the course of brain abscess. In AIDS patients (Table 26b), focal neurologic infections and processes of diverse and unusual etiologies have been recognized. The most common cause of focal neurologic lesions is toxoplasmosis, followed by lymphoma.

Routine laboratory studies are usually not helpful for diagnosis of brain abscess; they may show peripheral leukocytosis

Table 25 Microbiologic etiology of brain abscess in the immunologically uncompromised host

Etiologic organisms	Isolation frequency, %
Streptococci	
S. intermedius group including S. anginosus	60–70
S. pneumoniae	<1
Staphylococcus aureus	10–15
Gram-negative organisms	
Bacteroides and *Prevotella*	20–40
Enterobacteriaceae	23–33
Haemophilus influenzae	<1
Fungi	10–15
Protozoa, helminthes	*Consider:* Variable (Heavily dependent on geographic locale)

Adapted from Wispelwey et al. [31]; with permission

Table 26a Differential diagnosis of brain abscess in the immunologically uncompromised host

Subdural empyema
Pyogenic meningitis
Viral encephalitis (especially herpes simplex)
Cysticercosis
Cerebral infarction
Mycotic aneurysms
Epidural abscess
Primary cerebral neoplasms (glioblastoma)
Metastatic malignancies
Hemorrhagic leukoencephalitis
Echinococcosis
Cryptococcosis
Central nervous system vasculitis
Chronic subdural hematoma
Intracerebral thrombophlebitis
Arteriovenous malformation (AVM)
Tumefactive multiple sclerosis
Neurosarcoidosis

Adapted from Klein et al. [34]; with permission

Table 26b Differential diagnosis of brain abscesses in patients with AIDS

Toxoplasmosis
Primary central nervous system lymphoma
Mycobacterium tuberculosis
Mycobacterium avium-intracellulare
Progressive multifocal leukoencephalopathy
Cryptococcus neoformans
Candida species
Listeria monocytogenes
Nocardia asteroides
Salmonella group B
Aspergillus species

Adapted from Klein et al. [34]; with permission

and increased erythrocyte sedimentation rate, but these findings are nonspecific. In addition to complete blood count, chest radiograph, electrocardiogram, and echocardiogram as needed, blood cultures should also be obtained. Lumbar puncture may reveal a parameningeal response, but the procedure is usually contraindicated until an imaging study of the brain has been performed. CT imaging should be performed with and without contrast (Fig. 13). MRI is even more sensitive, and reveals abscess or cerebritis at earlier stages of development than CT (Fig. 14).

Treatment of brain abscess (Table 27) usually consists of both surgical and medical therapy. CT-guided aspiration of the abscess is needed for microbiological diagnosis [32]. Surgical treatment is generally contraindicated when there are multiple abscesses, but multiloculated abscesses are excised at times. Medical therapy consists of empirical antibiotic therapy until specific agents and sensitivities are determined. Treatment of complications include corticosteroids for life-threatening mass effects, anticonvulsants for seizures, ventricular drainage for hydrocephalus, and antibiotics and ventricular drainage for ventriculitis/meningitis.

Statistical analysis clearly revealed that aggressive treatment was significantly beneficial. Over the past five decades, the case fatality rate decreased from 40% to 10%, and the rate of patients with full recovery increased from 33% to 70% [33].

Viral Infections

The numerous viruses causing nervous system infections can be classified according to virus characteristics and the type of disease produced (Table 28). Viruses are classified according to their nucleic acid type (RNA or DNA), sensitivity to lipid solvents (enveloped *vs* nonenveloped), and their size. The infections produced may be either acute or chronic. In temperate zones of the northern hemisphere, some of the viruses causing meningitis and encephalitis have a distinct seasonal activity—especially the enteroviruses and mosquito-borne and tick-borne arboviruses that have peak epidemic activity in the spring and summer. Mumps is more often seen in late winter or spring, and lymphocytic choriomeningitis, in the fall and winter. Herpesviruses are endemic and cause disease in any season.

Acute viral infections of the CNS may cause three syndromes: viral (aseptic) meningitis, encephalitis, and myelitis (Table 29). Acute viral meningitis is a self-limited illness, accompanied by fever, headache, photophobia, and nuchal rigidity. Encephalitis implies involvement of the brain parenchyma, causing alteration of consciousness, seizures, and focal neurologic deficits. When both meningeal and encephalitic signs are present on examination, the term *meningoencephalitis* is sometimes used in the diagnosis. Viral myelitis is an infection of the spinal cord. The myelitis is most often considered a demyelinating white matter syndrome (transverse myelitis), but spinal motor neurons (poliomyelitis, paralytic disease), sensory neurons, and autonomic neurons (bladder paralysis) may be affected. If encephalitis and myelitis occur together, the term *encephalomyelitis* is used. The CSF for-

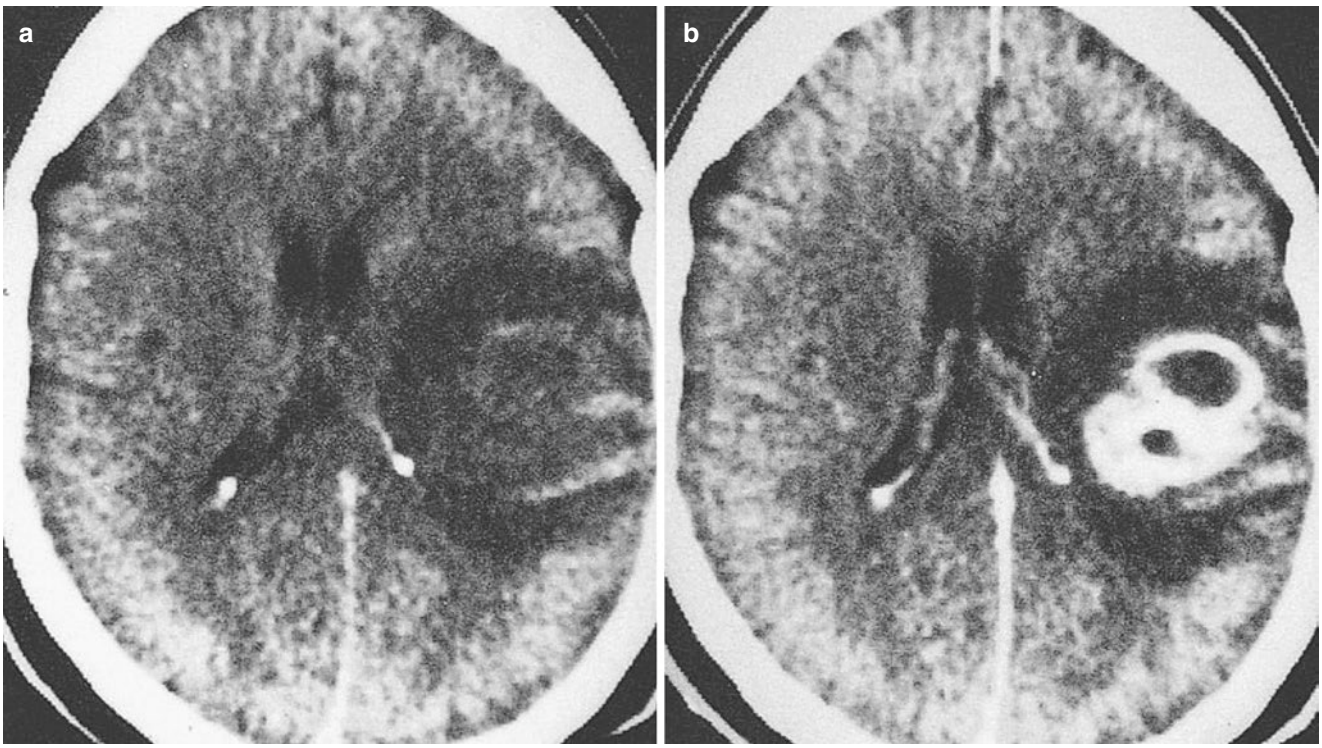

Fig. 13 CT imaging studies for brain abscess. (**a**) Plain axial CT reveals mass effect in the left hemisphere with effacement of the sylvian fissure and the ipsilateral ventricle. (From Wispelwey et al. [31], with permission.) (**b**) With contrast, CT reveals a multiloculated, ring-enhanced lesion. The surrounding area of decreased attenuation represents cerebral edema. (From Falcone and Post [35], with permission)

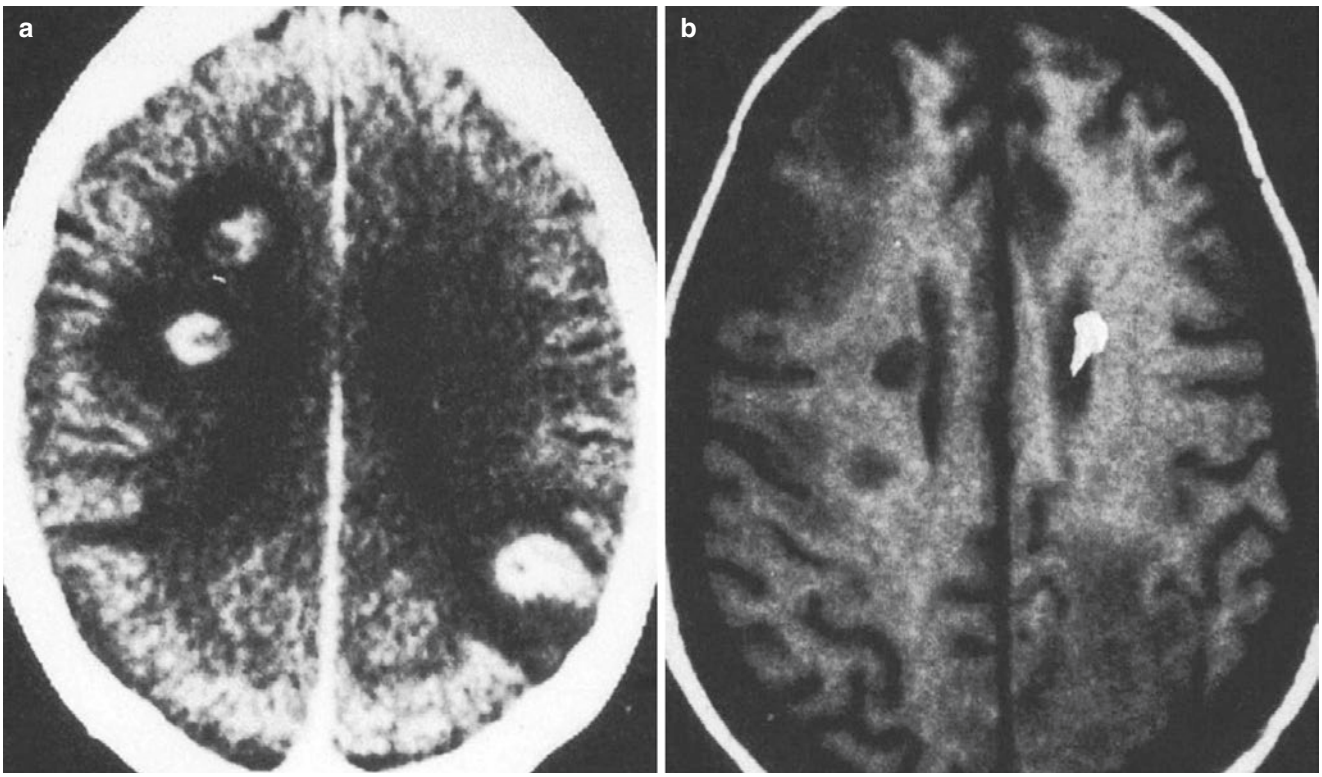

Fig. 14 (**a**) Axial CT scan showing multiple areas of contrast enhancement in a patient with AIDS and cerebral toxoplasmosis. (**b**) T1-weighted images showing periventricular and gray-white junction lesions consistent with hematogenous dissemination. (**c**) After gadolinium administration, contrast enhancement is seen on the T1-weighted image corresponding to that in (**b**). (**d**) Axial T2-weighted image showing edema surrounding multiple cortical and subcortical lesions. (From Kastenbauer et al. [36])

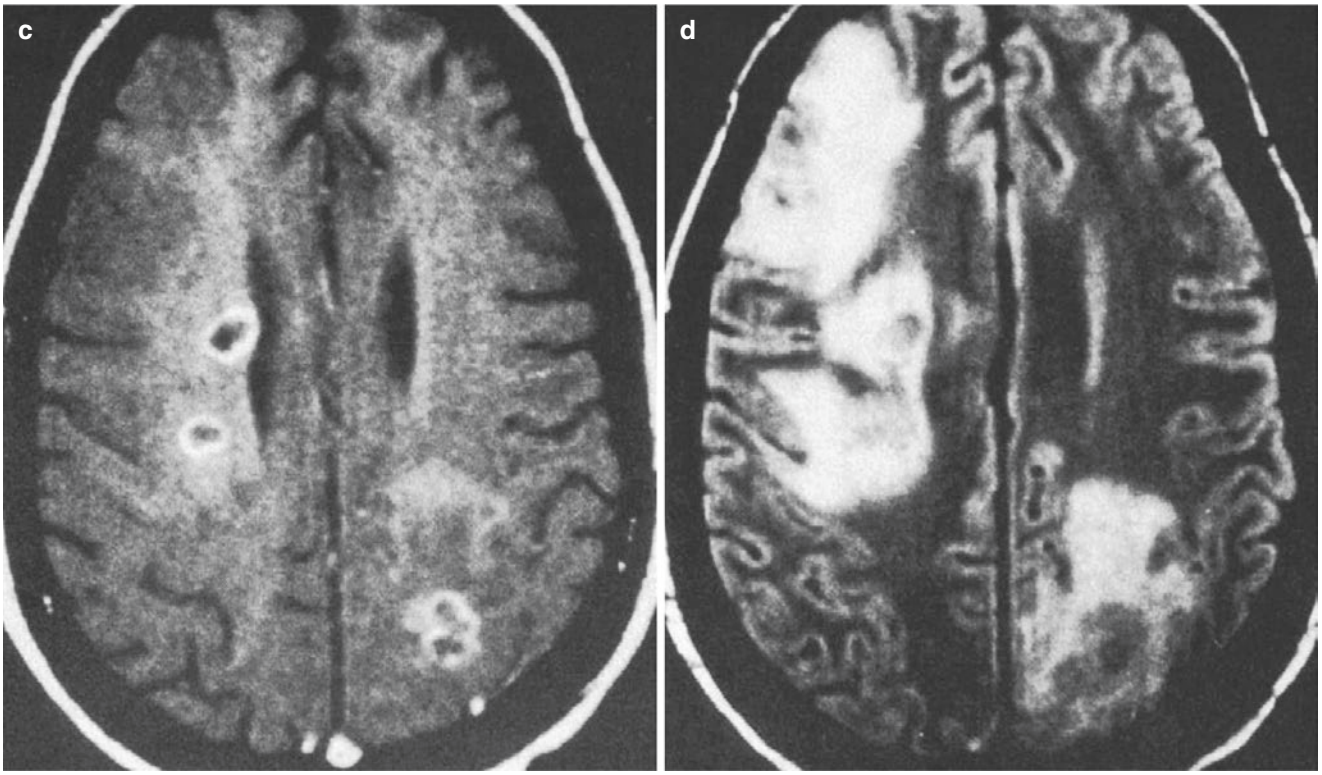

Fig. 14 (continued)

Table 27 Treatment of brain abscess

Surgical treatment
Aspiration
Excision—When aspiration fails
Medical treatment
Antimicrobal therapy—Empirical
Community acquired, immunocompetent patient
Third-generation cephalosporin (ceftriaxone or cefotaxime) and metronidazole
Posttraumatic or postoperative
Meropenem (or cefepime) and vancomycin
Corticosteroids—Only for severe edema with mass effect and possible herniation
Anticonvulsant (AC) for seizures
Start AC for patients having seizures
Prophylactic AC controversial
Ventricular drainage for hydrocephalus

Adapted from Klein et al. [34]; with permission

mula in all these viral syndromes is similar, usually showing a mononuclear pleocytosis of 50 to 500 cells per mm^3, normal glucose level, and elevated protein level and pressure. Decreased CSF glucose levels may rarely be seen in viral syndromes caused by lymphocytic choriomeningitis virus, cytomegalovirus (CMV), Epstein-Barr virus (EBV), or varicella zoster virus (VZV). A clinical continuum exists between viral meningitis and encephalitis, as the same spectrum of viruses cause both syndromes, although some viruses more often cause meningitis and others, encephalitis. The role of mumps virus in the etiology of these syndromes has decreased greatly since the 1970s because of vaccination programs.

Specific virologic (culture, nucleic acid detection, antigen detection) and serologic studies are used in the diagnosis of acute CNS viral syndromes (Table 30). Viruses may be isolated from extraneural sites. For most infections, except reactivated infections such as with herpes simplex virus type 1 or herpes zoster, extraneural isolation is usually diagnostic, but obviously isolating virus from the CSF is preferred. Detection of virus-specific nucleic acid by PCR is now readily available for most viral infections. Antigen detection usually requires the use of biopsy material. Serologic studies require a fourfold increase between the acute and convalescent specimen to be considered positive. Acute-phase sera should be obtained immediately or as soon as infection is suspected. If the acute-phase sera is not obtained until the end of the first week of the disease, the chances of seeing a fourfold rise drops to 50%. Most viral infections of the CNS result in the intrathecal synthesis of specific antibody. When analyzing CSF antibody synthesis, one looks for an increased CSF-to-serum antibody ratio. Therefore, paired CSF and serum samples are required. A correction should also be used for blood-brain barrier breakdown, which results in serum-to-CSF antibody leakage. This correction can be performed by using CSF-to-serum albumin or other viral antibody ratios. Unfortunately, most antibody studies are not positive until at least 1 week after the onset of infection.

Table 28 Viral infections of the nervous system

RNA viruses	Representative viruses responsible for neurologic disease
Enterovirus (EV) (picornavirus)	Poliovirus
	Coxsackievirus
	Echovirus
	Enterovirus 70 and 71
Hepatovirus (picornavirus)	Hepatitis A
Togavirus: alphavirus (arbovirus)	Equine encephalitis (Eastern, Western, Venezuela)
Flavivirus (arbovirus)	St. Louis encephalitis
	West Nile encephalitis
	Japanese encephalitis
	Tick-borne encephalitis
Bunyavirus (arbovirus)	California encephalitis
Reovirus: coltivirus (arbovirus)	Colorado tick fever
Togavirus: rubivirus	Rubella
Orthomyxovirus	Influenza
Paramyxovirus	Measles and subacute sclerosing panencephalitis
	Mumps
Arenavirus	Lymphocytic choriomeningitis
Rhabdovirus	Rabies
Retrovirus	HIV, AIDS
	Human T-cell lymphotropic virus (HTLV)
DNA viruses	
Herpesviruses	Herpes simplex (HSV)
	Varicella-zoster (VZV)
	Cytomegalovirus (CMV)
	Epstein-Barr (EBV) (infectious mononucleosis)
	Human herpes virus (6–8)
Papovavirus	Progressive multifocal leukoencephalopathy (PML)
Poxvirus	Vaccinia
Adenovirus	Adenovirus serotypes

Adapted from Jubelt [37]

Table 29 Relative frequency of meningitis and encephalitis of known viral etiology

Viral agent	Viral meningitis, 1976[a], patients, *n (%)*	Viral encephalitis, 1976[bc], patients, *n (%)*	Viral encephalitis, 1981[cd], patients, *n (%)*
Enteroviruses	324 (83)	13 (2)	82 (23)
Mumps	28 (7)	71 (10)	7 (2)
Arboviruses	6 (2)	424 (60)	107 (30)
Herpes simplex	15 (4)	69 (10)	97 (27)
Measles	3 (1)	44 (6)	1 (0.3)
Varicella	5 (1)	58 (8)	30 (8)

[a]Data from Centers for Disease Control and Prevention: Aseptic Meningitis Surveillance, Annual Summary from 1976. Issued January 1979. There were 2534 cases of indeterminate etiology
[b]Data from Centers for Disease Control and Prevention: MMWR-Annual Summary 1977. There were 1121 cases of indeterminate etiology
[c]Includes both primary and postinfectious encephalitis. Almost all cases caused by measles and varicella are postinfectious
[d]There were 1121 cases of indeterminate etiology

Viral Meningitis

Acute viral meningitis (Table 31) is sometimes referred to as "aseptic" meningitis, but the terms are not synonymous, because agents other than viruses—for example, parameningeal infection, autoimmune disease, vasculitis, malignancies, and chemicals—also cause aseptic meningitis. Acute viral meningitis usually begins abruptly with a combination of CNS signs of nuchal rigidity, headache, photophobia, and occasionally lethargy, along with systemic manifestations. If the alteration in the level of consciousness is more pronounced than lethargy, another diagnosis should be considered. The CSF profile is that of all viral syndromes, with lymphocytic pleocytosis, mildly elevated protein levels, and a normal glucose level. Because the intensity of the inflammatory response in the CSF is low (usually 0 to 500 cells per mm^3), nuchal rigidity is usually the only sign of meningeal irritation, and Kernig's and Brudzinski's signs are often absent. In a few cases, however, marked pleocytosis may be seen (>1000 cells per mm^3), often accompanied by Kernig's and Brudzinski's signs. The meningitis is self-limited, usually resolving in 1 week.

Table 32 lists the differential diagnosis of acute viral meningitis. It is important to exclude nonviral causes of meningitis, which may require specific therapy or more emergent therapy. During the first 24 h of viral meningitis, polymorphonuclear leukocytes may appear in the CSF sample, similar to bacterial meningitis. Repeat lumbar puncture after 12–24 h shows an evolution from polymorphonuclear leukocytes to lymphocytes. In partially treated bacterial meningitis, the glucose level may be normal. Usually in tuberculous, fungal, spirochetal, and parasitic meningitis, the glucose level is depressed. Cytologic examination should differentiate neoplastic meningitis, whereas serologic studies help to exclude autoimmune disease. Imaging studies usually detect parameningeal inflammation.

Enteroviruses are the most common cause of viral meningitis. In addition to aseptic meningitis, several other syndromes have been associated with enteroviruses (Table 33). Encephalitis is the second most common syndrome caused by enteroviruses, and in some years, enteroviruses account for a fourth of all cases of encephalitis of known etiology. The encephalitis is usually mild, with obtundation, coma (rarely), isolated seizures, behavior changes, and mild focal defects (rarely severe). The prognosis is excellent, with resolution in 3–4 weeks, although concentration and intellectual abilities may not resolve for 3–6 months. The exceptions to this good prognosis are the fulminant encephalitis cases seen with group B coxsackievirus sys-

Table 30 Virologic and serologic studies for acute CNS viral syndromes

Agent	Specimens for virus detection	Serologic studies
Enteroviruses		
Poliovirus	Throat washing, stool, and CSF	Acute/convalescent sera
Coxsackievirus	Throat washing, stool, and CSF	
Echovirus	Throat washing, stool, and CSF	
Lymphocytic choriomeningitis virus	Blood, CSF	Acute/convalescent sera
Mumps	Saliva, throat washing, CSF, urine	Acute/convalescent sera
Measles	Throat washing, urine, conjunctival secretions	Acute/convalescent sera
		IgM ELISA of serum
Arboviruses	Blood, C5F	IgM antibody ELISA of CSF or serum
		Acute/convalescent sera
Herpesviruses		
HSV		
Type 1	Brain biopsy, PCR of CSF	CSF antibody detection after day 10
		Acute/convalescent sera (±)
Type 2	CSF, genital and vesicle fluid, blood	Acute/convalescent sera
Varicella-zoster	Vesicle fluid, CSF	Acute/convalescent sera
Cytomegalovirus	Urine, saliva, blood (circulating leukocytes), CSF	Acute/convalescent sera
Epstein-Barr virus	Rarely cultured	Acute sera for antibody profile
Rabies	Saliva, CSF, neck skin biopsy, brain biopsy	Serum after day 15
Adenovirus	Nasal or conjunctival swab, urine, stool	Acute/convalescent sera
Influenza	Throat washing	Acute/convalescent sera

Adapted from Jubelt [38]; with permission
ELISA enzyme-linked immunosorbent assay

Table 31 Clinical manifestations of acute viral meningitis

Systemic Manifestations	Central Nervous System Manifestations
Fever	Headache, usually frontal or retro-orbital
Malaise	Nuchal rigidity
Anorexia	Photophobia
Myalgia	Lethargy
Nausea and vomiting	
Agent-specific pharyngitis, URI, abdominal pain, diarrhea	

URI upper respiratory infection

Table 32 Differential diagnosis of acute viral meningitis

Bacterial meningitis
Early (0–24 h)
Also listeriosis, mycoplasmosis, brucellosis
Tuberculous meningitis
Fungal meningitis
Spirochetal meningitis: Syphilis, Lyme disease, leptospirosis
Parasitic meningitis
Parameningeal infections
Neoplastic meningitis
Autoimmune and inflammatory diseases; lupus, sarcoid, vasculitis
Drug reactions: Nonsteroidal anti-inflammatory agents, sulfamethoxazole, trim ethoprim, trimethoprim-sulfamethoxazole, isoniazid, carbamazepine, lamotrigine, azathioprine, intravenous immune globulin, intravenous monoclonal OKT3
Chemical meningitis: Intrathecal drugs, central nervous system tumors, myelography, isotope cisternography

temic neonatal infections, the chronic encephalitis that appears with chronic persistent infection in agammaglobulinemic patients, and the EV71 brainstem encephalitis case seen in Asian-Pacific regions. Paralytic disease is discussed in the section on myelitis and related infections (*see* Figs. 25, 26 and Table 45). Acute cerebellar ataxia and isolated cranial nerve palsies are infrequent and have a good prognosis. Chronic (persistent) enterovirus infections are caused mainly by echoviruses and live vaccine strains of polioviruses in agammaglobulinemic children. The echoviruses cause chronic encephalitis that progresses over several years, possibly accompanied by dermatomyositis. Polioviruses cause chronic encephalitis, but because of ensuing paralysis, the course usually lasts only months to a year. The prognosis is poor despite the intrathecal administration of specific antibody, which may result in temporary remissions but usually not clearance of virus from the CNS. Systemic manifestations of enterovirus infection include hand-foot-and-mouth disease, other rashes, upper respiratory infections, pleurodynia, and pericarditis.

Herpes Simplex Virus Type 2

Herpes simplex type 2 (HSV-2) meningitis is spread primarily by venereal contact (Table 34). Most primary infections occur between the ages of 14 and 35 years, and most often manifest as genital infections of the penis in men and of the vulva, perineum, buttocks, cervix, and vagina in women. Approximately 25% of those infected by venereal transmission develop aseptic meningitis as part of the primary infection. Primary infection of a fetus can occur in utero or during delivery through an infected birth canal, which may result in severe and often fatal disseminated infection with encephalitis of the neonate. A similar disseminated infection may

Table 33 Neurologic syndromes associated with enteroviruses…

Syndrome	Virus type
Aseptic meningitis	Polioviruses 1–3
	Coxsackieviruses A1–11, 14, 16–18, 22, 24
	Coxsackieviruses B1–6
	Echoviruses 1–7, 9, 11–25, 27, 30–33
Encephalitis	Enterovirus 71
	Polioviruses 1–3
	Coxsackieviruses A2, 4–9
	Coxsackieviruses B1–6
	Echoviruses 2–4, 6, 7, 9, 11, 14, 17–19, 25
	Enterovirus 71
	Enterovirus 72 (hepatitis A virus)
Paralytic disease	Poliovirus 1–3
	Coxsackieviruses A2–4, 6–11, 14, 16, 21
	Coxsackieviruses B1–6
	Echoviruses 1–4, 6, 7, 9, 11, 13, 14, 16, 18–20, 30, 31
	Enteroviruses 70, 71
Acute cerebellar ataxia	Polioviruses 1, 3
	Coxsackieviruses A2, 4, 7, 9, B1–6
	Echoviruses 6, 9
	Enterovirus 71
Isolated cranial nerve palsies, especially facial	Poliovirus 1–3
	Coxsackieviruses A10, B5
	Echoviruses 4
	Enteroviruses 70
Chronic infections	Polioviruses 1–3 (vaccine-like strains)
	Coxsackieviruses A15, B3
	Echoviruses 2, 3, 5, 7, 9, 11, 15, 17–19, 22, 24, 25, 27, 29, 30, 33

Adapted from Jubelt and Lipton [39]; with permission

occur in the immunocompromised host after venereal transmission. Because the sacral ganglia receive sensory fibers from the external genitalia, the virus is transported axonally to the ganglia, where it becomes latent; the virus later reactivates and causes recurrent disease. Recurrent disease usually is limited to the genitalia, but aseptic meningitis and radiculitis may occur. Recurrent meningitis is sometimes referred to as Mollaret's meningitis. Radiculitis is manifested by dysesthesia, which is often painful and may be burning or lancinating in character, and may cause sciatica. Sacral radiculitis may also result in bladder and bowel dysfunction, such as retention or incontinence.

Table 35 outlines the treatment of HSV-2 infections. Acyclovir is the major drug in use today for treating herpes simplex infections. It is available in three formulations: intravenous (IV), oral, and topical (5% ointment). For the primary genital infection, oral acyclovir is indicated. Treatment for aseptic meningitis has not been well studied, but it is a self-limited disease. Although there is no standard treatment, usually IV acyclovir is followed by oral acyclovir upon discharge for a total of 10–14 days. Intravenous acyclovir is needed for disseminated infection with or without encephalitis. Frequent recurrences are usually treated in the immunocompetent host with 1 year of oral acyclovir for suppression. The immunocompromised host requires treatment for each recurrence, and probably continuous oral treatment for suppression as a preventative measure.

Viral Encephalitis

The term *encephalitis* implies involvement of the brain parenchyma. In acute viral encephalitis (Table 36), often the meningeal manifestations seen in acute viral meningitis are also present in addition to the signs of brain dysfunction (meningoencephalitis). The signs of brain dysfunction may be focal or diffuse; these may manifest as mental status changes, seizures (in more than 50% of patients), or hard focal signs. All types of focal deficits have been reported. Viral encephalitis can be divided into primary and secondary types. In primary encephalitis, there is viral invasion and infection of the brain parenchyma, usually of the gray matter. Secondary encephalitis is postinfectious encephalitis (or encephalomyelitis), in which an immune-mediated attack against myelin and white matter apparently occurs. Despite the different locations (gray *vs* white matter) of these pathologic insults, one cannot distinguish between the two based on the clinical symptoms and signs. The CSF profile is similar to that of any acute viral syndrome, with lymphocytic pleocytosis (usually 5–500 cells per mm^3), normal glucose levels, increased protein levels, and increased pressure.

A wide variety of diseases that affect the brain parenchyma can simulate acute viral encephalitis (Table 37). The differential diagnosis includes both infectious and noninfectious diseases.

The arboviruses (insect-borne) have distinct geographic locations throughout the world, and other viruses may occur in seasonal, epidemic, or endemic fashion depending on the geographic location (Table 37). Therefore, the travel history may be very important for making the diagnosis.

Herpes Simplex Type 1 Encephalitis

Herpes simplex type 1 (HSV-1) causes a focal encephalitis involving the medial temporal and orbitofrontal lobes (Table 38a, b). At presentation, however, when the diagnosis needs to be made for institution of therapy, hard focal signs are present only in a minority of patients. The most common manifestations at presentation (alteration in consciousness and personality changes including bizarre behavior and hallucinations) are not very localizing and can be seen in diffuse processes. Localization of the lesion depends upon diagnostic tests.

Table 34 Pathogenesis of HSV-2 infections

	Adolescents and adults	Newborns	Immunocompromised host
Transmission	Venereal	In utero or at delivery	Venereal
Primary infection	Genital herpes; aseptic meningitis	Disseminated infection with hepatic and adrenal necrosis and encephalitis	Genital herpes
			Cutaneous herpes
			Disseminated infection with encephalitis
Latency	Sacral dorsal root ganglia	Unknown, usually fatal	Same as adolescent and adults
Recurrence	Genital herpes	–	Same as adolescent and adults if patient survives
	Cutaneous herpes		
	Aseptic meningitis		
	Radiculitis		

Table 35 Acyclovir treatment of herpes simplex

Type 2 infections	
Type of infection	Recommended treatment
Primary infection	
Genital lesions	Oral acyclovir, 200 mg daily 5× for 10 d
Aseptic meningitis	None or oral acyclovir (but not studied)
Disseminated infection with or without encephalitis	IV acyclovir, 10 mg/kg q8h for 21 d
Recurrent infection	
Immunocompetent host	
Infrequent	No treatment
Frequent	Oral acyclovir for suppression for up to 1 y, 200 mg tid or qid
Immunocompromised host	
Localized infection	Oral or IV acyclovir
Disseminated infection	IV acyclovir
Preventative	Oral acyclovir, 200–400 mg 2× to 5× per day

Table 36 Clinical manifestations of acute viral encephalitis

Acute febrile illness of abrupt onset
Systemic manifestations—malaise, anorexia, myalgias, pain, nausea and vomiting, diarrhea
Meningeal irritation—headache, photophobia, nuchal rigidity
Parenchymal (brain) dysfunction
Altered level of consciousness
Lethargy to coma
Confusion, disorientation
Delirium
Mental changes—personality and behavioral changes, including agitation, hallucinations, and psychosis
Seizures—focal or generalized
Extensor plantar responses and hyperreflexia
Focal deficits—less frequent
Aphasia
Ataxia
Hemiparesis
Tremor
Cranial nerve palsies

Table 37 Differential diagnosis acute viral encephalitis

Bacterial infections	Fungal infections	Spirochete infections
Parameningeal—Epidural abscess, subdural empyema, brain abscess	Fungal abscess	Lyme disease
	Fungal meningitis—Late with parenchymal involvement	Leptospirosis
Tuberculous meningitis—Late with parenchymal involvement		
	Parasitic infections	Noninfectious causes
Bacterial endocarditis	Toxoplasmosis	Encephalopathy—Toxins, drugs, metabolic disorders
Rocky Mountain spotted fever	Amebic meningoencephalitis	
Brucellosis	Cysticercosis	Autoimmune and inflammatory causes—Collagen vascular disease, vasculitis, sarcoid, paraneoplastic
Mycoplasma pneumonia	Malaria	
Legionella pneumonia	Trichinellosis	
		Neoplasia
	Trypanosomiasis	Primary brain tumors

Figure 15 illustrates the pathogenesis of HSV encephalitis. Anatomical pathways may explain the localization of HSV-1 encephalitis to the orbitofrontal and medial temporal lobes. Direct infections via the olfactory bulb could cause orbital-frontal infection with secondary spread to the temporal lobe. Recurrent sensory branches from the trigeminal

Table 38a Geographic distribution of the major causes of viral encephalitides worldwide

Virus	Geographic distribution
Japanese encephalitis	Eastern Asia, India
St. Louis encephalitis	US, Caribbean
California group encephalitis	North America
Eastern equine encephalitis	US Atlantic and Gulf coasts, Caribbean, South America
Western equine encephalitis	Western US and Canada, Central and South America
Venezuelan equine encephalitis	Texas, Florida, Central and South America
West Nile encephalitis	Africa, Middle East, eastern Europe, North America
Murray Valley encephalitis	Australia, New Guinea
Rocio	Brazil
Tick-borne encephalitis complex	Worldwide
Lymphocytic choriomeningitis	Americas, Europe, Africa
Mumps	Worldwide
Measles	Worldwide
Rabies	Worldwide (except UK and Japan)
Herpes simplex encephalitis	Worldwide
Epstein-Barr encephalitis	Worldwide
Varicella-zoster encephalitis	Worldwide
HIV	Worldwide

Table 38b Major causes of viral encephalitides in the United States

Virus	Geographic distribution
Herpes simplex	Nationwide
Mumps	Nationwide
St. Louis	Nationwide (esp. south and central)
California/La Crosse	Central and eastern US
Western equine	Western
Eastern equine	Atlantic and Gulf coasts
West Nile encephalitis	Nationwide
Colorado tick fever	Western US
Venezuelan equine	Texas and Florida
Rabies	Nationwide

ganglia project to the basilar dura of the anterior and middle cranial fossa. This may explain temporal lobe localization of HSV encephalitis when the virus reactivates in the trigeminal ganglia. Based on serologic studies, about 30% of HSV encephalitis is due to direct invasion and 70% from reactivation (Table 39).

Subarachnoid hemorrhage is frequent in HSV encephalitis (Fig. 16) and results in the large number of erythrocytes often found in the cerebrospinal fluid.

Eosinophilic inclusion bodies may be seen in HSV encephalitis, other herpesvirus infections, and subacute measles encephalitis (Fig. 17). The nuclear chromatin is marginated. These inclusion bodies can also be seen in glia and are a helpful diagnostic sign.

Table 39 Clinical manifestations HSV-1 encephalitis

	NIAID Collaborative Study[a]	Swedish Study[b]
Symptoms		
Altered consciousness	97% (109/112)	100% (53/53)
Fever	90% (101/112)	100% (53/53)
Headache	81% (89/110)	74% (39/53)
Seizures	67% (73/109)	
Vomiting	46% (51/111)	38% (20/53)
Hemiparesis	33% (33/100)	
Memory loss	24% (14/59)	
Signs		
Fever	92% (101/110)	
Personality alteration (confusion, disorientation)	85% (69/81)	57% (30/53)
Dysphasia	76% (58/76)	36% (19/53)
Autonomic dysfunction	60% (53/88)	
Ataxia	40% (22/55)	
Hemiparesis	38% (41/107)	40% (21/33)
Seizures	38% (43/112)	62% (33/53)
Focal	(28/43)	
Generalized	(10/43)	
Both	(5/43)	
Cranial nerve deficits	32% (34/105)	
Papilledema	14% (16/111)	

NIAID National Institute of Allergy and Infectious Diseases
[a]Data from Whitley et al. [42]
[b]Data from Sköldenberg et al. [43]

The initial diagnostic test should be a brain CT scan to exclude other lesions and to check for mass effect (Fig. 18). Usually the CT scan does not become positive until the end of the first week of infection. If there is mass effect, treatment should commence with mannitol or steroids and acyclovir. Diagnosis can then be confirmed by MRI scanning. If the CT is normal or there is no mass effect, lumbar puncture should be performed. Within the first day or two of onset, 5–10% of CSF examinations are normal, but usually there is a lymphocytic pleocytosis, normal glucose, elevated protein, and pressure similar to other CNS viral infections. In HSV encephalitis, however, there may be significant necrosis, hemorrhage, and erythrocytes in the CSF. The use of polymerase chain reaction (PCR) for amplification of HSV DNA from the CSF is a rapid and sensitive method of diagnosis, though it may be

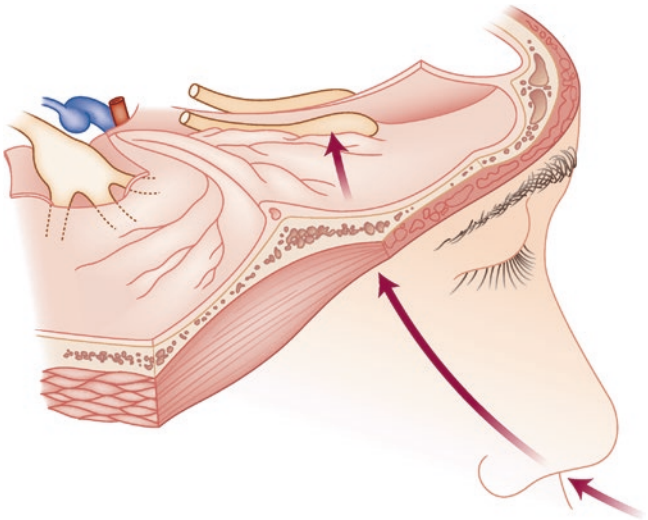

Fig. 15 Pathogenesis of HSV-1 encephalitis [44]

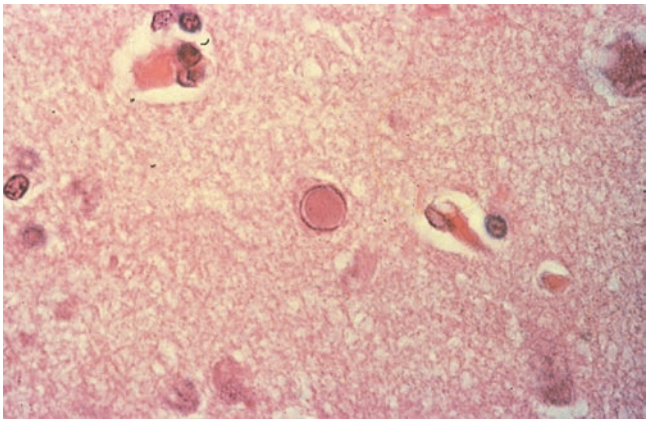

Fig. 17 Histologic slide showing microscopic anatomy of HSV encephalitis (hematoxylin-eosin stain). Shown is a type A intranuclear inclusion body within the nucleus of a small nerve cell. This section was taken from the temporal lobe cortex of a person with HSV encephalitis. (From Wilson [4])

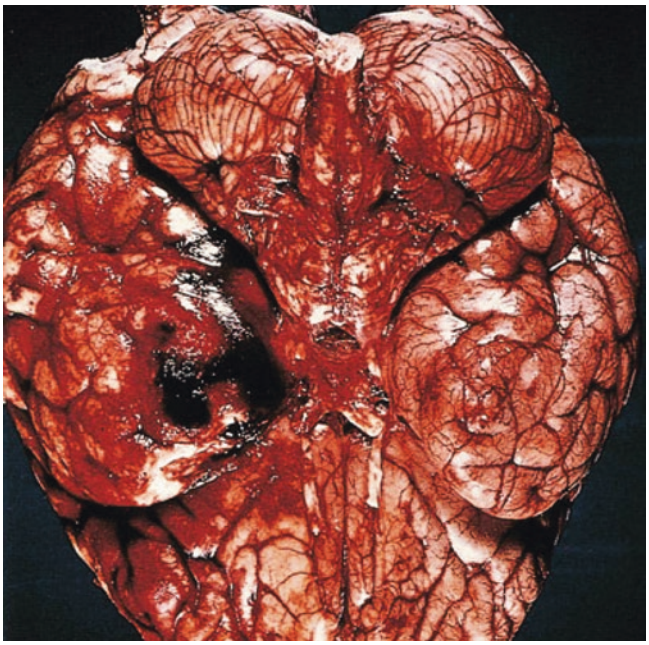

Fig. 16 Gross anatomy of the brain in HSV encephalitis. There is a hemorrhagic necrotic lesion of the left medial temporal lobe. (From Hirano et al. [45]; with permission)

falsely negative in the first 72 h of symptoms. HSV IgG antibodies can be detected in the serum and CSF after 8–10 days, so they are not useful for early detection of the infection. If the CSF is abnormal, MRI scanning should be performed, and acyclovir should be started if the MRI is consistent with herpes encephalitis. If there is a delay in obtaining the MRI, then acyclovir should be started first. The electroencephalogram (EEG) can also be a useful test, as it may reveal temporal lobe foci earlier than CT scanning. If the diagnosis is not confirmed from the MRI and EEG, then a brain biopsy may be needed.

MRI has become the diagnostic test of choice for HSV encephalitis and is abnormal in more than 90% of cases (Fig. 19). MRI will usually reveal a hyperintense lesion with T2 weighting due to inflammation and edema within a day or two of onset, even when the CT scan is normal. DWI (diffusion-weighted imaging) is superior to other sequences in detecting early brain involvement. Lesions may be seen not only in the temporal lobe but also in the orbital frontal lobes and insular cortex. Coronal images are the most useful for seeing the lesion.

Treatment for suspected HSV-1 encephalitis should start immediately, given the potential for severe residual neurologic deficits. It consists of IV acyclovir 10 mg/kg every 8 h for 14–21 days.

Arbovirus Encephalitis

The term *arbovirus* is no longer used as official viral nomenclature, but it is still useful to designate all the arthropod-borne viruses. There are about 20 arboviruses worldwide that primarily cause encephalitis (Table 40). Many other arboviruses cause systemic febrile illnesses or hemorrhagic fevers (*eg*, yellow fever virus), but they seldom cause encephalitis. Arboviruses are usually geographically localized and seasonally restricted.

West Nile virus (WNV) infections appeared in New York City in August 1999. Since then, the virus has spread to all of the continental United States, Canada, and Mexico. WNV is now the most common cause of epidemic viral encephalitis in the United States, with nearly 20,000 confirmed cases. Symptomatic infections include generalized illness (West Nile fever) and West Nile neuroinvasive disease (WNND), which includes meningitis, encephalitis, brainstem encephalitis, and poliomyelitis-like acute flaccid paralysis. About 40% of patients with WNND have a neutrophil predominance in the initial CSF examination. Diagnosis depends primarily on finding specific IgM antibodies in the CSF. If the initial

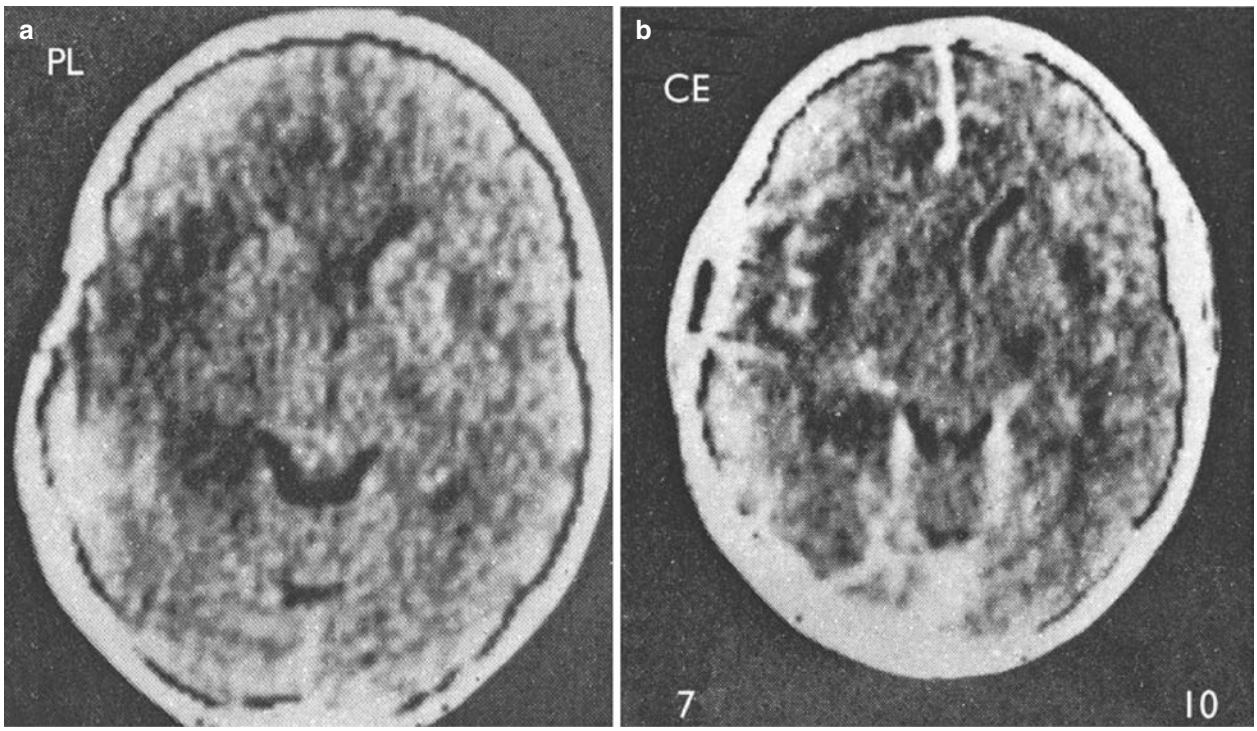

Fig. 18 CT scans of HSV encephalitis. (**a**) CT scan on day 10 revealing a low-density lesion in the right temporal and deep frontal lobes. (**b**) The corresponding enhanced CT scan reveals gyral enhancement in the sylvian fissure and insular regions, which are greater on the right

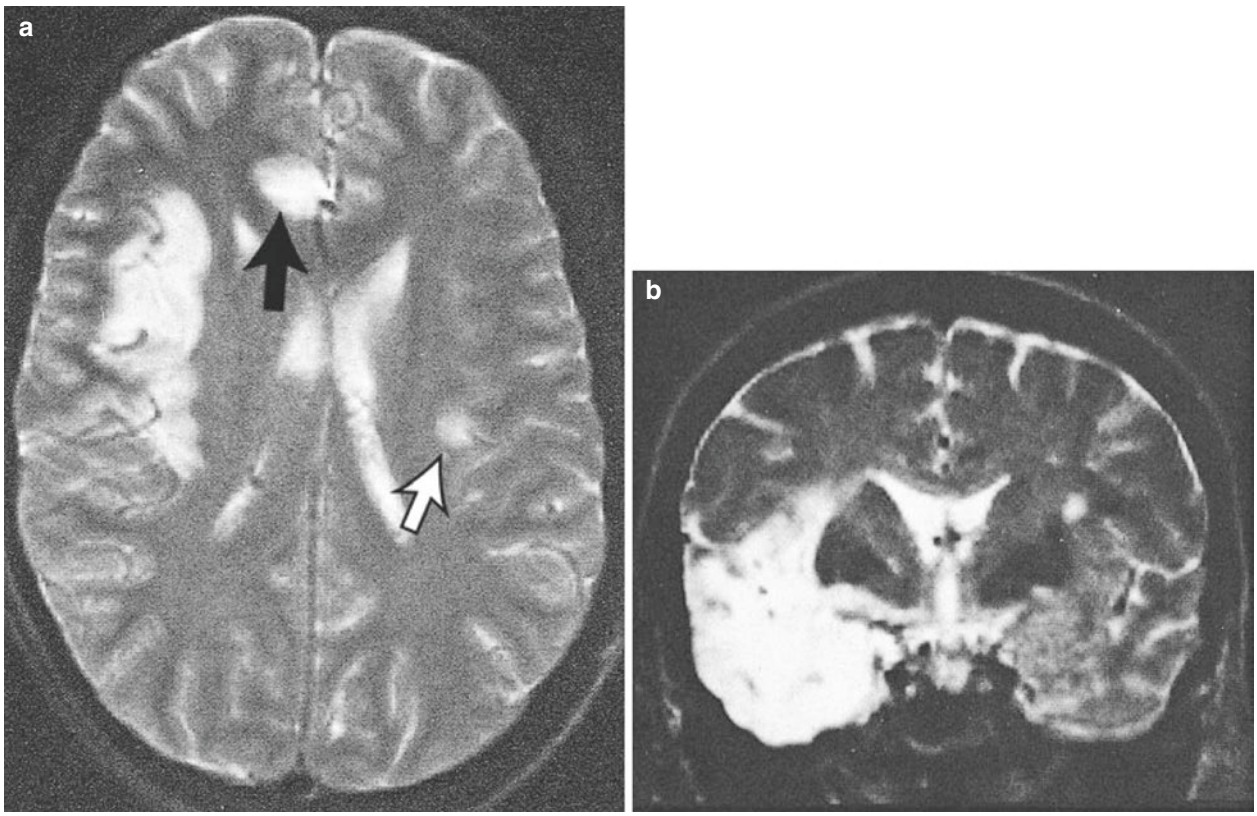

Fig. 19 MRI scans used in the diagnosis of herpes simplex virus (HSV). (**a**) T2-weighted axial MRI shows high signal intensity in the right insular cortex, medial right frontal cortex (*black arrow*), and left insular cortex (*white arrow*). (From Runge [46], with permission). (**b**) T2-weighted coronal image shows increased signal in the left temporal lobe and beginning involvement of the right side. (From Schroth et al. [47], with permission)

Table 40 Major arboviral encephalitides

Mosquito-borne viruses	Location	Tick-borne viruses	Location
Togaviridae (alphaviruses)		Flaviviridae (flaviruses)	
Eastern equine encephalitis	US Atlantic and Gulf coasts, Caribbean	Tick-borne complex	
		Far Eastern	Eastern Russia
Venezuelan equine encephalitis	Texas Florida, Central and South America	Central European	Eastern Europe, Scandinavia, France, Switzerland
Western equine encephalitis	Western US and Canada, Central and South America	Russian spring-summer	Eastern Europe, Asia
		Kyasanur Forest disease complex	India
Flaviviridae (flaviruses)			
St. Louis encephalitis	US, Caribbean	Negishi	Japan
Japanese encephalitis	Eastern Asia, India	Powassan	North central US, eastern Canada
Murray Valley encephalitis	Australia, New Guinea	Louping ill	Great Britain
Rocio	Brazil	Reoviridae (coltivirus)	
West Nile	Africa, Middle East, eastern Europe, North America	Colorado tick fever	US and Canadian Rocky Mountains
Ilheus	Central and South America		
Bunyaviridae (bunyaviruses)			
California encephalitis group			
California	Western US		
La Crosse	Central and eastern US		
Tahyna (phlebovirus)	Central and southern Europe		
Rift Valley fever	East and South Africa		

Adapted from Hanley et al. [40] and Solomon [41]

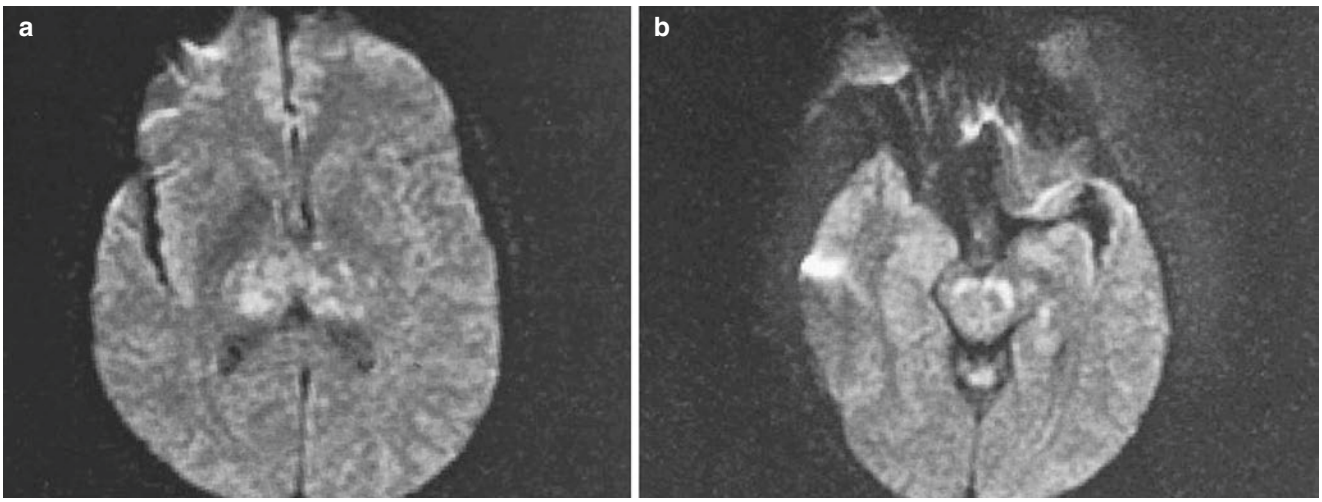

Fig. 20 West Nile virus (WNV) neuroinvasive disease. MRI DWI images on day 6 of WNV encephalitis in thalami (**a**) and substantia nigra (**b**). (From Davis et al. [48]; with permission)

IgM antibodies are negative and there is a significant suspicion for the disease, repeat serum and CSF testing should be undertaken 10 days after disease onset. Neuroimaging studies may help with diagnosis. MRI abnormalities have been reported in 20–70% of cases and appear to increase over the first week of illness. Abnormalities are usually seen in deep gray matter structures (basal ganglia, thalami), brainstem, and cerebellum on T2, FLAIR, and DWI (Fig. 20). At present, there is no specific treatment.

Rabies

Rabies is caused by the neurotropic rabies virus in the Rhabdoviridae family, genus Lyssavirus. Amplified virions from the site of inoculation enter nearby motor/ sensory nerves, then migrate retrogradely into the spinal cord and the brain.

Table 41 lists the clinical manifestations of rabies and their frequency during the course of the disease. At onset, about half of the patients have pain or paresthesia at the

Table 41 Clinical manifestations of rabies

Finding	%
Fever	73
Dysphagia	58
Altered mental state	55
Pain, paresthesia referable to site of exposure	45
Excitement, agitation	45
Paralysis, weakness	26
Hydrophobia	21
Hypersalivation	16
Nausea, vomiting	18.6
Malaise	16.3
Dyspnea	14
Headache	14
Convulsions, spasms	9.1
Coma	4.5
Miscellaneous (lethargy, dysuria, anorexia, hydrophobia)	16.3
No history of rabies exposure	16

Adapted from Robinson [49]; with permission

Table 42 Clinical progression of rabies.

Stage	Duration	Clinical manifestations
Incubation period	30–90 d: ~ 50% of cases	No clinical findings
	< 30 d: ~ 25%	
	> 90 d to 1 y: ~ 5%	
	> 1 y: ~ 5%	
Prodrome and early clinical symptoms	2–10 d	Paresthesia and/or pain at site of bite
		Fever, malaise
		Anorexia, nausea, vomiting
		Headache
Acute neurologic disease	2–7 d	"Furious rabies" (80% of cases)
		Hallucinations, bizarre behavior, anxiety, agitation, biting
		Autonomic dysfunction
		"Paralytic rabies" (20% of cases)
		Flaccid paralysis
		Paresis and plegias
		Ascending paralysis
Coma	0–14 d	SIADH
		Diabetes insipidus
		Multiorgan failure
		Respiratory or cardiac failure
Death (common)	Variable	–
Recovery (rare)	Variable	Several sequelae

Rupprecht, CE, et al [50]
SIADH syndrome of inappropriate secretion of antidiuretic hormone

bite site. Other initial manifestations include fever, malaise, anorexia, and drowsiness.

The clinical course of rabies (Table 42) consists of five stages. The prolonged incubation period lasts more than 90 days in 25% of patients, and more than 1 year in 5%. After the initial manifestations with lethargy, a state of excitability ensues, when external stimuli may cause focal or generalized convulsions. Spasmodic contractions of the larynx and pharynx are precipitated by any attempt to drink or eat, thus the term *hydrophobia*. During this stage, the temperature may reach 105–107 °F. This hyperexcitability stage passes into the comatose stage, with generalized paralysis. Occasionally, the disease begins as "dumb rabies," in which flaccid paralysis of one or more limbs occurs, rather than a hyperexcitable period. Death is usually caused by respiratory paralysis followed by cardiovascular collapse.

The Negri body (Fig. 21), a cytoplasmic eosinophilic inclusion with central basophilic granules, is pathognomonic of rabies. Unfortunately, these inclusions may not be seen; they are present in only 70–80% of cases. The inclusions contain rabies virus antigens. Negri bodies are found only in neurons, most commonly the hippocampal pyramidal cells and cerebellar Purkinje cells, but they may occur in other cortical neurons and other regions of the CNS. Perivascular inflammation is mild to minimal, perhaps because rabies virus is transported axonally and transsynaptically, with little extracellular virus extension. A microglial rod cell response usually occurs, as do diffuse degenerative changes of neurons.

Rabies cannot be diagnosed before the onset of clinical disease. Except for biopsy of the brain, the most useful diagnostic tests (Table 43) include biopsy of neck skin for fluorescent staining and the CSF antibody (which is not present until at least the second week), and PCR nucleic acid amplification. The differential diagnosis includes all causes of encephalitis, both primary and postinfectious. In Australia, the closely related *lyssavirus* has caused several cases of fatal encephalitis clinically similar to rabies [51]. Treatable causes such as HSV encephalitis are especially important to exclude. Muscular rigidity due to tetanus is also an important differential consideration. Hydrophobia is virtually diagnostic of rabies. In countries where rabies is common, rabies psychosis or hysteria may be seen in those exposed to possibly rabid animals. Paralytic disease caused by poliomyelitis, other enterovirus infections, paralytic zoster, transverse myelitis, and Guillain-Barré syndrome must be excluded.

Over 1 million people in the United States are bitten by animals each year; for each of these bites, a decision must be made about instituting postexposure prophylaxis (Fig. 22). Worldwide, dog bites are the main cause of rabies. Fortunately, because of the domestic animal rabies control programs instituted in the 1950s, the chances of getting rabies from a dog in the United States is minimal.

Table 44 suggests a postexposure rabies prophylaxis regimen. There is no specific treatment for rabies once the clinical disease begins; maximum supportive care in an intensive care unit is the patient's only hope for survival. For individuals at high risk (rabies laboratory workers,

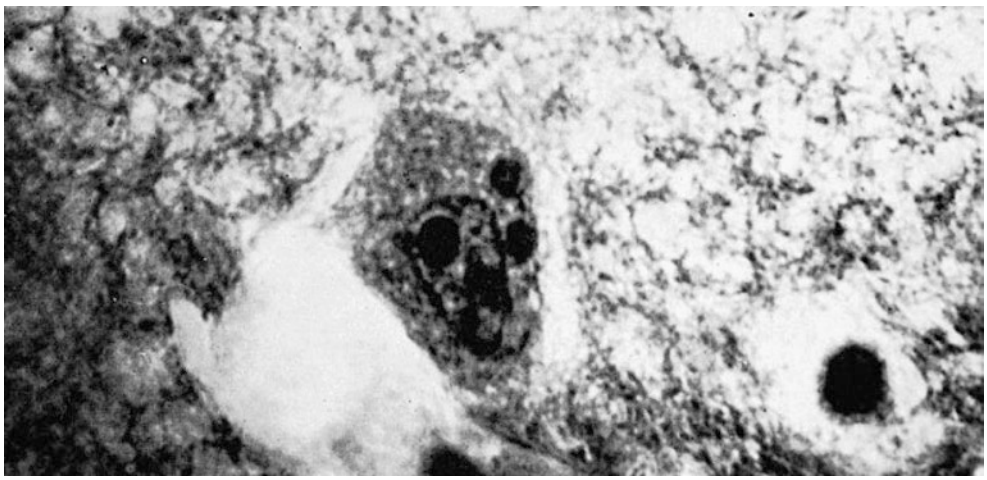

Fig. 21 Negri body, a cytoplasmic eosinophilic inclusion with central basophilic granules, which is pathognomonic of rabies. (From Jubelt [37]; with permission)

Table 43 Diagnostic tests for rabies

No preclinical diagnostic tests
CSF—standard viral syndrome
Lymphocytic pleocytosis
Increased pressure
Increased protein level
Normal glucose level
Neck skin biopsy for fluorescent antibody test
Need 6–8 mm full-thickness specimen
Posterior aspects of neck just above hairline
First week of illness 50% positive, greater thereafter
Corneal impression test—less sensitive, less specific than neck skin biopsy
Rabies antibody in serum and CSF—high CSF titers seen only in clinical disease
Culture of rabies virus from saliva, urine sediment, CSF and brain tissue (brain biopsy)

some veterinarians, animal control and wildlife workers in endemic areas, and spelunkers and travelers to highly endemic areas in which exposure could occur), preexposure prophylaxis should be used. Postexposure prophylaxis includes local wound care, passive immunization with rabies antiserum, and active immunization with rabies vaccine. Both the antiserum and the vaccine should be started immediately. To avoid the formation of antigen-antibody complexes, vaccine and antisera should not be given in the same inoculation or even inoculated into the same anatomic site. Thus, the postexposure prophylaxis should be given at an even later time, considering that the latency period between exposure and disease is quite long (1–6 years). If human rabies immune globulin (HRIG) is not available, equine antirabies serum can be used, but serum sickness may result. The three rabies vaccines (human diploid cell vaccine [HDCV], rabies vaccine absorbed, and purified chick embryo cell) are equally effective and safe; severe reactions are rare]. There have been three cases of recovery from rabies; these patients were treated ineffectively with preexposure or postexposure prophylaxis with the older nonhuman rabies animal vaccines before the onset of clinical disease. Rabies postexposure prophylaxis with HRIG and HDCV (or rabies vaccine) has been 100% effective in the United States. With any deviations from the prophylaxis regimen, the efficacy of the immunization can be verified by antibody testing at 7–14 days after the final dose. Case reports of failure from outside the United States may relate to the use of inappropriate inoculation sites, vaccine administration in the gluteal area, and failure to treat the wound adequately.

Postinfectious Encephalitis

Postinfectious encephalitis (PIE) is secondary encephalitis in which an immune-mediated attack appears to be mounted against central myelin. At times the spinal cord is also involved, causing encephalomyelitis. Presumably virus does not need to invade the CNS to cause the syndrome, as the immune system can become sensitized to myelin peripherally by sequence homology between viral proteins and myelin proteins. The common causes of PIE are chickenpox (varicella), mumps, and nonspecific upper respiratory infections. Usually this syndrome begins 3 days to 3 weeks after onset of the preceding infection. PIE occurs in cerebral and cerebellar forms. Clinically, the cerebral form looks like primary encephalitis (*see* Table 36).

The acute cerebellar ataxic form is the type most often caused by chickenpox, with 100 to 200 cases reported annually in the United States (Fig. 23). It has a good prognosis.

The best diagnostic test for PIE is MRI (Fig. 24), which demonstrates white matter disease. Whether the form is cerebral or cerebellar, the CSF profile is similar to that of other acute viral syndromes, with lymphocytic pleocytosis, normal glucose level, and elevated protein level and pressure. One CSF test that may be helpful is the myelin basic protein level, which is usually elevated; unfortunately, in most places, it takes 1–2 weeks to receive results.

Treatment should be started once the diagnosis is made based on the clinical presentation, including causative disease,

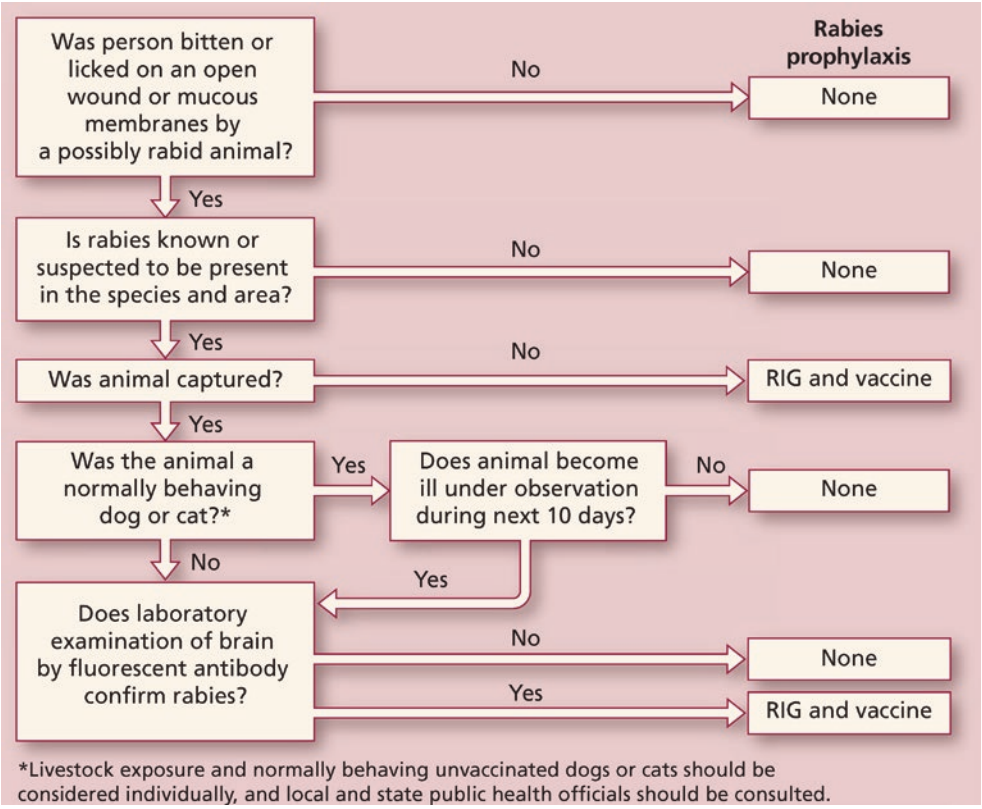

Fig. 22 Rabies postexposure prophylaxis algorithm. *RIG* rabies immune globulin (*Livestock exposure and normally behaving unvaccinated dogs or cats should be considered individually, and local and state public health officials should be consulted)

Table 44 Postexposure rabies prophylaxis regimen in the United States

	Rabies-naïve patients	Previously immunized patients
Local wound care and passive immunization with rabies antiserum	Cleanse wound with soap and water and a virucidal agent	Cleanse wound with soap and water and a virucidal agent
	HRIG, up to 20 U/kg, with as much as possible by local infiltration into wound; any remaining HRIG given intramuscularly in gluteus or thigh	Administration of HRIG is contraindicated
Active immunization with rabies vaccine	Rabies vaccine, 1-mL dose intramuscularly in deltoid, × 5 doses (given on days 0, 3, 7, 14, and 28)	Rabies vaccine, 1-mL dose intramuscularly in deltoid or thigh, × 2 doses (given on days 0 and 3)
	The vaccine should not be administered in the gluteal muscle, as the antibody response was noted to be lower in this setting	
	Of note, the 5th dose is usually reserved for immunosuppressed patients	

Deltoid area in adults and older children and anterolateral thigh in young children
Adapted from Advisory Committee on Immunization Practices [52]
HRIG Human Rabies Immune Globulin

a CSF picture consistent with encephalitis, and a positive MRI scan. Treatment consists of high-dose intravenous steroids (1.0 g methylprednisolone daily for 7–10 days) to stop the perivascular demyelination. Plasma exchange and IVIg have also been used for treatment [54].

Poliomyelitis, Myelitis, and Radiculitis

The term *poliomyelitis* is from the Greek words for gray marrow ("polio") and spinal cord ("myelitis"): "the gray marrow of the spinal cord." Sometimes the term *anterior* is added as a reminder that it is the anterior rather than the posterior horns that are inflamed in poliomyelitis. Only about 1–2% of those infected with the virus develop paralysis (major illness) with or without the nonspecific, systemic, febrile minor illness. Figure 25 demonstrates the correlation of clinical forms of poliomyelitis with the time of viral replication and antibody production. Paralysis is usually asymmetric and flaccid, and can occur in all four extremities, as well as in the brain stem, causing bulbar polio with cranial nerve palsies, respiratory insufficiency, dysphagia, and coma. The use of oral polio vaccine has eradicated poliomyelitis caused by wild-type virus in the United States and other developed countries, but poliomyelitis is still a significant problem in underdeveloped areas. Killed polio vaccine is now used in the United States for vaccination.

The paralysis in poliomyelitis is caused by poliovirus infecting the large anterior horn motor neurons. With

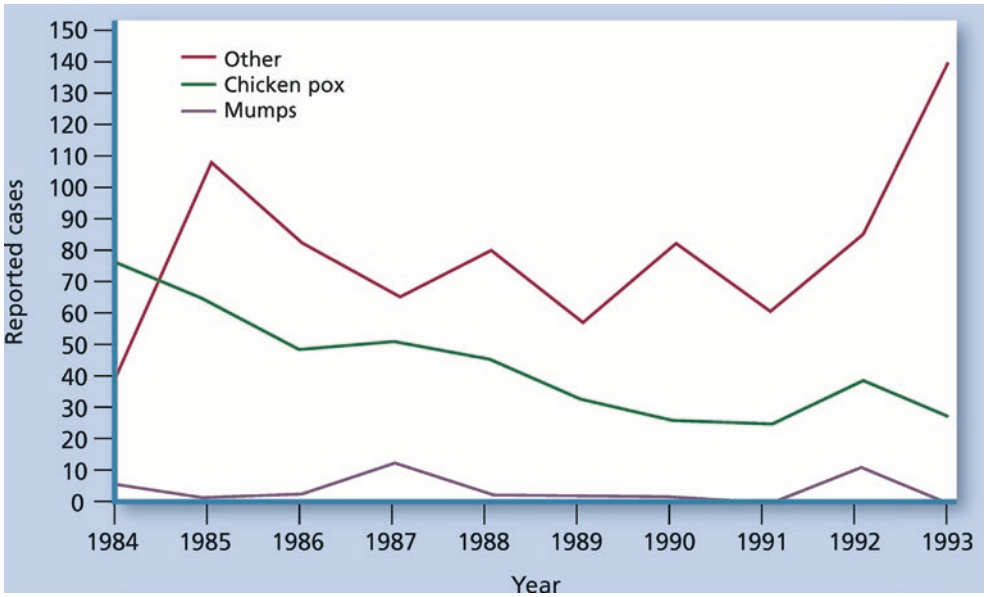

Fig. 23 Incidence of postinfectious encephalitis (PIE) in the United States from 1984 to 1993. (Adapted from centers for Disease Control and Prevention [53])

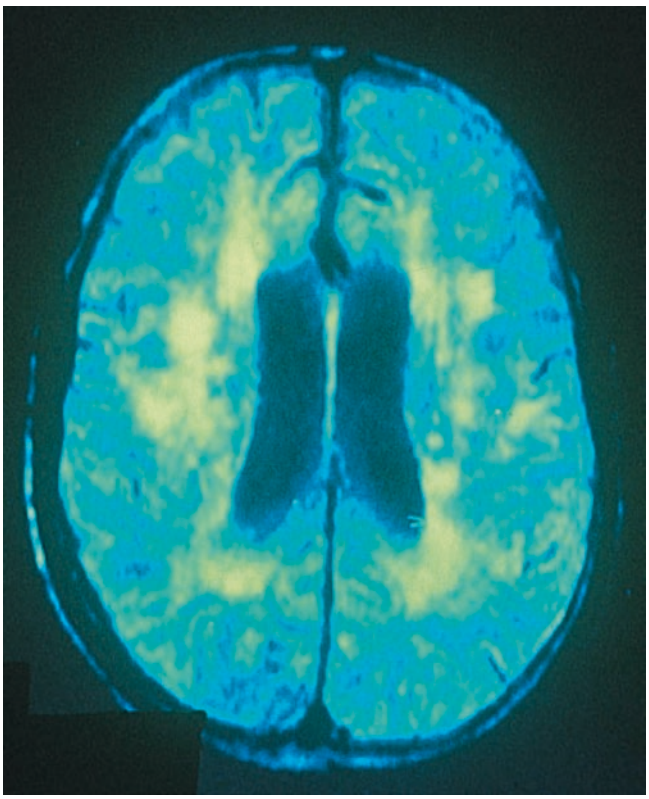

Fig. 24 Proton-density MRI scan showing demyelination in PIE that occurred 2 weeks after a nonspecific upper respiratory infection. (Courtesy of B. Jubelt, MD)

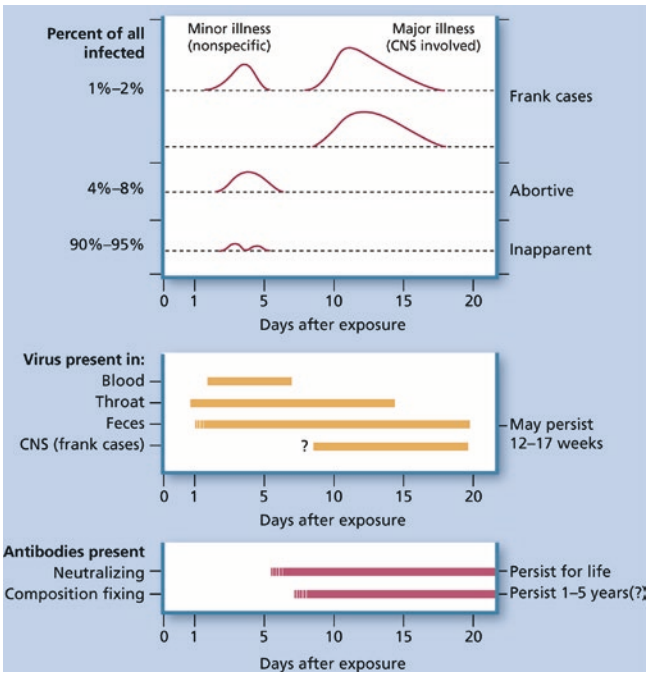

Fig. 25 Correlation of clinical forms of poliomyelitis with the time of viral replication and antibody production. (Adapted from Horstmann [55]; with permission)

destruction of these motor neurons, an intense inflammatory response ensues (Fig. 26). With fluorescent antibody staining, immunofluorescence is prominent in the cytoplasm and processes of the cells, but it is not seen in the nucleus because poliovirus is an RNA virus that replicates in the cytoplasm. Anterior horn cells can show various stages of neuronal degeneration. The inflammatory response consists of perivascular mononuclear cell cuffing; parenchymal, mononuclear, and microglial cell infiltrates; and neuronophagia.

The diagnosis of poliomyelitis is based on the clinical paralysis, the CSF profile picture of an acute viral syndrome, isolation of virus from the throat or stool, and a fourfold rise in the serum antibody level. The differential diagnosis (Table 45) includes other causes of acute lower motor neuron flaccid paralysis. Paralysis is usually asymmetric, without bladder or sensory involvement, but poliovirus has caused

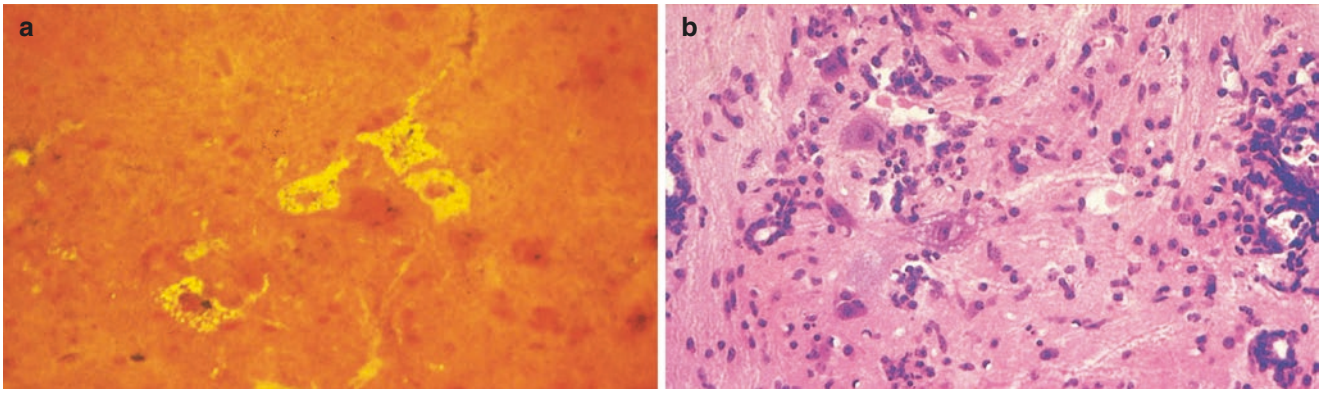

Fig. 26 Histology slides showing pathogenesis and pathology of poliomyelitis. (**a**) Fluorescent antibody staining of type 2 poliovirus antigen in large anterior horn cells of the lumbar spinal cord in a mouse model of human poliomyelitis. Immunofluorescence is prominent in the cytoplasm and processes of these cells, but there is no immunofluorescence in the nucleus. Adjacent to the infected cells are dark, unstained, uninfected neurons. (**b**) Cervical cord showing poliomyelitis due to intracerebral injection of Lansing type 2 poliovirus in a mouse model of human poliomyelitis. Anterior horn cells show various stages of neuronal degeneration. The inflammatory response consists of perivascular mononuclear cell cuffing; parenchymal, mononuclear, and microglial cell infiltrates; and neuronophagia. (From Jubelt et al. [56]; with permission)

Table 45 Differential diagnosis of poliomyelitis

Non-polio enteroviruses (EV)
Coxsackieviruses—rare, mild paralysis
Echoviruses—rare, mild paralysis
EV 70—severe paralysis in Asia, Africa, Europe; no paralysis in the New World
EV 71—severe paralysis in Eastern Europe; rare, mild paralysis in the New World
West Nile virus—acute, flaccid paralysis
Rabies virus—paralytic or "dumb" rabies
Herpes zoster—"zoster paresis"
Guillain-Barré syndrome—usually symmetric
Botulism—symmetric
Acute toxic neuropathies—symmetric with stocking/glove sensory loss
Acute intermittent porphyria—symmetric paralysis, psychiatric symptoms, delirium, abdominal pain, seizures
Acute transverse myelitis—usually symmetric with sensory level and bowel and bladder involvement
Cord compression from epidural abscess—same as transverse myelitis, also localized back percussion tenderness

bladder and sensory involvement, resulting in a picture of transverse myelitis, thus expanding the differential diagnosis to this entity.

Treatment of the acute disease is supportive. The only specific treatment for poliomyelitis is prevention with poliovirus vaccine. Both the live attenuated oral vaccine (Sabin type) and the inactive injectable vaccine (Salk type) are used throughout the world.

Acute Transverse Myelitis

The syndrome of "acute transverse myelitis" consists of acute flaccid paralysis with hyporeflexia (later may develop spasticity with hyperreflexia), sensory loss usually with a sensory level, and bowel and bladder involvement. The paralysis is symmetric and thus different from the usual asymmetric paralysis seen in poliomyelitis. In addition to viruses (Table 46), this clinical syndrome may be caused by cord compression from epidural abscess or epidural tumor that hemorrhages; intraspinal abscess or intraspinal hemorrhaging tumor; spinal cord infarct; vasculitis (*eg*, systemic lupus erythematosus) causing infarction; postinfectious immune-mediated myelitis; multiple sclerosis; neuromyelitis optica (NMO), and remote effects of cancer. Treatment consists of the use of a specific antiviral agent when the agent is identified, with or without high-dose intravenous methylprednisolone [57].

Table 46 Viruses causing acute transverse myelitis[a]

Common	Uncommon	Rare
Herpes simplex virus type 2	Mumps	Poliovirus
Cytomegalovirus	Influenza	Coxsackievirus
Varicella-zoster virus	Rubella	Echovirus
Epstein-Barr virus		Rabies
		Hepatitis A and B
		Measles

Viruses causing encephalomyelitis, in which myelitis occurs only with encephalitis, are not listed

Cytomegalovirus Polyradiculitis

Prior to the occurrence of the AIDS epidemic in the United States, cytomegalovirus (CMV) was known primarily for causing cytomegalic inclusion body disease, an infrequent congenital disease of newborns. Table 47 lists current CMV neurologic infections. Cases of CMV encephalitis have been recognized rarely in immunocompetent individuals.

Table 47 Cytomegalovirus neurologic infections

Disease and features	Host and frequency
Cytomegalic inclusion body disease	Neonate, congenital disease—rare
Encephalitis	
Microencephaly	
Seizures	
Mental retardation	
Periventricular calcifications	
Disseminated disease	Immunocompromised patient (described primarily in AIDS patients)—uncommon
Encephalitis/ventriculitis	
Subacute course (1–3 mo)	
Progressive mental status changes	Immunocompromised patient—rare
Disseminated disease in the immunocompromised patient	
MRI—periventricular hyperintensities, meningeal enhancement	
Polyradiculitis/polyradiculomyelitis	Immunocompromised patient (described only in AIDS patients)—common
Pain and paresthesia in legs and perineum	
Sacral hypesthesia	
Urinary retention	
Subacute ascending hypotonic paraparesis	
Eventually ascend to cause myelitis	
CSF—pleocytosis (PMNs > lymphocytes), low glucose level, high protein level, CMV positive by culture or PCR	
Usually disseminated disease	
MRI—lumbosacral leptomeningeal enhancement	
Multifocal neuropathy	Immunocompromised patient (described only in AIDS)—uncommon
Markedly asymmetric	
Numbness, painful paresthesia for months, followed by sensorimotor neuropathy	
Usually disseminated disease	
CMV positive in CSF by culture or PCR	

PMNs polymorphonuclear leukocytes

CMV ventriculitis and encephalitis occur most often as an opportunistic infection in AIDS patients. The most common syndrome caused by CMV today is CMV polyradiculitis (polyradiculopathy/polyradiculomyelitis/polyradiculomyelopathy) (Fig. 27). This syndrome occurs relatively late in the course of AIDS, when the $CD4^+$ T-lymphocyte count is usually less than 100. Less frequent and also late in the course of AIDS is CMV multifocal neuropathy. Dual therapy with intravenous ganciclovir and foscarnet is the current preferred approach to severe disease. Monotherapy with oral valganciclovir is recommended for mild disease [58].

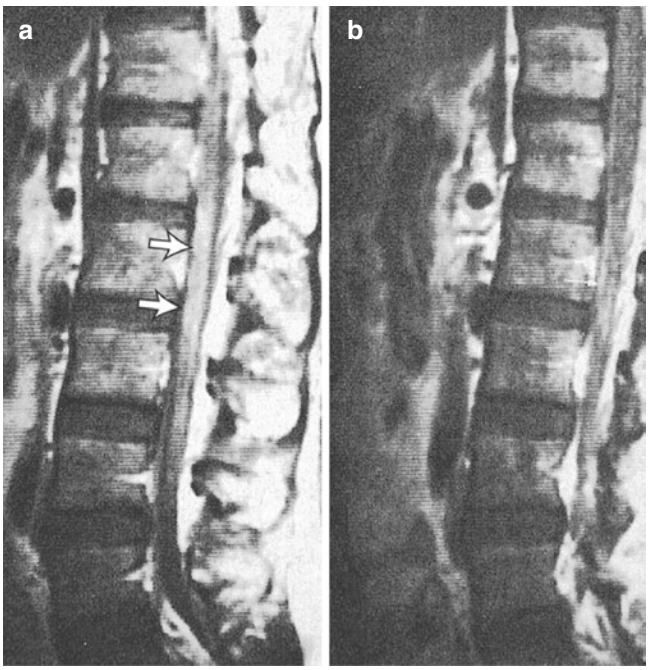

Fig. 27 (**a**) Enhanced T1-weighted sagittal MRI of nerve roots from L1 to L4 and the cauda equina region (*arrows*) in a patient with CMV polyradiculitis/polyradiculomyelitis. In the right half of the picture, the pial lining of the sac is also enhanced. (**b**) Usually these lesions are visible only with enhancement. (From Talpes et al. [59], with permission)

Herpes Zoster

Herpes zoster is a distinctive syndrome caused by the varicella zoster virus (VZV), which also causes chickenpox (varicella). The chickenpox virus travels from the skin up the sensory nerves to become latent in the dorsal root ganglia. Later in life, the virus reactivates, replicates in the ganglia, and travels down the nerve to the skin to cause a dermatomal vesicular eruption (Fig. 28). The incidence of zoster increases with age and is more common in those with compromised cellular immunity. Typically, patients experience dermatomal paresthesia or dysesthesias (itching, burning pain, tingling) for 1–2 days, after which the vesicular eruption occurs. Most patients have hypalgesia and hypesthesia in the affected dermatome.

As shown in Fig. 29, most cases occur in the thoracic nerves, the lumbar nerves, and the ophthalmic divisions of the trigeminal nerve (ophthalmic zoster). Approximately 40–50% of patients younger than 50 years of age develop postherpetic neuralgia (PHN), which is pain persisting for more than 6 weeks after the rash clears. The pain can be severe. PHN can be helped with amitriptyline and carbamazepine; local application of capsaicin may also help. For patients

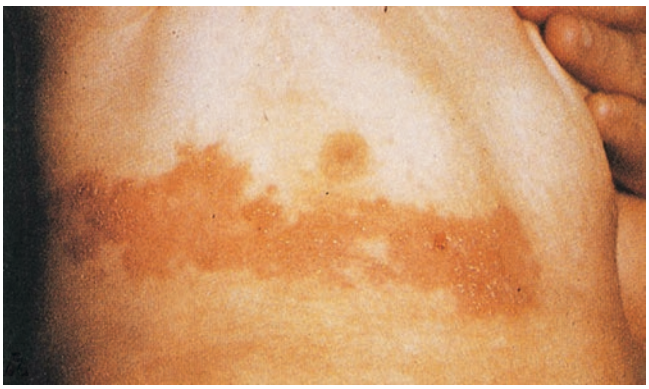

Fig. 28 Herpes zoster in a thoracic dermatome

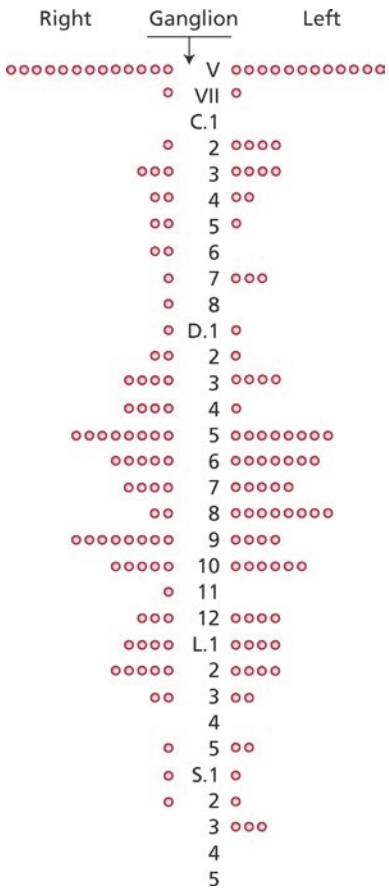

Fig. 29 Segmental distribution of herpes zoster. (Adapted from Hope-Simpson [62]; with permission)

over 50 years of age who present within 72 h from symptom onset, antiviral therapy with oral valacyclovir, or famciclovir for 7 days is recommended. Although early treatment can decrease the severity of acute neuritis, it is unclear whether it decreases the risk and duration of PHN. Complications of herpes zoster include zoster paresis, myelitis, encephalitis, disseminated disease, and infection of the eye. Secondary to ophthalmic zoster (*see* Fig. 28) are keratitis, conjunctivitis, ocular muscle palsies, ptosis, mydriasis, contralateral hemiplegia due to viral spread to the ipsilateral carotid or middle cerebral artery, and the Ramsay Hunt syndrome (geniculate zoster, herpes zoster oticus) with facial palsy, loss of taste, and vesicles in the external auditory meatus. Intravenous acyclovir is indicated for disseminated zoster and probably for most of these complications, although controlled studies of its use for complications have not been reported. A recent study using a highly potent varicella vaccine reduced the incidence of zoster (shingles) by 51% and PHN by 66.5%. Among those who did develop shingles, the vaccine significantly reduced morbidity [61]. Given these findings, vaccination is recommended for individuals who are 50 years of age or older [63].

Table 48 Slow viral infections of the central nervous system

Conventional viruses
Retroviruses
AIDS
HTLV-1-associated myelopathy/tropical spastic paraparesis
Progressive multifocal leukoencephalopathy
Subacute sclerosing panencephalitis
Subacute measles encephalitis
Progressive rubella panencephalitis
Enteroviruses—polioviruses, echoviruses
Other—cytomegalovirus, adenovirus
Prion diseases (spongiform encephalopathy agents)
Kuru
Creutzfeldt-Jakob disease
Gerstmann-Sträussler syndrome
Fatal familial insomnia

Slow or Chronic Viral Infections

Slow or chronic viral infections that result in chronic neurologic disease are caused by both conventional viruses and the prion agents (Table 48). Prion agents (unconventional transmissible spongiform encephalopathy agents) are not true viruses and are reviewed in the next section. The conventional viruses are true viruses with RNA or DNA genetic material and a recognizable structure on electron microscopy. Slow infections to be reviewed in detail are caused by retroviruses (AIDS, human T-cell lymphotropic virus [HTLV]-1–associated myelopathy/tropical spastic paraparesis), papovaviruses (progressive multifocal leukoencephalopathy), and measles virus (subacute sclerosing panencephalitis [SSPE]).

Subacute measles encephalitis (SME) has also been referred to as "immunosuppressive measles encephalitis" and "measles inclusion body encephalitis" because of the large number of Cowdry type A intranuclear inclusions present. SME occurs most often in children immunosuppressed with chemotherapy for lymphoma or leukemia. A few cases have occurred in adults. The incubation period is less than 6 months

from the time of measles exposure. Clinical manifestations are seizures, hemiparesis, retinitis, and cortical blindness followed by coma and death in weeks to months. There is no treatment. The CSF is usually normal except for increased measles antibody titers. The EEG may reveal focal slowing but no periodic complexes. Because of the immunosuppressed state, a large load of virus appears to reach the CNS.

Progressive rubella panencephalitis was recognized as a distinct disease entity in 1974, at which time only several dozen cases had been reported. The disease develops during adolescence, usually in patients having stigmata) of congenital rubella. Clinically, the disease resembles SSPE in onset with dementia. Myoclonus and seizures are less prominent than in SSPE, but cerebellar ataxia is more prominent. The course is protracted over 8–10 years to death. There is no treatment. High levels of rubella antibody appear in the serum and CSF. Both CSF protein and IgG are increased, oligoclonal bands are present, and some patients have CSF pleocytosis (10–40 monocytes/mm^3). The EEG reveals diffuse slowing (rarely periodicity). Persistent infection is believed to cause the formation of immune complexes that are deposited in vessel walls, causing vasculitis.

Persistent enterovirus infections in agammaglobulinemic children have been caused by both attenuated polioviruses (vaccine strains) and echoviruses. The illness caused by polioviruses consists of a course of 2–3 months with both diffuse encephalitis and lower motor neuron paralysis. In the echovirus infections, the course may last months to several years with just encephalitis. About half the patients, however, have a polymyositis-like syndrome from echoviral infection of muscles. These patients may have remissions with intrathecal administration of antibodies, although as yet there are no definite cures. As previously noted (*see* Table 47), CMV can cause subacute to chronic infections in AIDS patients, as can adenovirus, but less frequently.

AIDS

The various neurologic syndromes occurring in HIV-infected patients (Table 49) are caused by the direct effects of HIV or opportunistic processes.

The timing and relative frequency of neurologic complications vary according to the direct effects of HIV infection (Fig. 30). No clinical or CSF features distinguish HIV acute aseptic meningitis from other viral meningitides, but the HIV p24 core protein and HIV antibody are often found in the CSF. The chronic persistent pleocytosis is more often asymptomatic than symptomatic. As noted in Table 49, both acute and chronic demyelinating polyneuropathies (AIDP, CIDP) may occur, which are clinically similar to non-HIV AIDP

Table 49 Neurologic syndromes in patients with HIV infection

Syndrome	HIV related	Opportunistic process
Leptomeningeal disease	Acute, aseptic meningitis	Other viruses: HSV, VZV, EBV, CMV, hepatitis B
	Chronic meningitis	Fungal: primarily *Cryptococcus*[a]
		Bacterial: syphilis, mycobacteria[a], listeriosis, pyogenic bacteria
		Lymphomatosis meningitis
Cerebral syndromes	Acute HIV encephalopathy[a]	Toxoplasmosis[a]
	Chronic HIV-encephalopathy/encephalitis (AIDS dementia complex)	CMV encephalitis[a]
		HSV encephalitis
		PML[a]
		Abscesses; bacterial, fungal
		Diffuse atypical mycobacterium[a]
		Primary central nervous system lymphoma[a]
		Metastatic lymphoma[a] Kaposi's sarcoma[a]
Spinal cord syndromes	HIV vacuolar myelopathy	Viral myelitis: HSV, VZV, CMV
	Anterior horn cell disease	CMV anterior horn cell disease?
		HAM/TSP
Cranial neuropathies	Immune-complex retinopathy	CMV, toxoplasmosis, and *Candida* retinitis
	Others secondary to meningitis	Others secondary to meningitis
Peripheral neuropathies	Predominantly sensory polyneuropathy	CMV polyradiculitis
	Acute and chronic inflammatory demyelinating polyneuropathies	CMV mononeuritis multiplex
	Mononeuritis multiplex	
Muscle disease	HIV myopathy	*Toxoplasma* myositis

EBV Epstein Barr virus, *HAM/TSP* HTLV-1–associated myelopathy and tropical spastic paraparesis, *PML* progressive multifocal leukoencephalopathy, *VZV* varicella zoster virus

[a]AIDS indicator diseases

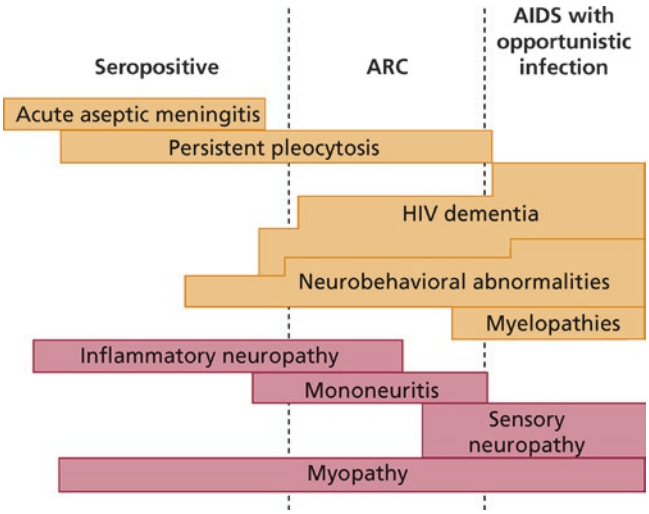

Fig. 30 Timing and relative frequency of neurologic complications due to the direct effects of HIV infection. Diseases that affect the central nervous system are shaded in *orange*, whereas those affecting the peripheral nervous system are shaded in *pink*. The relative frequency of each complication is indicated by the height of each box. *ARC* AIDS-related complex

(Guillain-Barré syndrome) and CIDP. Usually, however, a CSF pleocytosis appears rather than the typical albuminocytologic dissociation. Treatment is plasmapheresis or intravenous administration of immunoglobulins.

As the HIV infection progresses, patients become symptomatic with neurobehavioral abnormalities and dementia (HIV encephalopathy), also referred to as the AIDS dementia complex. At approximately the same time, a mononeuritis multiplex may occur, which is thought to be due to ischemic injury. It must be distinguished from CMV mononeuritis multiplex.

Late in the course of infection, when patients have met the criteria for the diagnosis of AIDS (<200 $CD4^+$ T lymphocytes or the occurrence of indicator diseases), opportunistic infections are more likely to occur, but HIV also causes several syndromes. One is the chronic vacuolar myelopathy that results in corticospinal tract and posterior column sensory signs (vibration and position sense loss). It needs to be distinguished from secondary human T-cell lymphotropic virus-1–associated myelopathy/tropical spastic paraparesis. Other viral myelitides are too acute (HSV, VZV) or subacute (CMV) to fit the picture. Also, distal, primarily sensory polyneuropathy, the most common neuropathy to appear late in the disease, occurs in about a third of AIDS patients. The neuropathy is painful and there is loss of pain sensation, temperature sensation, light touch, and reflexes. CMV polyradiculitis is the primary differential diagnosis. An HIV myopathy may also be seen but is infrequent; a myopathy secondary to zidovudine therapy is more likely.

HIV encephalopathy (AIDS dementia complex) can be recognized from the clinical features listed in Table 50. In the early manifestation of AIDS dementia, HIV encephalopathy presents as a subcortical white matter disconnection syndrome with psychomotor slowing and impaired concentration. Gait ataxia is also a common early sign. In the late manifestations, AIDS dementia becomes global and psychomotor slowing severe. Patients often do not speak spontaneously and exhibit a delayed response to questions.

Table 50 Manifestations of AIDS dementia complex

(a) Early manifestations of the AIDS dementia complex	
Symptoms	Signs
Cognition	Mental status
Impaired concentration	Psychomotor slowing
Forgetfulness	Impaired serial 7 s or reversals
Mental slowing	Organic psychosis
Motor	Neurologic examination
Unsteady gait	Impaired rapid movements (limbs, eyes)
Leg weakness	Hyperreflexia
Loss of coordination, impaired handwriting	Release reflexes (snout, glabellar, grasp)
Tremor	Gait ataxia (impaired tandem gait, rapid turns)
Behavior	Tremor (postural)
Apathy, withdrawal, personality change	Leg weakness
Agitation, confusion, hallucinations	

(b) Late manifestations of AIDS dementia complex	
Mental status	Neurologic signs
Global dementia	Weakness (legs, arms)
Psychomotor slowing: verbal responses delayed, near or absolute mutism, vacant stare	Ataxia
Unawareness of illness, disinhibition	Pyramidal tract signs: spasticity, hyperreflexia, extensor plantar responses
Confusion, disorientation	Bladder and bowel incontinence
Organic psychosis	Myoclonus

Adapted from Price et al. [65]

The pathologic hallmarks of HIV encephalopathy (Fig. 31) are multinucleated giant cells and microglial nodules. These cells appear throughout the cortex and white matter and are infected with HIV. HIV antigen is also found in glia and endothelial cells, but not in neurons. Therefore, neuronal dysfunction is not the result of viral replication, and has not been clarified.

By the end of 2005, over 1 million cumulative cases of AIDS had been reported to the Centers for Disease Control and Prevention (CDC) from the United States and its territories. Of these patients, 62% had died. The World Health Organization estimates that there have been 40 million cases worldwide. It is estimated that about two thirds of AIDS patients develop HIV encephalopathy. Table 51 lists the common complications of AIDS. Obviously, less frequent complications such as bacterial brain abscesses (<1%),

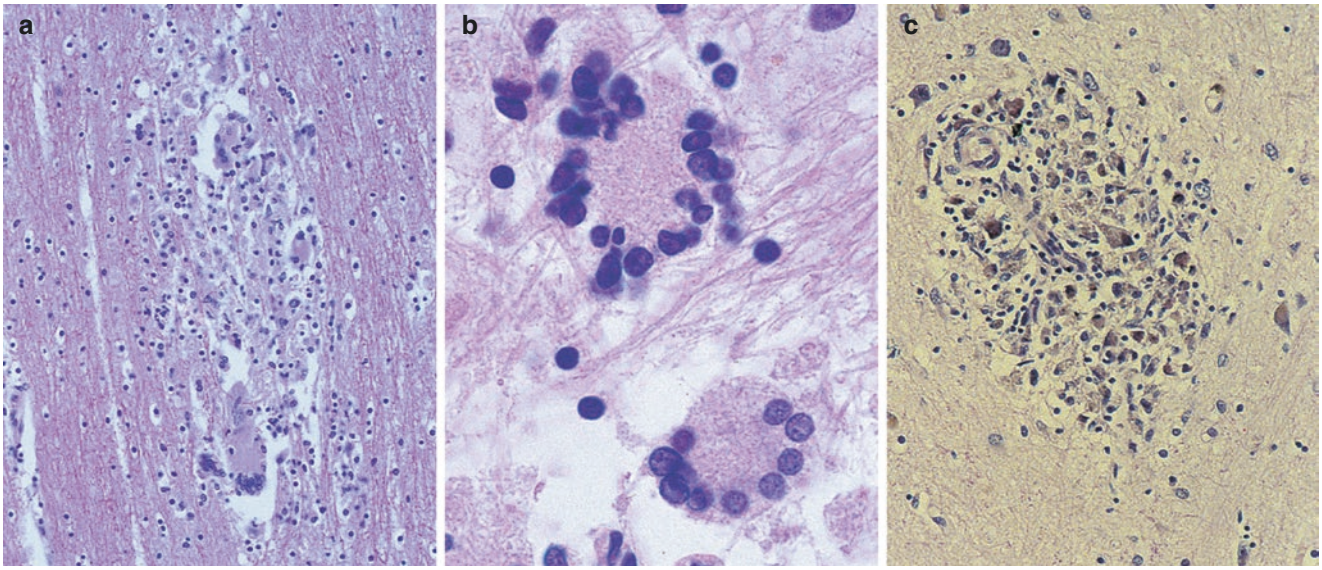

Fig. 31 Pathology of HIV encephalopathy. (**a**) Focal area of inflammation with a multinucleated giant cell and tissue disruption in HIV encephalopathy. Lesions are usually composed of macrophages and microglia. (**b**) Multinucleated giant cells of macrophage origin. These cells appear to be the result of syncytial fusion of HIV-infected macrophages and microglia. (**c**) Microglial nodule composed of macrophages and microglia. (From Hanley et al. [40]; with permission)

Table 51 Differential diagnosis of HIV encephalopathy and common complications of AIDS

	Clinical manifestations					Neuroimaging findings	
Disorder	Approximate incidence, %	Onset	Alertness	Features	Lesions, *n*	Type of lesions	Location of lesions
AIDS dementia (HIV) encephalopathy	67	Weeks to months	Preserved	Personality change, unsteady gait, seizures, dementia	None, multiple, or diffuse	Increased MRI T2 signal, no enhancement or mass effect	White matter, basal ganglia
Cerebral toxoplasmosis	15	Days	Reduced	Fever, headaches, focal deficits, seizures	Multiple	Multiple, low-density ring-enhancing lesions on CT and T1-weighted MRI; spherical, increased T2-weighted MRI signal; mass effect	Cortex, basal ganglia
Cryptococcal meningitis	~ 9	Weeks	Variable	Fever, headaches, nausea and vomiting, confusion	None, hydrocephalus	–	–
Progressive multifocal leukoencephalopathy	4	Weeks	Preserved	Multiple focal deficits, late dementia	Multiple	Multiple, diffuse lesions; increased signal on T2-weighted sequences and DWI; nonenhancing; no mass effect	White matter, adjacent to cortex and greater than periventricular, corpus callosum, brainstem, cerebellum
Primary central nervous system lymphoma	1	Days to weeks	Variable	Headache, focal deficits, seizures	One or few	Single > multiple; diffuse > ring enhancement; mass effect	Periventricular, white matter

Adapted from Price et al. [65] and Fauci and Lane [66]

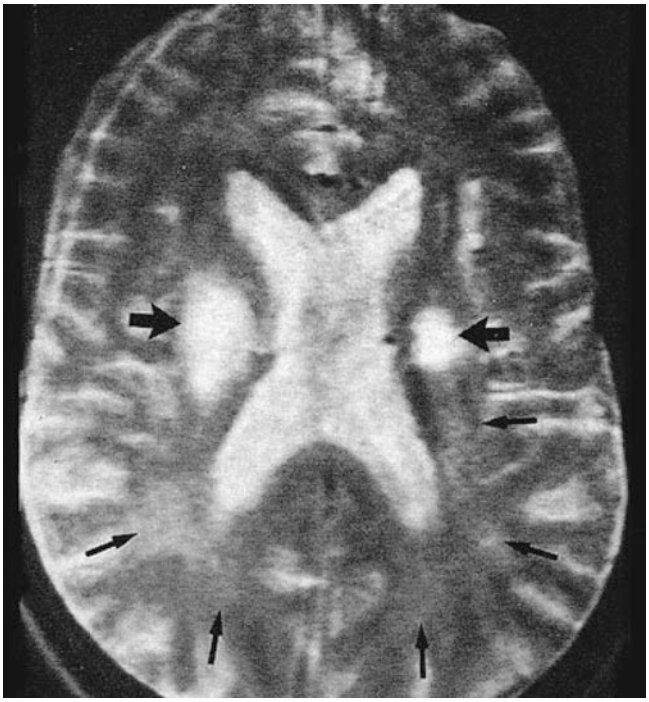

Fig. 32 T2-weighted MRI scan showing bilateral diffuse lesions (*small arrows*) and patchy white-matter lesions (*large arrows*) in the brain of an AIDS patient

tuberculous meningitis with hydrocephalus and infection (1%), and other encephalitides (HSV, VZV, and CMV) may be part of the differential diagnosis at times.

CT scans of HIV encephalopathy are nonspecific and reveal only diffuse atrophy with diffuse cortical atrophy and enlarged ventricles. T1-weighted MRI scans will also reveal diffuse atrophy. On T2-weighted MRI scans (Fig. 32), in addition to atrophy, increased signal in the white matter is seen in 25–30% of AIDS patients. These changes may be diffuse or may be focal, patchy, or punctate.

Table 52 outlines the treatment of HIV encephalopathy and other syndromes caused by the direct effects of HIV infection. Specific antiretroviral agents can be used for all syndromes caused directly by HIV. Over 20 drugs in five classes have been approved for HIV treatment. Specific agents for the treatment of HIV infections include nucleoside reverse transcriptase inhibitors (NRTIs), protease inhibitors (PIs), nonnucleoside reverse transcriptase inhibitors (NNRTIs), nucleotide analogue reverse transcriptase inhibitors (NTRTIs), fusion inhibitors, integrase strand transfer inhibitors (INSTIs), CCR5 antagonists, and fixed-dose combinations. Therapy is recommended for all patients with symptomatic, established HIV infection. Combination therapy is usually used. Initial regimens of two NRTIs plus a third active agent is recommended [67]. Both $CD4^+$ cell levels and HIV RNA levels are used to decide when to start and change therapy [67]. In addition, when choosing a regimen, comorbidities such as cardiac, renal, or hepatic disease should be considered. When prescribing anti-HIV therapy, it is important to know the interactions between these agents as well as the interactions between these agents and other medication classes (antihistamines, antifungals, antimycobacterials, oral contraceptives, cytochrome P450 metabolized drugs, benzodiazepines, antibiotics, methadone, anticonvulsants, antiarrhythmics, calcium channel blockers, and ergot alkaloids).

Symptomatic treatment such as antidepressants or antipsychotics for HIV encephalopathy may be useful. For the painful sensory neuropathy, analgesics, antidepressants (especially tricyclics, such as amitriptyline, nortriptyline and a serotonin/norepinephrine reuptake inhibitor such as duloxetine), anticonvulsants (gabapentin, carbamazepine, phenytoin), and topical capsaicin ointment may be helpful.

HTLV-1–Associated Myelopathy/Tropical Spastic Paraparesis

Table 53 lists neurologic signs of human T-cell lymphotropic virus (HTLV)-1–associated myelopathy and tropical spastic paraparesis (HAM/TSP). HAM/TSP is characterized by a chronic progressive spastic paraparesis, usually with a neurogenic bladder. Patients may have paresthesia and pain in the legs. Both posterior column and spinothalamic sensory loss have been seen, but usually in a minority of cases. Infrequently, cranial nerve (CN) signs are seen, with optic atrophy the most common. Other CN signs include nystagmus, diplopia, deafness, and facial paresis. Antibodies to HTLV-1 have been found in 80% to 100% of cases, and HTLV-1 has been isolated from the CSF. The pathogenesis appears more likely to be an immune-mediated process, as cytotoxic T lymphocytes rather than HTLV-1 viral titer levels are related to the demyelinating lesions. Pathologic changes include inflammation of the leptomeninges, perivascular cuffing, and inflammation of the cord parenchyma. Symmetrical demyelination of the corticospinal tracts occurs, and demyelination of the posterior columns and spinothalamic and spinocerebellar tracts also may occur, to a lesser degree and frequency. Much less often, patients with HTLV-1 infections have presented with an ALS-like picture, polyneuropathy, and inflammatory and noninflammatory myopathies [68].

Most cases of HAM/TSP occur in warm areas along the equator, where the virus is endemic. Isolated cases have occurred in more northern and southern latitudes, including

Table 52 AIDS chemotherapeutic agents

Generic name[a]	Abbreviation	Common side effects
Nucleoside reverse transcriptase inhibitors (NRTIs)		
Zidovudine	AZT, ZDV	Bone marrow suppression, hepatitis, GI upset, myopathy
Didanosine	ddI	Painful sensory neuropathy, pancreatitis, diarrhea
Stavudine	D4T	Painful sensory neuropathy, hepatitis
Lamivudine	3TC	Bone marrow suppression, GI upset
Abacavir	ABC	Hypersensitivity reactions[a], GI upset
Adefovir	ADV	Hypersensitivity reaction in patients positive for HLA-B[a]5701 allele, GI upset
Emtricitabine	FTC	Headache, GI upset, rash
Protease inhibitors (PIs)		
Saquinavir	SQV	Diarrhea, abdominal pain
Ritonavir	RTV	GI upset, diarrhea, fatigue, circumoral paresthesias
Indinavir	IDV	GI upset, diarrhea, kidney stones, hyperbilirubinemia
Nelfinavir	NFV	Diarrhea
Amprenavir	141 W94	Rash (including Stevens-Johnson), GI upset, headache
Lopinavir	LPV	Pancreatitis, diarrhea
Fosamprenavir	FPV	GI upset, diarrhea, headache, rash
Atazanavir	ATV	Rash (including Stevens-Johnson), hyperbilirubinemia, GI upset
Tipranavir	TPV	GI upset, diarrhea, fatigue, headache, rash, pyrexia
Darunavir	TMC114	GI upset, headache, nasopharyngitis
Nonnucleoside reverse transcriptase inhibitors (NNRTIs)		
Nevirapine	NVP	Hepatitis, rash, headache
Delavirdine	DLV	Rash
Etravirine	ETR	Rash, endocrine, GI
Efavirenz	EFV	Encephalopathy (25% transient, 3% limiting), hepatitis, rash
Nucleotide analogue reverse transcriptase inhibitors (NTRTIs)		
Tenofovir disoproxil fumarate	TDF	Hepatitis, rash, headache, nephrotoxicity, osteoporosis
Fusion inhibitors		
Enfuvirtide	T20	Injection site reaction, diarrhea, fatigue, pneumonia
Integrase strand transfer inhibitors (INSTIs)		
Dolutegravir	DTG	Transaminitis, neutropenia, headache, fatigue
Elvitegravir	EVG	Diarrhea, hematuria, pancreatitis, dyslipidemia
Raltegravir	RAL	Headache, dizziness, fatigue
Combination drugs		
Abacavir-lamivudine	ABC-3TC	Hypersensitivity reaction[a]
Abacavir-lamivudine-zidovudine	ABC/3TC/ZDV	Hypersensitivity reaction[a]
Abacavir-dolutegravir-lamivudine	ABC/DTG/3TC	Hypersensitivity reaction[a]
Efavirenz-emtricitabine-tenofovir	EFV/FTC/TDF	
Elvitegravir-cobicistat-emtricitabine-tenofovir-disoproxil	EVG/COBI/FTC/TDF	
Emtricitabine-rilpivirine-tenofovir-disoproxil	FTC /RPV /TDF	
Emtricitabine-tenofovir-disoproxil	FTC/TDF	
Lamivudine-zidovudine	3TC/ ZDV	

GI gastrointestinal

[a]Abacavir-related drug combinations should not be considered for patients who are positive for the HLA-B*5701 allele, as there is a high risk for developing an abacavir hypersensitivity reaction

northern areas of the United States. The disease usually begins in the third or fourth decade and women are more commonly affected, with a female-to-male ratio of about 2 to 1. The virus appears to be transmitted by vertical transmission through sexual contact, intravenous drug use, blood transfusions, or from the mother to the infant through breastfeeding. For cases reported from the United States (except for the endemic area of South Florida), 20–25% of the time the mode of transmission cannot be determined.

The differential diagnosis of HAM/TSP (Table 54) is that of a chronic spastic progressive paraparesis. The diagnosis can be made by analysis of the CSF. Less than half of patients have mild pleocytosis, whereas more than half have an elevated protein level. Specific CSF tests include the presence of HTLV-1 antibody and HTLV-1 oligoclonal bands, virus isolation from the CSF, and the detection of the HTLV-1 genome using PCR amplification. MRI may reveal nonspecific demyelination in the spinal cord and brain.

Table 53 Neurologic signs of HAM/TSP

Abnormal signs	Affected, %
Corticospinal signs	
Legs	
Spasticity	100
Weakness	90–100
Arms	
Spasticity	60–90
Weakness	20–50
Increased jaw jerk	30–70
Bladder dysfunction	70–90
Impaired position, vibration sense	10–60
Root or cord sensation	20–65
Optic atrophy	2–20
Cerebellar signs	3–10

Adapted from Rodgers-Johnson et al. [69]

Table 54 Differential diagnosis of HAM/TSP

Cervical or thoracic cord compression	Nutritional disorders
Chiari malformations	Combined systems disease (B_{12} deficiency)
Foramen magnum tumors	Vitamin E (tocopherol) deficiency
Cervical spondylosis	Lathyrism
Cervical and thoracic herniated discs	Neoplastic disease
Arteriovenous malformations	Extramedullary (metastatic) or intramedullary tumors (primary or metastatic)
Motor neuron disease or related syndromes	Paraneoplastic myelopathy
Amyotrophic lateral sclerosis	Other disorders
Primary lateral sclerosis	Adrenoleukodystrophy
Hereditary spastic paraplegia	Hepatic myelopathy
Inflammatory disorders	
Multiple sclerosis	
Systemic lupus erythematosus	
Sarcoid	
Infectious diseases	
HIV myelopathy	
Bacterial disease	
Syphilis	
Tuberculosis (cord tuberculoma, compression)	
Parasites	
Schistosomiasis	
Strongyloidosis	

Adapted from Izumo et al. [70]; with permission

For treatment, prednisone and danazol have been reported to be beneficial but have not been tested in a controlled fashion. In a recent double-blind, controlled study, however, two thirds of the patients reported a benefit from 3.0 million units per day of interferon-α.

Table 55 Clinical manifestations of Progressive Multifocal Leukoencephalopathy

Multifocal symptoms and signs
Hemiparesis
Hemianopsia
Hemisensory deficit
Aphasia
Limb ataxia
Gait ataxia
Dysarthria
Late mental status changes
Personality changes
Dementia

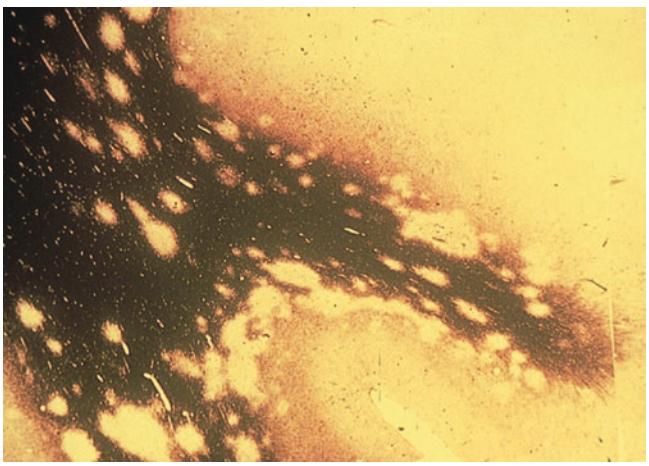

Fig. 33 Photomicrograph showing multiple pale areas of demyelination, which are usually well-circumscribed, in progressive multifocal leukoencephalopathy (PML) (lower power, myelin stain). (Courtesy of Richard Johnson, MD, Johns Hopkins Medical School, Baltimore, MD)

Progressive Multifocal Leukoencephalopathy

Progressive multifocal leukoencephalopathy (PML) is caused by the opportunistic JC papovavirus. Multiple areas of demyelination occur, leading to the accumulation of multifocal deficits (Table 55). When the lesions become extensive throughout the white matter, mental status changes ensue. PML occurs in immunosuppressed individuals. Before the AIDS epidemic, it was seen most often in those treated for lymphoproliferative disease (leukemia/lymphoma). PML is now much more common in AIDS patients, with a prevalence of about 2.5%. Recently, PML was reported in two multiple sclerosis patients enrolled in a clinical trial who received combination therapy of natalizumab and interferon-β-1a [71]. The disease progresses to death in months. There is no specific treatment.

The photomicrograph in Fig. 33 shows the multiple pale areas of demyelination in PML. These areas contain macrophages and virally infected astrocytes and oligodendroglia. The opportunistic JC papovavirus infects oligodendroglia of immunocompromised patients. The multiple areas of

demyelination that result are greater in the cerebral white matter than in the brain stem and cerebellum. Hyperplasia of astrocytes also occurs, and eosinophilic intranuclear inclusions are visible in enlarged oligodendroglia nuclei.

In diagnosing PML, the CSF is usually normal, with no specific findings, and the electroencephalographic changes are nonspecific. Serologic testing is not helpful, as most adults already have antibody to JC virus. PCR amplification of JC viral DNA from the CSF is positive in about 80% of patients with PML. CT scans reveal low-density, nonenhancing lesions without mass effect. MRI scans (T2-weighted, FLAIR, or diffusion-weighted images) reveal increased signal intensity, and involvement of the subcortical U-fibers is characteristic (Fig. 34); enhancement is minimal in 10–15% of cases. Biopsy of the brain may be necessary for a definitive diagnosis.

Subacute Sclerosing Panencephalitis

Table 56 lists the clinical stages of subacute sclerosing panencephalitis (SSPE). SSPE has become a rare disease in the United States, with fewer than 10 cases per year since the introduction of measles vaccine. Most patients had their measles infection prior to the age of 2 years, followed by a latent period before the onset of disease, which occurs between the ages of 5 and 15 years in 85% of patients. The disease usually begins with poor school performance, personality changes, and then dementia (forgetfulness, regressive speech), which is referred to as stage I. Myoclonus, seizures, and movement disorders occur in stage II. Eventually the comatose and akinetic mutism stages ensue. Death usually occurs in 1–3 years, but has ranged from several months to 15 years.

SSPE apparently is caused by the lack of production of the measles virus M protein, which is needed by the virus to bud out of the cell and spread efficiently to the next cell. The result is a cell-associated infection. The measles virus can spread only by cell fusion, which is slow and inefficient. Diagnosis is made from clinical manifestations and the characteristic laboratory abnormalities. One of the most characteristic laboratory tests is the EEG, which reveals periodic patterns of bursts occurring every 5–7 s, followed by periods of background attenuation (burst-suppression). The CSF gamma globulin and measles antibody titers are usually elevated. CT and MRI performed late in the course reveal diffuse atrophy of the cortex and white matter, with ex vacuo ventricular enlargement. MRI usually reveals multifocal gray and white matter lesions. Although there is no specific treatment, intrathecal administration of interferon-α with oral inosiplex has resulted in remissions. SSPE can be prevented with measles vaccination [72].

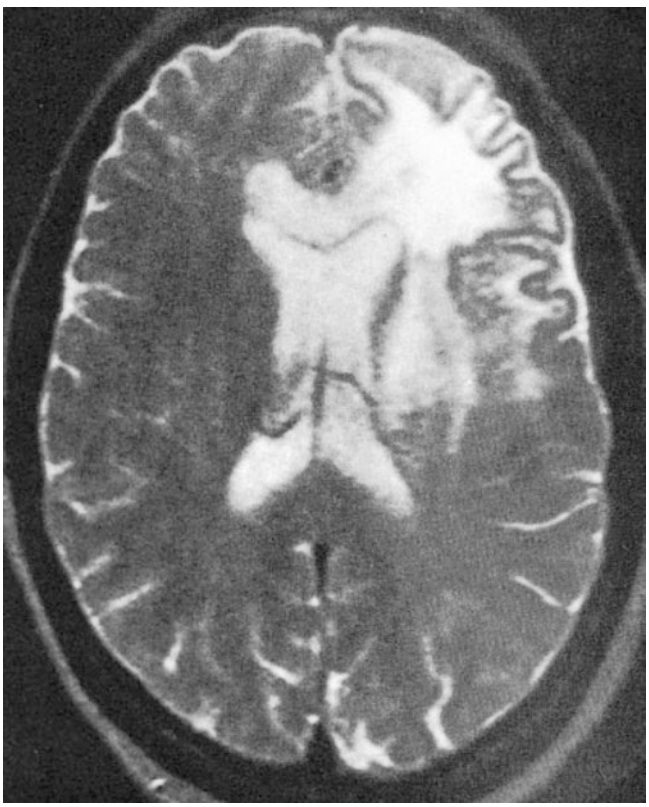

Fig. 34 T2-weighted axial MRI scan in a patient with PML, with increased signal intensity in the left frontal lobe and corona radiata, with extension across the midline

Table 56 Clinical stages of SSPE

Stage I: Cerebral signs (mental, behavioral)
Irritability
Affectionate displays
Lethargy
Forgetfulness
Indifference
Withdrawal
Drooling
Regressive speech
Slurred speech
Stage II: Convulsive, motor signs
Myoclonus of head, limbs, trunk
Incoordination of trunk, limbs
Dyskinesia—choreoathetoid postures, movements, tremors
Stage III: Coma, opisthotonus
No responsiveness to any stimulus
Extensor hypertonus
Decerebrate rigidity
Irregular, stertorous respiration
Stage IV: Mutism, loss of cerebral cortex function, myoclonus
Pathologic laughter, crying
Wandering of eyes
Flexion of upper and lower limbs
Hypotonia
Turning of head to one side
Occasional limb myoclonus
Startling by noise

Adapted from Ohya et al. [73]; with permission

The Prion Diseases

The prion diseases (Table 57) have also been referred to as transmissible spongiform encephalopathy agents. The first of these diseases, scrapie, was recognized to be transmissible in sheep in the 1930s. The latest epidemic of bovine spongiform encephalopathy in Britain, referred to by the lay public as "mad cow disease," is believed to have been transmitted to humans via the ingestion of contaminated beef, resulting in a progressive dementia that has been named *new variant Creutzfeldt-Jakob disease* (nvCJD). The disease caused by nvCJD occurs in younger people, and disease progression is slower [64]. Kuru is of historical interest because it was the first human prion disease to be recognized as transmissible. It occurs in the Fore Indians of New Guinea, beginning with gait, trunk, and limb ataxia and involuntary movements (myoclonus, chorea, tremor) followed by dementia at a later date. Because it is transmitted primarily through cannibalistic rituals, which are now restricted, kuru is rare.

Table 58 lists characteristics of the prion diseases and agents. One of the important characteristics of these agents is that they do not contain detectable nucleic acids (DNA, RNA) but do contain a protein, the prion protein (PrP), which must be transmitted for disease to occur. This finding led to the "prion" terminology, which was derived from "protein" and "infectious." There is no specific treatment for the various prion diseases, but the agent (prions) can be disinfected with various sterilization procedures.

Spongiform change is confined to the cerebral cortex with sparing of the white matter (Fig. 35). Other gray matter areas such as the basal ganglia, thalamus, and cerebellum may also be involved. Spongiform change can also be due to the development of vacuoles in the neurons more than in the astrocytes, resulting in an overall loss of neurons. As previously noted, the prion protein (PrP) is associated with the transmission of disease. It is a hydrophobic protein with a molecular weight of 27–30 kD, referred to as PrP^{Sc} 27–30. Scrapie (Sc) is the prototype prion disease that has been analyzed in these studies. PrP^{Sc} 27–30 is the protease-resistant component of a larger protein, PrP^{Sc} 33–35. Subsequently, it was found that uninfected brains also contained a similar protein, PrP^{C} 33–35, which in humans has its gene (*PRNP*) on the short arm of chromosome 20. PrP^{C} 33–35 is fully degraded, but PrP^{Sc} 33–35 is degraded only to PrP^{Sc} 27–30, which collapses to produce amyloid deposition. On electron micrographs, "prion rods" (or "scrapie-associated fibrils") may be seen. PrP^{C} is found on the cell surface and has two transmembrane domains, whereas PrP^{Sc} accumulates within cells and extracellularly. The role of PrP^{C} is unknown. These findings have led to the hypothesis that in infected animals, PrP^{C} undergoes posttranslational modification, being converted to the PrP^{Sc} isoform. This posttranslational modification would be the explanation for the sporadic prion diseases (Creutzfeldt-Jakob disease [CJD]). Prion disease can also be infectious (kuru, accidental CJD), or genetic (familial CJD, Gerstmann-Sträussler-Schenker syndrome, fatal familial insomnia). CJD has been transmitted by surgical instruments, stereotactic EEG needles, growth hormone preparations, dura mater grafts, and corneal transplants. In the genetic cases, there are mutations in the *PRNP* gene. How the agent

Table 57 Prion diseases of humans and animals

Disease	Host
Scrapie	Sheep, goats
Transmissible mink encephalopathy	Mink
Chronic wasting disease	Mule deer, elk
Bovine spongiform encephalopathy	Cattle
Feline spongiform encephalopathy	Cats
Kuru	Humans
CDJ	Humans
nvCJD	Humans
Gerstmann-Sträussler syndrome	Humans
Fatal familial insomnia	Humans

Table 58 Characteristics of prion diseases and agents

Prolonged incubation period of months to years
Progressive course of weeks to months to death
No host immune response (except astrocytosis)
Pathologic lesions confined to the central nervous system
Similar histopathology
Nonspecific treatment
Causative agents (prions) have specific properties:
No detectable nucleic acid
Resistant to alcohol, formalin, heat, ultraviolet irradiation, nucleases[a]
Susceptible to proteolytic enzymes, denaturing agents, organic solvents[b]
Sterilized by:
Steam autoclaving 1 h at 132 °C
Immersion in 1 N NaOH for 1 h at room temperature

[a]Agents that hydrolyze or modify nucleic acids
[b]Agents that digest, denature, or modify proteins

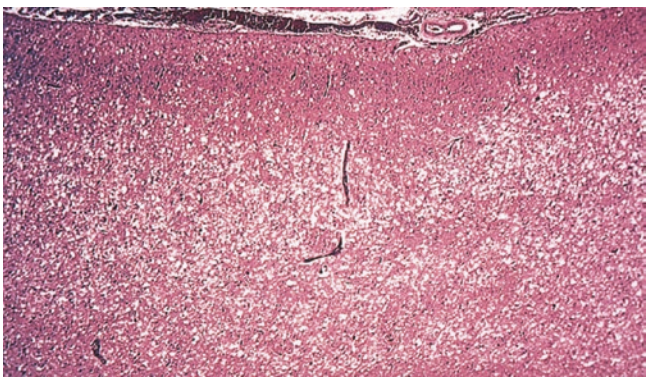

Fig. 35 Low-power view of hematoxylin-eosin stain showing spongiform change confined to the cerebral cortex with sparing of the white matter. (From Hirano et al. [45]; with permission)

actually replicates in the sporadic and infectious cases is unclear. Pathologic changes are similar in all prion diseases, with varying degrees of each feature. These features include spongiform change, astrocytosis, and deposition of amyloid or kuru plaques.

Creutzfeldt-Jakob Disease

In CJD, there is usually a gradual onset of dementia in middle or late life (Table 59). Prodromal symptoms may include anxiety, dizziness, blurred vision, unusual behavior, poor judgment, and fatigue. In addition to dementia, cerebellar signs often occur early, and involuntary movements (especially myoclonus) and corticospinal tract and extrapyramidal signs eventually become prominent. So-called variant types, for example—lower motor neuron type and occipital type—have been categorized when these features are prominent early in the course. The incidence of CJD is 1 case per 1 million people per year and is the same throughout the world except for a few areas of high incidence (Libya, North Africa, Slovakia). CJD is not contagious but is transmissible; general trauma, head and neck trauma, and head and neck surgery predispose a patient to the disease. Familial cases make up 5–15% of cases, with an autosomal dominant pattern of inheritance. Mutations have been found in the *PRNP* gene in some of these familial cases, most often at codons 178 and 200. In a recent series, the range for the age of onset was 16–82 years, but only one patient was younger than 30 years old, and four were younger than 40. The mean duration of disease was 8 months; 80–90% of patients die in 1 year. As previously noted, CJD is not contagious but the mode of transmission is unknown. The agent is not found in saliva or stool and only very rarely in urine, so it does not seem necessary to isolate patients. Because the agent is present in internal organs, blood and CSF serum hepatitis precautions should be taken.

In the diagnosis of CJD, routine blood studies are normal. The CSF is also usually normal, although the protein may be increased. Two-dimensional isoelectric focusing of CSF proteins have revealed two abnormal protein species, now referred to as 14-3-3 neuronal proteins. The assay is positive in about 85% of sporadic CJD CSF samples. The assay may also be positive in other diseases with acute, massive neuronal destruction, such as herpes simplex encephalitis and acute infarction. CSF tau protein and neuronal enolase are also often increased in CJD. The EEG (Fig. 36) is an important diagnostic test. Various series report that 60–95% of patients will have periodic complexes occurring on the average of one per second (range 0.5–2.5 s). Serial EEG may be needed to detect the periodicity, as it is usually absent at onset and early in the course, and may also be absent late in the course. MRI may be of equal sensitivity to the 14-3-3 assay for diagnostic purposes. Increased signal intensity may be seen on T2-weighted images, FLAIR, or DWI (Fig. 37). Two patterns may be seen: The first is a diffuse pattern primarily seen in the basal ganglia and occasionally in the thalamus. The second is a cortical ribbon or gyriform pattern in

Table 59 Clinical characteristics of 232 experimentally transmitted cases of sporadic Creutzfeldt-Jakob disease

	Patients with symptoms or signs, %		
Symptoms/Signs	At Onset	On first exam	During course
Mental deterioration	69	85	100
Memory loss	48	66	100
Behavioral abnormalities	29	40	57
Higher cortical functions	16	36	73
Cerebellar	33	56	71
Visual/oculomotor	19	32	42
Vertigo/dizziness	13	15	19
Headache	11	11	18
Sensory	6	7	11
Involuntary movements	4	18	91
Myoclonus	1	9	78
Other (including tremor)	3	12	36
Pyramidal	2	15	62
Extrapyramidal	0.5	9	56
Lower motor neuron	0.5	3	12
Seizures	0	2	19
Pseudobulbar	0.5	1	7
Periodic electroencephalogram[a]	0	0	60
Triphasic 1 cycle/sec	0	0	48
Burst suppression	0	0	14

Adapted from Brown et al. [74]; with permission

[a]The figures shown are much lower than those published in a small series of repeatedly studied patients

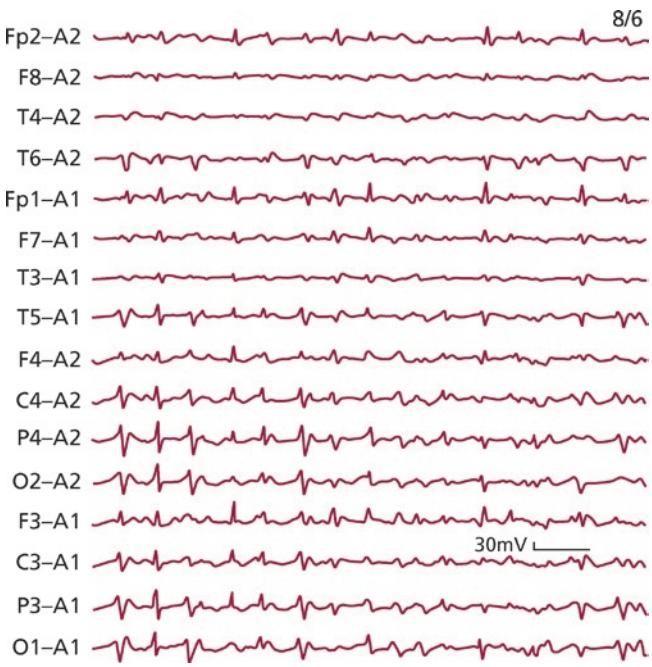

Fig. 36 Electroencephalogram from a 65-year-old man with CJD, showing periodic spikes or sharp waves every 0.7 s. (Adapted from Jubelt [75])

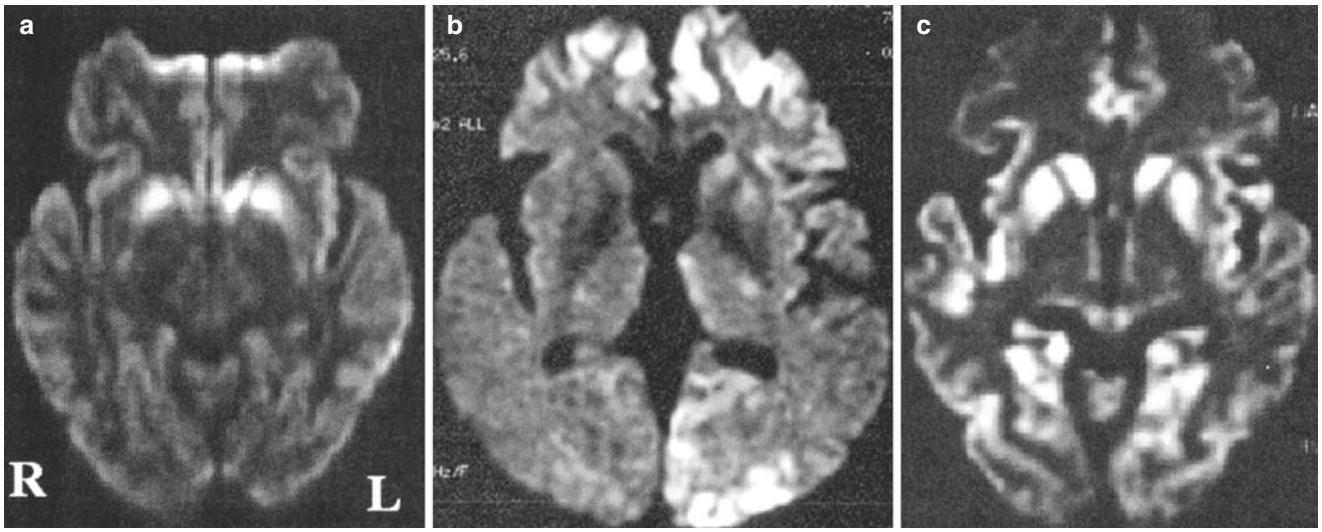

Fig. 37 MRI of Creutzfeldt-Jakob disease, with three patterns of high-intensity lesions seen on DWI: striatal lesions (**a**) cerebral cortical lesions (**b**) and a combination of both lesions (**c**). (From Shiga et al. [76], with permission)

Table 60 Clinical features of variant Creutzfeldt-Jakob disease

	Patients with symptoms or signs, % (n = 35)	
Symptoms/signs	At onset	During course
Psychiatric	63	97
Sensory symptoms	20	68
Limb pain	11	37
Ataxia	8	100
Forgetfulness	17	83
Involuntary movements	6	94
Dystonia	6	34
Chorea	0	57
Myoclonus	0	71
Upgaze paresis	0	40
Dementia	0	100
Akinetic	0	57

Adapted from Will et al. [77]; with permission

the cortex and cerebellum. DWI (with 90–100% sensitivity) appears to be more sensitive than either FLAIR or T2 imaging (about 50%). Diagnosis can also be made from brain biopsy, but usually biopsy is not required.

Variant Creutzfeldt-Jakob disease (vCJD) occurs at a younger age than classic CJD, with 89% dying before the age of 40. The duration of vCJD is also longer, with a median duration of illness of 14 months, compared with 9–11 months for classic CJD. Psychiatric symptoms and painful sensory symptoms usually occur first in vCJD, rather than memory loss (Table 60). Similar to classic CJD, dementia, ataxia, and involuntary movements eventually occur (*see* Table 59). Another unusual feature of vCJD is that the typical periodic triphasic complexes seen on EEGs from classic CJD patients have not been reported. MRI may reveal abnormalities in the thalamus, but this finding is not specific for vCJD.

Table 61 Characteristics of GSS syndrome

Familial autosomal dominant disease—*PRNP* gene mutations, most frequently at codons 102, 117, 198
Age of onset—midlife
Clinical signs
Early—cerebellar ataxia with gait ataxia
Later—limb ataxia, dysarthria, nystagmus, dementia, parkinsonism, deafness, blindness, gaze palsies
Eventually—corticospinal tract signs
Course—lengthy, 2 to 10 years
Treatment—supportive

Gerstmann-Sträussler-Schenker Syndrome

Gerstmann-Sträussler-Schenker syndrome (GSS) is an autosomal dominant familial disease. Clinically, patients appear to have spinocerebellar degeneration or olivopontocerebellar degeneration with cerebellar ataxia, which is the first, most severe manifestation of the disease (Table 61). Myoclonus is much less common. Eventually dementia and parkinsonism develop in most patients. The EEG usually does not show periodicity. In one reported case, diffusion-weighted MRI revealed a cortical gyriform pattern in the frontal, temporal, and occipital cortices early in the course, followed by atrophy late in the course.

Fatal Familial Insomnia

Fatal familial insomnia (FFI) is a rapidly progressive, autosomal dominant disease of middle or late life. Mutation at codon 178 of the *PRNP* gene has been demonstrated. This change is similar to that reported for some cases of familial CJD, but the clinical picture is much different (Table 62). FFI is characterized primarily by insomnia, dysautonomia, and ataxia. Dementia and a periodic EEG are uncommon. The course progresses to death in 6 months to 2 years.

Table 62 Clinical features of FFI

Case	Sex	Age of onset, *y*	Course, *mo*	Insomnia	Dysautonomia	Ataxia	Myoclonus	Seizures	EEG
IV-20	F	48	7	+	+	+	+	–	–
IV-21[a]	M	52	+++[b]	+++	+	+	–	–	
IV-34	F	45	7	+++	+	+++	+	–	–
IV-37[a]	M	61	18	+++	+	++	+	–	–
IV-75	M	54	18	++	++	++	+	–	–
IV-92	M	45	7	++	+++		+	–	+[d]
V-58[a]	F	35	25	+	+++	+++	+++	+[c]	

Adapted from Manetto et al. [78]; with permission
+ minimal, ++ mild, +++ severe
[a]Clinically examined and longitudinally observed
[b]Polygraphically proven
[c]Grand mal type
[d]Periodic spike activity

Table 63 Spectrum of involvement for fungi that can infect the CNS

			Chief pathologic manifestations		
Organisms	Incidence	Predilection to involve the CNS[a]	Meningitis	Abscess or inflammatory mass	Infarct
Cryptococcus	Common	++++	++++	+	+
Coccidioides	Common	+++	++++	+	+
Candida	Common	++	++	++	—
Aspergillus	Occasional	++	+	+++	++++
Zygomycetes[b]	Occasional	++	+	+++	++++
Histoplasma	Occasional	+	+	+	+
Blastomyces	Occasional	+	+	+	—
Sporothrix	Occasional	+	+	—	—
Paracoccidioides	Rare	±	±	±	—
Dematiaceous fungi	Rare	+++	±	++++	—
Pseudallescheria	Rare	+	++	++	—

++++ common, ± rare, —does not occur
[a]Versus other body sites
[b]*The class of Zygomycetes or Phycomycetes includes genera Rhizopus and Mucor*

Fungal Infections

The clinical syndromes caused by fungi invading the CNS (Table 63) can be divided into meningitis, abscess or inflammatory mass (granuloma formations), and arterial thrombosis causing infarction. Fungi exist in two forms: yeasts and molds. Yeasts are unicellular organisms that have a thick cell wall surrounded by a well-defined capsule (*see* Fig. 38). Molds are composed of tubular filaments that sometimes have a branched form (hyphae). In the brain, dimorphic and fungal yeasts are more likely to cause meningitis, whereas molds are more likely to cause vasculitis with subsequent thrombosis and infarction. The major pathogenic molds are species of the genus *Aspergillus* and the class of Zygomycetes.

As previously noted, most fungal infections are opportunistic. Specific factors predispose to specific fungal infections (Table 64).

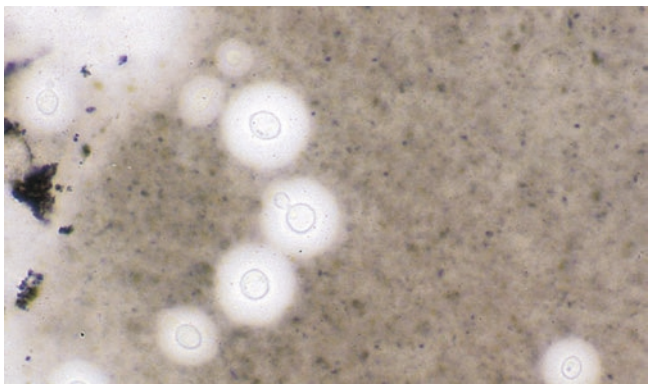

Fig. 38 An India ink preparation used in the diagnosis of cryptococcal meningitis that demonstrates the prominent capsule of *Cryptococcus neoformans*. (From Tunkel and Crous [79]; with permission)

Fungal Meningitis

The symptoms and signs of fungal meningitis, one of the many causes of chronic meningitis, vary somewhat depending on the specific organism (Table 65).

Cryptococcal Meningitis

Table 66a lists the clinical presentations and laboratory findings in patients with cryptococcal meningitis. *Cryptococcus* is the most frequent cause of fungal meningitis in both non-AIDS and AIDS patients. It is a chronic meningitis, but in AIDS patients it may progress even more slowly and present only with fever and headache instead of the usual manifestations of meningeal signs, mental status changes, and cranial nerve palsies. Most patients with cryptococcal meningitis are immunocompromised [81].

The usual CSF profile in cryptococcal meningitis (as well as most other causes of fungal meningitis) is that of mononuclear (lymphocytic) pleocytosis, a low glucose level, and an elevated protein level (Table 66b). AIDS patients, however, often do not fit this typical CSF picture. Most striking is the fact that 65% of AIDS patients have a normal CSF cell count of fewer than 5 cells/mm^3. Diagnosis is confirmed by positive CSF culture result or a positive CSF cryptococcal antigen test [82]. MRI may reveal gelatinous pseudocyst formation in the basal ganglia.

Figure 38 shows an India ink preparation used in the diagnosis of cryptococcal meningitis that demonstrates the prominent capsule of *Cryptococcus neoformans*. The India ink test is positive 50–60% of the time, and slightly more frequently in patients with AIDS.

Coccidioidal Meningitis

MRI (Fig. 39) may show enlargement of the third ventricle and a patent aqueduct (*arrow*), which are findings consistent with a communicating hydrocephalus. The diagnosis

Table 64 Factors predisposing to fungal CNS infections

Predisposing factors	Typical organisms
Prematurity	*Candida*
Inherited immune defects CGD, SCID, etc.	*Candida, Cryptococcus, Aspergillus*
Acquired immune defects	
Corticosteroids	*Cryptococcus, Candida*
Cytotoxic agents	*Aspergillus, Candida*
HIV infection	*Cryptococcus, Histoplasma*
Alcoholism	*Sporothrix*
Hematologic malignancies	*Candida, Aspergillus, Cryptococcus, Histoplasma*
Iron chelator therapy	Zygomycetes
Deferoxamine	
Intravenous drug abuse	Zygomycetes, *Candida*
Diabetic ketoacidosis	Zygomycetes, *Candida*
Trauma, surgery, foreign body, near-drowning	*Candida, Pseudallescheria,* dematiaceous fungi

Adapted from Tunkel and Crous [79], Gozdasoglu et al. [80]; with permission
CGD chronic granulomatous disease, *SCID* severe combined immune deficiency

Table 66 Clinical (a) & Lab (b) cryptococcal

(a) Clinical presentation in non-AIDS and AIDS patients		
Clinical presentation	Non-AIDS, %	AIDS, %
Headache	87	81
Fever	60	88
Nausea, vomiting, malaise	53	38
Mental status changes	52	19
Meningeal signs	50	31
Visual changes, photophobia	33	19
Seizures	15	8
No symptoms or signs	10	12

(b) Laboratory studies in non-AIDS and AIDS patients		
Laboratory findings	Non-AIDS, %	AIDS, %
Positive blood culture	–	30–63
Positive serum cryptococcal antigen	66	99
CSF opening pressure > 200 mm H_2O	72	62
CSF glucose <2.2 mmol/L (40 mg/dL)	73	33
CSF protein >0.45 g/L (45 mg/dL)	89	58
CSF leukocytes >20 × 10^6/L	70	23
Positive CSF India ink preparation	60	74
Positive CSF culture	96	95
Positive CSF cryptococcal antigen	86	91–100

Adapted from Tunkel and Scheld [82]; with permission

Table 65 Signs and symptoms of fungal meningitis

Fungal organism	Fever (>101 °F)	Headache	Stiff neck	Change in mentation	Focal signs	Visual disturbance
Blastomyces	+	+++	+++	+	++	+
Candida	+++	+++	++	+	+	+
Coccidioides	+	+++	+	++	++	++
Cryptococcus	+	+++	+++	+	+	+++
Histoplasma	++	+	++	+	+	+
Sporothrix	+	++	++	++	+	?

+ rare, ++ occasionally to moderately frequently, +++ usually

of coccidioidal meningitis depends on the recognition of the clinical picture of fungal meningitis and the extraneural manifestations of pulmonary and skin involvement. Unlike other fungal infections, about 70% of patients have a CSF eosinophilia. Otherwise, the CSF picture is as expected—a lymphocytic pleocytosis, elevated protein, and low glucose. Positive CSF culture and antibody assays are required as the definitive criteria. On MRI, hydrocephalus is a common complication of coccidioidal meningitis; it may be communicating or noncommunicating and usually requires shunting. Patients with hydrocephalus have the highest mortality rates. Contrast enhancement of the basal cisterns may also be seen.

The clinical features of "cocci" meningitis are similar to those of cryptococcal meningitis except that changes in the patient's mental state are more likely to occur because of the earlier development of hydrocephalus.

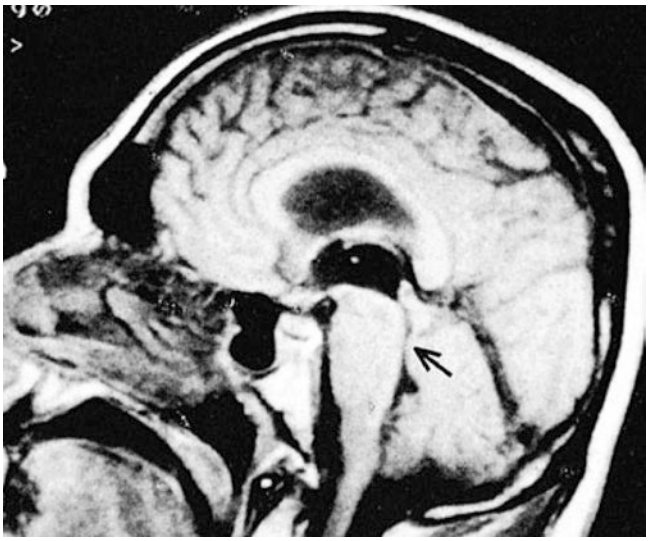

Fig. 39 MRI showing enlargement of the third ventricle and a patent aqueduct (*arrow*), findings consistent with a communicating hydrocephalus in coccidioidal meningitis. (From Galgiani [83], with permission)

Other manifestations include fever, headache (75%), and meningismus. *Coccidioides* is a common cause of fungal meningitis in areas where it is endemic. Fortunately, it is endemic only in the San Joaquin Valley and the desert areas of the southwestern United States. It is also found in Central and South America. Meningitis is the most lethal complication.

Other Fungal Infections of the CNS

Unlike cryptococcosis, other fungi that cause meningitis have extraneural clinical manifestations that may be diagnostically valuable (Table 67). These extraneural infections usually involve the respiratory tract, the skin, and hair. Clinical respiratory manifestations may be upper respiratory infection or pneumonia; the chest radiogram is often abnormal.

Other than extraneural manifestations, the main diagnostic studies for fungal meningitis are those performed on the CSF (Table 68). Most patients with fungal meningitis have mononuclear pleocytosis, low glucose levels, and a high protein level similar to that seen in cryptococcal meningitis (*see* Table 66b). Conclusive proof of diagnosis relies on culture and antigen and antibody tests. Unfortunately, CSF cultures often are not positive, but the likelihood of a positive result increases by culturing a large volume of CSF (15–30 mL). CT or MRI scans usually reveal at least some degree of hydrocephalus. Less frequently, single or multiple enhancing parenchymal lesions (abscesses) may be seen.

Fungal meningitis is a subacute to chronic process with a course lasting over weeks to months, and the differential diagnosis of chronic meningitis is extensive (Table 69).

Amphotericin B has been the main drug used for treatment of fungal meningitis for over 30 years. It remains the agent of choice alone or in combination with other treatment for most species (Table 70). Amphotericin is primarily given intravenously (rarely intrathecally for *Coccidioides*). For many species, this induction therapy

Table 67 Extraneural manifestations of fungi that cause meningitis

Clinical manifestations				
Species	Respiratory tract	Skin/membranes	Hair	Bone/joints
Coccidioides	+++	++	–	+
Candida	+	+++	++	+
Histoplasma	++	+	–	–
Blastomyces	+++	+++	+	+
Sporothrix	+	++	–	++

+ low frequency, ++ moderate frequency, +++ high frequency

Table 68 CSF tests—fungal meningitis

Species	Positive culture results	CSF serologic tests
Blastomyces dermatitidis	Rare	Ab
Candida	50%	Ab/Ag
Coccidioides immitis	25–45%	Ab
Cryptococcus neoformans	75–80%	Ag
Dematiaceous fungi	Rare	None
Histoplasma capsulatum	50%	Ab
Paracoccidioides brasiliensis	Rare	Ab
Sporothrix schenckii	Rare	Ab

Ab antigen, *Ag* antibody

Table 69 Differential diagnosis of fungal meningitis syndrome

Infectious	Noninfectious
Bacterial	Neoplasm
Tuberculosis	Sarcoidosis
Spirochetal (Lyme disease, syphilis, *Leptospira*)	Vasculitis
Agents that cause sinus tracts (*Actinomyces*, *Arachnia*, *Nocardia*)	Primary central nervous system angiitis
Brucellosis	Systemic (giant cell arteritis, systemic lupus erythematosus, Sjögren's syndrome, rheumatoid arthritis, lymphomatoid granulomatosis, polyarteritis nodosa, Wegener's granulomatosis)
Listeria monocytogenes	Behçet's disease
Fungal	Chemical meningitis
Common (*Candida*, *Coccidioides*, *Cryptococcus*, *Histoplasma*)	Endogenous
Uncommon (*Aspergillus*, *Blastomyces*, dematiaceous fungi, *Paracoccidioides*, *Pseudallescheria*, *Sporothrix*, *Mucormycetes*)	Exogenous
	Intrathecal administration of systemic drugs
Parasitic	Chronic benign lymphocytic meningitis
Cysticercosis	Idiopathic hypertrophic pachymeningitis
Granulomatous amebic meningoencephalitis (acanthamoebiasis)	Vogt-Koyanagi-Harada disease
Eosinophilic meningitis (angiostrongyloidiasis)	
Toxoplasmosis	
Coenurus cerebralis	
Viral	
Retrovirus (HIV-1, human T-cell lymphotropic virus [HTLV-1])	
Enterovirus (in hypogammaglobulinemia)	
Parameningeal infections—epidural abscess, subdural empyema, brain abscess	

Table 70 Primary antifungal therapy for fungal meningitides

Aspergillus	Voriconazole
Blastomyces dermatitidis	Amphotericin B then fluconazole
Candida	Amphotericin B plus 5-FC then fluconazole
Coccidioides immitis	Fluconazole then amphotericin B prn
Cryptococcus neoformans	Amphotericin B plus 5-FC then fluconazole
Histoplasma capsulatum	Amphotericin B then itraconazole
Sporothrix schenckii	Amphotericin B and/or itraconazole then itraconazole alone
Zygomycetes	Amphotericin B or liposomal amphotericin B

5-FC—5-fluorocytosine

is followed with suppressive therapy with fluconazole or itraconazole.

Antifungal drugs have significant toxicity. Close monitoring is needed for renal insufficiency, hematologic abnormalities, and electrolyte imbalance during therapy. The immune reconstitution inflammatory syndrome (IRIS) may be seen in solid organ transplant recipients with cryptococcal meningoencephalitis, as well as in HIV-infected patients infected with *Cryptococcus neoformans* when antiretroviral therapy is initiated [81].

Fungal Abscess and Infarction

Table 71 outlines the etiology of fungal abscess of the CNS. Over the past 30 years, fungal abscess has become more frequent owing to the use of broad-spectrum antibiotics and immunosuppressive agents, as well as the AIDS epidemic. Treatment may require agents to decrease intracranial pressure (mannitol, corticosteroids), surgical decompression, and antifungal chemotherapy agents (*see* Table 70).

For focal CNS fungal infections, CT and MRI are the diagnostic tests of choice. The CSF analysis may be contraindicated because of increased intracranial pressure with a focal lesion. Culture specimens must be obtained at the time of surgical drainage and decompression.

Molds may cause CNS disease by direct extension, including rhinocerebral disease, and by invading blood vessels, causing infarctions (Table 72). It is rarely possible to culture these organisms from the cerebrospinal fluid (CSF) sample, but CSF antigen and antibody assays are available for *Aspergillus*, as is a CSF antibody assay for Zygomycetes genera (*Mucorales* or *Mucor*). There are no CSF antigen or antibody tests for *Pseudallescheria boydii*. Aggressive treatment with surgery to remove necrotic tissue and antifungal chemotherapy are needed to cure these infections.

Table 71 Etiology of CNS fungal abscess

Species	Distribution of cases %	Years of survey	Species	Distribution of cases, %	Years of survey
Total cases, 39		1964–1973	Total cases, 61[a]		1956–1985
Candida	49		*Candida*	44	
Cryptococcus	23		*Aspergillus*	28	
Mucormycoses	13		*Cryptococcus*	23	
Aspergillus	5		Mucormycoses	3	
Histoplasmosis	5		Histoplasmosis	2	
Total cases, 11		1955–1971	Total cases, 57[b]		1984–1992
Aspergillus	64		*Aspergillus*	58	
Mucormycoses	27		*Candida*	34	
Candida	9		Mucormycoses	8	

[a]Includes meningitis plus abscess cases
[b]Bone narrow transplant recipients

Table 72 Pathogenic molds in the CNS

	Aspergillus Species	Mucorales	*Pseudallescheria boydii*
Patients at risk	Hematologic neoplasm	Diabetes with ketoacidosis (> 70%)	Near-drowning
	Neutropenia on broad-spectrum antibiotics	Hematologic neoplasm	Intravenous drug use
	Corticosteroids	Neutropenia on broad-spectrum antibiotics	Neutropenia on broad-spectrum antibiotics
	Organ transplants	Renal transplant	Hematologic malignancy
	Intravenous drug use	Intravenous drug use	Head trauma
	Liver disease	Deferoxamine therapy	
	Postcraniotomy	Acidosis	
	Subtropical farming		
Pathogenesis	Hematogenous	Rhinocerebral	Hematogenous
	Direct extension, including rhinocerebral (rare)	Hematogenous	Direct extension
			Traumatic implantation
Microscopic appearance	Septate hyphae	Nonseptate hyphae	Narrow septate hyphae with rare branching
	Acute branching	Broad right-angle branching	
Culture from CSF	Rare	Seldom	Occasional
Treatment	Surgery	Surgery	Surgery
	Amphotericin B	Amphotericin B	Voriconazole
	? ± fluconazole		
	? Itraconazole		

Spirochete Infections

Neurosyphilis

Syndromes of neurosyphilis develop over three decades (Fig. 40), starting with the onset of the primary syphilitic infection of skin chancre, usually on the penis or perineum. Syphilitic meningitis occurs with either secondary or tertiary syphilis. All other syndromes of neurosyphilis occur during the tertiary stage. All forms of syphilis of the CNS ultimately result from active meningeal inflammation. When the meningeal inflammation extends to the cerebral blood vessels, cerebrovascular neurosyphilis results, usually within 5 years after the primary infection. The parenchymal forms of neurosyphilis—general paresis (dementia) and tabes dorsalis—occur after 5 years. Although each syndrome has a predictable time course, appearances often overlap and several syndromes may occur at the same time.

Table 73 lists the classification of neurosyphilis. Neurosyphilis encompasses several different syndromes because the causative organism, *Treponema pallidum*, is able to infect the meninges, the blood vessels, and the brain and spinal cord parenchyma. Asymptomatic neurosyphilis is diagnosed by positive serologic findings in both the blood and the CSF of asymptomatic patients. CSF pleocytosis with mononuclear cells could allow diagnosis of asymptomatic syphilitic meningitis.

Symptomatic meningeal syphilis usually occurs during the first 2 years after the primary infection. In approxi-

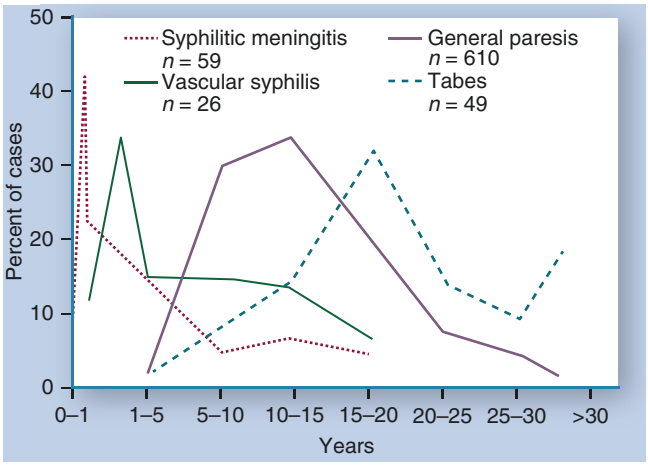

Fig. 40 Time course for the appearance of neurosyphilitic manifestations

mately 10% of cases, syphilitic meningitis occurs with the rash of secondary syphilis, but most cases occur during the tertiary stage. Patients present with headache, meningismus, and malaise. They may or may not have a low-grade fever. Lymphocytic pleocytosis of up to several hundred cells occurs; the glucose level in the CSF is reduced, but usually is greater than 25 mg/dL; the CSF protein level is increased and may exceed 100 mg/dL; and the CSF pressure may be elevated. This syndrome is diagnosed with positive blood and CSF serologic tests (serologic tests for syphilis: Venereal Disease Research Laboratories, rapid plasma reagin). The syndrome may resolve on its own, or complications may ensue. Because the meningitis is most concentrated at the base, cranial nerve palsies are often seen, sometimes bilaterally but usually asymmetrically (Table 74). Obstruction of CSF pathways may result in subacute to chronic hydrocephalus.

Table 73 Classification of neurosyphilis

Type	Clinical symptoms	Pathology	CSF Leukocyte, *cells/mm*^{3}	Brain CT or MRI
Asymptomatic	No symptoms; CSF abnormal	Various. Chiefly leptomeningitis; arteritis or encephalitis may be present	<5	Normal
			>5	Meningeal enhancement
Meningeal and vascular (early forms)				
Cerebral meningeal diffuse (syphilitic meningitis)	Increased intracranial pressure; cranial nerve palsies	Leptomeningitis with hydrocephalus; degeneration of cranial nerves; arteritis	>5	Leptomeningeal enhancement
Cerebral focal (gumma)	Increased intracranial pressure; focal cerebral symptoms and signs of slow onset	Granuloma formation (gumma)	>5 or more Or: Normal or high	Mass lesion
Cerebrovascular (meningovascular)	Focal cerebral symptoms and signs of sudden onset	Endarteritis with infarcts	5 or more Or: Normal or high	Subcortical or cortical infarct
Spinal meningeal and vascular	Paresthesia, weakness, atrophy, and sensory loss in limbs and trunk	Admixture of endarteritis and meningeal infiltration and thickening with degeneration of nerve roots and substance of the cord—myelomalacia	5 or more Or: Normal or high	Long segmental intrinsic spinal cord T2 hyperintensity
Ocular syphilis	Presents with diminished visual acuity and is often, but not always, accompanied by syphilitic meningitis	Ocular syphilis can involve almost any eye structure, but posterior uveitis and panuveitis are the most common	5 or more Or: Normal or high	NA
Parenchymatous (late forms)				
Tabetic	Pain, paresthesia, crises, ataxia, impairment of pupillary reflexes, loss of tendon reflexes, impaired proprioceptive sensation, and trophic changes	Leptomeningitis and degenerative changes in posterior roots, dorsal funiculi, and brain stem	5 or more Or: Normal or high	Spinal cord atrophy Dorsal column involvement
Paretic	Personality changes, convulsions, and dementia	Meningoencephalitis	5 or more Or: Normal or high	Generalized brain atrophy

Zunt and Baldwin [111]
NA not applicable

Table 74 Cranial nerve palsies in syphilitic meningitis[a]

Cranial nerves	Percent of abnormalities
I	2
II	27
III	24
IV	2
V	12
VI	22
VII	41
VIII	42
IX–X	6
XI	1
XII	4

Adapted from Merritt et al. [85]; with permission
[a]354 cranial nerve palsies in 195 patients

Cerebrovascular syphilis occurs when the inflammation in the subarachnoid space compromises arteries traversing this space. Vasculitis of middle-sized vessels occurs, resulting in ischemia. The middle cerebral artery is affected most often, but any cerebral or spinal vessel may be involved. Stroke syndromes occurring in neurosyphilis are no different from those occurring from other causes; focal clinical manifestations are determined by which vessel is involved (Fig. 41). The patients exhibit risk factors for venereal disease and are usually younger than those with atherosclerotic infarction. Differentiation depends upon the blood and CSF serologic results. CT or MRI scans of the brain reveal cortical or subcortical infarction. If the meningeal inflammation is intense enough, a prodrome of headache and personality change may precede the stroke by weeks (meningovascular syphilis). Penicillin effectively cures the infection, preventing further infarctions.

Paretic neurosyphilis (Fig. 42) has also been referred to as general paresis of the insane, syphilitic meningoencephalitis, dementia paralytica, and syphilitic dementia. Symptoms usually begin 5–15 years after the primary infection, with a range of 3–30 years. Paretic neurosyphilis was common in the preantibiotic era but is now infrequent. The symptoms and signs of general paresis are similar to any organic brain syndrome. Progressive dementia with personality changes is the most common feature. Behavioral changes with psychosis and grandiose delusional states are unusual. Seizures also are seen. Tremors of the face, tongue, lips, and extremities; dysarthria; masked facies; and hyperactive reflexes may also occur. Pathologically, there is chronic meningoencephalitis with cortical atrophy, enlarged ventricles, thickened meninges, and granular ependymitis. Microscopic lesions include mononuclear inflammatory cells, a prominent microglial rod cell response, and the presence of the organisms. Diagnosis depends on CSF abnormalities and serologic results. Usually patients are younger than those with other causes of dementia (less than 50 years of age). Penicillin is an effective therapy and usually arrests the progression of the dementia, but it will not reverse the existing damage.

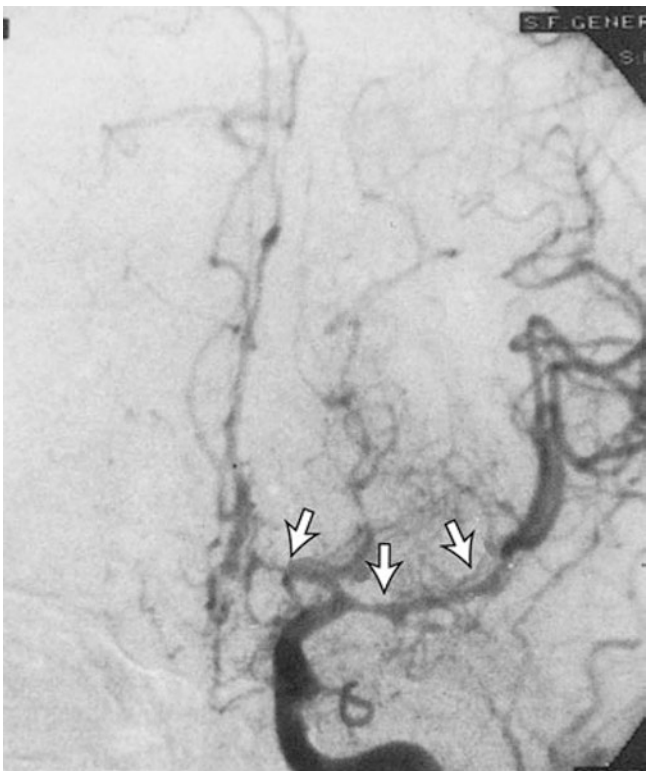

Fig. 41 Anteroposterior view, left carotid angiogram, of a 26-year-old man with meningovascular syphilis, showing constriction (*arrows*) of the anterior and middle segments of the middle cerebral artery. (From Simon and Bayne [86], with permission)

Tabetic neurosyphilis is also referred to as tabes dorsalis because of the degeneration of the posterior columns (Fig. 43). Tabes usually begins 10–20 years after the primary infection, but some cases have had onset after 30 years (range, 5–50 years). The most common and classic symptoms of tabes are the lancinating or lightning-like pains, ataxia, and bladder dysfunction (Table 75). Prominent signs include abnormal pupils including Argyll-Robertson pupils, absent reflexes in the lower extremities, loss of posterior column sensations, Romberg sign, and gait ataxia. As the disease progresses, bladder dysfunction and the sensory gait ataxia usually become the most disabling problems. Loss of deep pain sensation may occur with Abadie's sign (lost or delayed recognition of pain when the Achilles tendon is squeezed). Charcot joints and distal extremity ulcerations may be seen. Diagnosis is relatively easy because of the classic clinical manifestations, with positive serologic results, at least in the blood samples. The disease may arrest spontaneously or may be arrested with antibiotic treatment. The

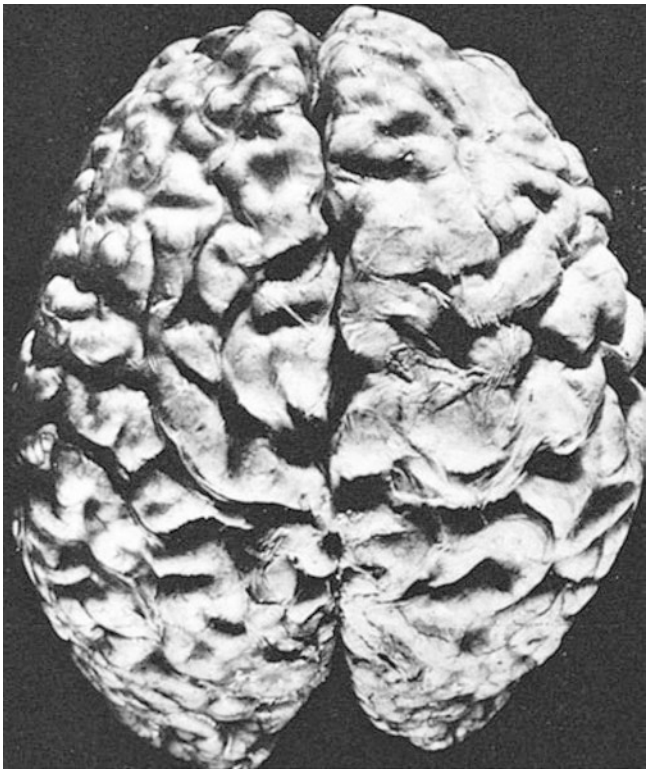

Fig. 42 Pathologic specimen from a brain with paretic neurosyphilis. (From Merritt et al. [85], with permission)

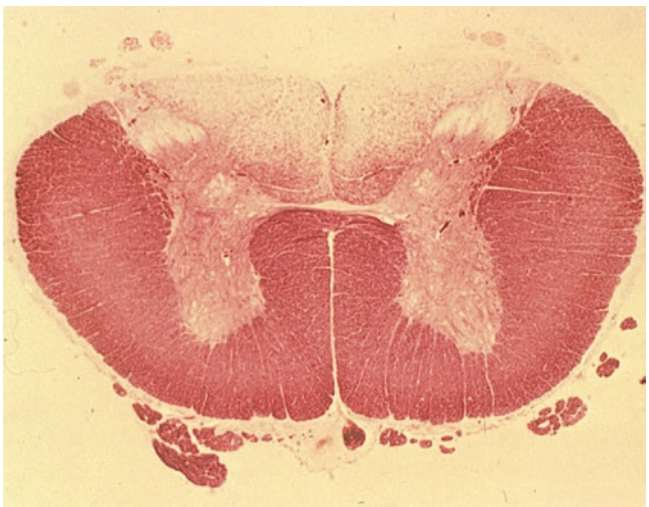

Fig. 43 Degeneration of the posterior columns and dorsal roots in tabetic neurosyphilis. (From Wilson [4], with permission)

latter is more likely to occur when the CSF shows signs of active inflammation (CSF pleocytosis), but many of the manifestations may continue to progress even after treatment and even when there is no active CSF inflammation. The pathogenesis of tabes is not understood. In contrast to paretic cortical lesions, spirochetes are not found in the affected areas of the spinal cord, which may explain why antibiotic therapy may not stop progression.

Table 75 Symptoms and signs of tabetic neurosyphilis (analysis of 150 cases)

Symptoms	%	Signs	%
Lancinating pain	75	Abnormal pupils	94
Ataxia	42	Argyll-Robertson	48
Bladder disturbance	33	Other abnormalities	46
Paresthesia	24	Absent reflexes	
Gastric or visceral crises	18	Ankle jerks	94
Optic atrophy	16	Knee jerks	81
Rectal incontinence	14	Biceps and triceps	11
Deafness	7	Romberg sign	55
Impotence	4	Impaired sensations	
		Vibratory sense	52
		Position sense	45
		Touch and pain	13
		Ocular palsy	10
		Charcot joints	7

Adapted from Merritt et al. [85]; with permission

Following the introduction of penicillin, the frequency of neurosyphilis per hospital admission fell from 5.9 per 100,000 population in 1942 to 0.1 per 100,000 in 1965. Beginning in the 1980s and coincident with the AIDS epidemic, this trend has been reversed. The incidence of neurosyphilis is unknown, but the incidence of primary and secondary syphilis rose from 13.7 per 100,000 population in 1981 to a peak of 20.1 per 100,000 in 1990. Since then, the incidence has dropped significantly, perhaps because of better surveillance and education. The overall frequency of neurosyphilis in HIV-positive and AIDS patients is estimated to be 2%. Also during the 1980s and 1990s, a shift occurred toward meningeal and vascular forms of neurosyphilis, with a decline in the parenchymal forms (Table 76). This change may be related to CSF abnormalities of neurosyphilis in HIV-infected patients, which are more intense than those of non–HIV-infected patients.

The diagnosis of active neurosyphilis is based upon a compatible clinical syndrome, an inflammatory CSF profile, and reactive serologic tests in the blood (treponemal antibody test) and CSF (nontreponemal test) (Table 77). The Centers for Disease Control and Prevention (CDC) recommends that CSF examination should be performed for the following: (1) Neurologic or ophthalmic symptoms or signs in any stage of syphilis; (2) Active tertiary syphilis affecting other parts of the body; (3) Treatment failure clinically or serologic test for syphilis (STS) titers that fail to fall; (4) HIV infection with late latent syphilis or unknown duration of syphilis [87]. CSF pleocytosis (primarily lymphocytic) is the best measure of disease activity. The number of cells varies with each clinical subtype, being maximal in the earlier acute-like stage of syphilitic meningitis. The glucose level is usually low in syphilitic meningitis and is more likely to be normal for other

Table 76 Frequency of different forms of symptomatic neurosyphilis[a]

	Preantibiotic Era		Antibiotic Era			AIDS Era	
						HIV(–)	HIV (+) or AIDS
	1	**2**	**3**	**4**	**5**	**6**	**7**
Tabetic	45	48	45	15	11	5	0
Paretic	17	48	8	12	4	9	4
Taboparetic	4	7	9	23	23	—	—
Vascular	15	19	9	19	61	41	38
Meningeal	8	8	19	23	0	23	46
Optic neuritis	4	—	—	—	—	14	42
Spinal cord	4	—	10	8	—	—	—
1 Merritt, Adams, Solomon, 1946 (457 patients).							
2 Kierland et al., 1942 (2019 patients).							
3 Wolters, 1987 (518 patients, 1930–1940).							
4 Wolters, 1987 (121 patients, 1970–1984).							
5 Burke, Schaberg, 1985 (26 patients).							
6, 7 Katz et al., 1993.							

[a]Numbers are a percentage of cases

Table 77 Abnormalities of cerebrospinal fluid (CSF) in neurosyphilis

Neurosyphilic syndrome	OP mm H_2O	Leukocyte Level, *per* mm^3	Glucose Level, *mg/dL*	Protein Level, *mg/dL*	VDRL	
					Blood	CSF
Meningitic	210–400[a] (<200 to >400)	100–500[b] (<10–2000)	20–40 (<20 to >80)	45–200 (<45–400)	1:64	1:4
Cerebrovascular	<200 (>200–250)	10–100 (<10 to >100)	Normal to mildly decreased	100–200 (15–260)	1:512	1:16
Paretic	<200 (<200–300)	10–100 (<10 to >100)	Normal to mildly decreased	45–100 (29–500)	1:128	1:8
Tabetic	<200 (<200–300)	Active 5–50 (5–165)	Normal	45–100 (14–250)	Active 1:15	1:28
		Inactive 0–5			Inactive 1:16	1:2

OP opening pressure, *VDRL* Venereal Disease Research Laboratory
[a]Numbers without parentheses are the common range. Numbers in parentheses are the overall range
[b]CSF pleocytosis is usually 80–100% lymphocytic mononuclear

subtypes. CSF protein levels are usually elevated for all subtypes. The CSF gamma globulin level may be increased and oligoclonal bands may be present.

Serologic tests used in the diagnosis of neurosyphilis (Table 78) include the fluorescent treponemal antibody absorption (FTA-ABS) test, the microhemagglutination test for *Treponema pallidum* (MHA-TP), the *Treponema Pallidum* particle agglutination (TPPA) assay and the enzyme immune assay (EIA). A positive blood (serum) treponemal test is diagnostic for syphilis, as the antibodies are highly specific and remain positive for years. If these tests are negative, the diagnosis of neurosyphilis is essentially excluded; they are not useful, however, for following disease activity because they do not revert with successful treatment. These treponemal antibody tests are not useful for CSF analysis. The serologic diagnosis of neurosyphilis requires a positive blood serologic result and a reactive CSF serologic test for syphilis (STS). The two STS tests used currently are the Venereal Disease Research Laboratory (VDRL) test and the rapid plasma reagin (RPR) test. The RPR test cannot be used on the CSF. The CSF VDRL test can be used to follow disease activity after treatment but is not as reliable as the CSF pleocytosis, as it may be falsely negative in up to 70% of patients with neurosyphilis.

The CSF inflammatory process (increased cell count) is the best indicator of disease activity and should be monitored for successful treatment. Normalization of CSF pleocytosis and protein level is the ultimate goal of treatment. The CSF VDRL test titer should also be followed, but it is not as sensitive to treatment as the CSF pleocytosis. Table 79 lists treatment regimens for neurosyphilis. Penicillin remains the drug of choice, but benzathine penicillin G does not produce adequate levels in the CSF for treatment. The same treatment regimen is recommended for HIV-coinfected patients as for non-HIV patients.

After treatment, the clinical examination should stabilize and the blood serologic test levels should decline. The CSF is examined at 6 and 12 months after treatment. At 6 months, the cell count should be normal and the protein level should be falling; by 12 months, both are usually normal. If cells are still present at 6 or 12 months, retreatment is required. If the

Table 78 Serologic tests used in the diagnosis of neurosyphilis

Test	Abnormality required for diagnosis	False/positive tests
FTA-ABS, MHA-TP, TTPA or EIA	+ in blood required	Rare
	– excludes diagnosis	Other spirochete diseases
		Autoimmune diseases, especially systemic lupus erythematosus (SLE)
VDRL	+ in CSF required for diagnosis	Contamination of CSF by blood
		CSF paraprotein
	– in CSF inactive or no neurosyphilis	Very high CSF protein level
		Autoimmune disease (such as SLE)
		Strong immunologic stimulus
		Acute bacterial or viral infections
		Early HIV infection
		Vaccination
		Central nervous system neoplasia
		Drug addiction
		Pregnancy
		Chronic liver disease

protein level is still elevated at 12 months, the CSF should be reexamined in 2 years. Retreatment is required if there has been clinical progression or the CSF is still abnormal.

Lyme Disease

Lyme disease results from infection by three species of the spirochete *Borrelia burgdorferi*, which is transmitted by ticks. Lyme disease may develop into a chronic, persistent infection in a fashion somewhat similar to syphilis. For this reason, Lyme disease has been divided into stages (Fig. 44). The nervous system is involved clinically in 10–15% of patients. Stage I, the acute stage (or early localized disease), is characterized by a rash—erythema chronicum migrans (ECM)—which is an erythematous ring that develops around the tick bite site about 8–9 (range 3–32) days after exposure. Smaller secondary (migratory) rings may occur later. Neurologic manifestations may occur in stage I concurrently with ECM, but they are more frequent in stage II. Stage II, the subacute stage (or early disseminated), is characterized by prominent cardiac and neurologic manifestations. This stage usually begins several months after the bite and the onset of ECM. Stage III, the chronic (or late) stage, is characterized by chronic arthritis. Neurologic manifestations also occur in stage III but they are less prominent than those of stage II. Stage III usually begins about 1 year after onset.

Table 79 Treatment regimens for neurosyphilis

Established
Aqueous crystalline penicillin G 18 to 24 million U IV daily (divided doses q4h) for 10–14d
Approved
Aqueous procaine penicillin G, 2.4 million U IM daily, plus probenecid 500 mg po qid for 10–14 d
Alternate drug regimens for penicillin-allergic patients
Desensitize to penicillin (preferred alternative)
Tetracycline hydrochloride 500 mg po qid for 30 d
Doxycycline 200 mg po bid for 21 d
Erythromycin 500 mg po qid for 30 d
Chloramphenicol 1 g IV qid for 14 d
Ceftriaxone 1 g q12h for 10 to 14d
Recommended treatment regimens for syphilis in HIV-coinfected patients
No change in therapy for early syphilis (CSF examination may be a useful guide to adequate treatment)
Benzathine penicillin should not be used
Examine CSF before and following treatment as a treatment guide
Aqueous crystalline penicillin G IV, 18 to 24 million U daily (2–4 million U q4h)
Aqueous procaine penicillin G, 2.4 million U IM daily plus probenecid 500 mg po qid

IM intramuscular, *IV* intravenous, *po* per os (by mouth)

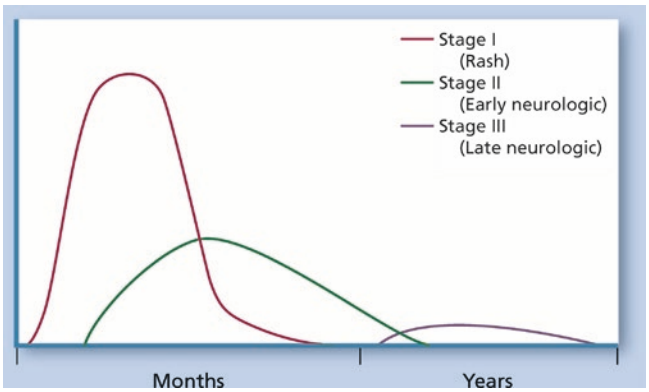

Fig. 44 Clinical stages of Lyme disease. (Adapted from Davis [88]; with permission)

In the acute stage I, a systemic, flulike syndrome with fever, chills, and malaise may occur. Neurologic manifestations include headache and neck stiffness but normal CSF parameters. Stage II is also referred to as the "early neurologic stage" because dissemination of the organism to the CNS begins. During this stage, aseptic meningitis with complications of cranial nerve palsies—especially facial (Bell's palsy)—and radiculoneuritis are most prominent. The facial or Bell's palsy is usually bilateral. The radiculoneuritis may take the form of a Guillain-Barré–like syndrome, but the CSF shows pleocytosis; sometimes the radiculoneuritis is focal. Occasionally, mild meningoencephalitis along with irritability, emotional lability, decreased concentration and memory, and sleep abnormalities may occur.

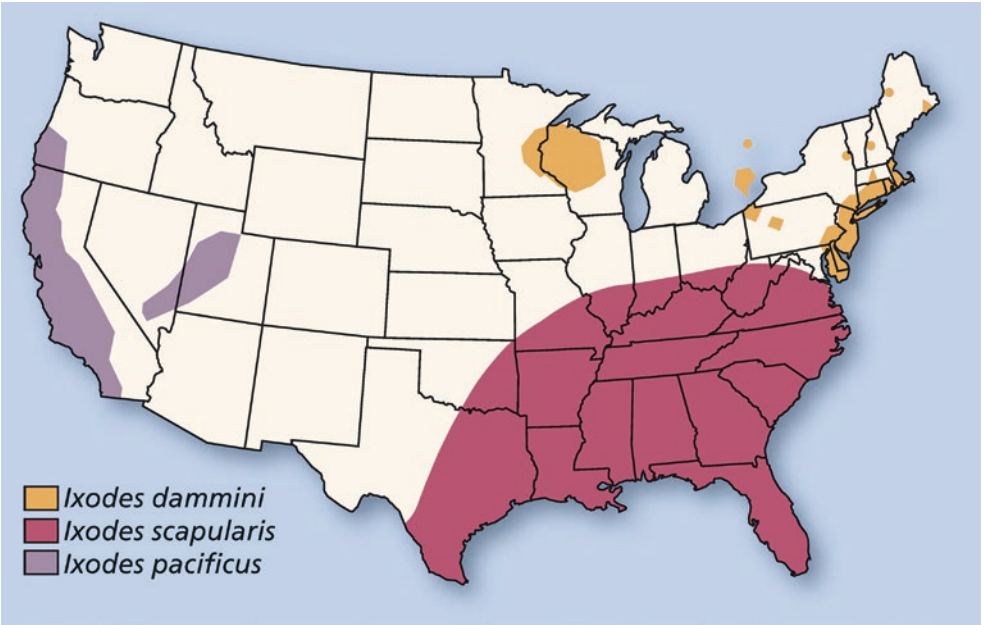

Fig. 45 Geographic distribution of ticks carrying Lyme disease in the United States. (Adapted from Anderson [89])

Stage III or the chronic stage is also referred to as the "late neurologic stage." This stage is characterized by chronic or late, persistent infection of the nervous system. Syndromes included in this stage are encephalopathy, encephalomyelopathy, and polyneuropathy. The encephalopathy is characterized by memory and other cognitive dysfunction. The encephalomyelopathic signs are combined with progressive long tract signs and optic nerve involvement. White matter lesions may be visible on MRI of the brain. The late polyneuropathy is primarily sensory.

Lyme disease accounts for about 90% of the vector-borne infections in the United States. In 2012, over 30,000 cases were reported to the Centers for Disease Control and Prevention. *Borrelia burgdorferi*, the spirochete that causes Lyme disease, is transmitted by *Ixodes* species (hard-body) ticks. Up to 50% of human infections are asymptomatic. The infection rate of different *Ixodes* species carrying the spirochete depends on the species. As seen on Fig. 45, *Ixodes dammini* (deer tick) is the principal vector in the Northeast (30–60% infection rate) and the upper Midwest (10–15% infection rate). *Ixodes pacificus* (western black-legged tick) is the vector in the West (1–5% infection rate). In the southeastern United States, *Ixodes scapularis* is the vector, but its infection rate is much lower even than that of *I. pacificus*.

The density of cases in the United States is due to the high infection rate of *Ixodes dammini*. The geographic density of cases is greatest in the Northeast and Upper Midwest (Fig. 46). The various infection rates of the different *Ixodes* species explain why 10 states account for almost 90% of the cases: New York (40%), followed by Connecticut, New Jersey, Pennsylvania, Rhode Island, Massachusetts, Maryland, Wisconsin, Minnesota, and California.

In Lyme disease meningitis and encephalomyelitis, the CSF is usually abnormal (Table 80), but it is generally normal in peripheral nervous system syndromes unless there is radicular involvement. CSF analysis has a higher diagnostic yield than electroencephalography (usually normal or nonspecific) or MRI (25% of patients have small cerebral white matter lesions). CSF analysis also offers the opportunity to test for the intrathecal production of *Borrelia burgdorferi* antibodies.

Serum antibodies, when present, prove exposure to the agent but cannot be used to determine when the infection occurred. Most antibody assays are now performed by an enzyme-linked immunosorbent assay (ELISA) technique. Western blot testing is required to confirm the diagnosis. PCR testing is still experimental. The demonstration of elevated *Borrelia burgdorferi* antibodies in the CSF is essentially diagnostic. About 95% of Lyme disease patients are seropositive, but false-positive and false-negative test results may occur, for reasons listed on Table 81.

Table 82 lists neurologic conditions in which Lyme disease should be considered in the differential diagnosis. The combination of meningitis, neuritis, and radiculitis without fever is highly suggestive of Lyme disease. If a history of tick exposure or erythema chronicum migrans is obtained, the diagnosis can be made with confidence. Because of the involvement of both the peripheral and the central nervous systems, the differential diagnosis is varied and extensive.

The antibiotic therapy for neurologic syndromes (Table 83) depends on the specific stage of Lyme disease. Intravenous ceftriaxone is now usually considered the drug of choice for stages II (early neurologic stage) or III (late neurologic stage). Most symptoms resolve with antibiotic treatment, but motor signs may last for 7–8 weeks. The duration of therapy has never been clarified. A postinfectious syndrome with symptoms of fatigue, headache, and muscle and joint pain may last for months to several years.

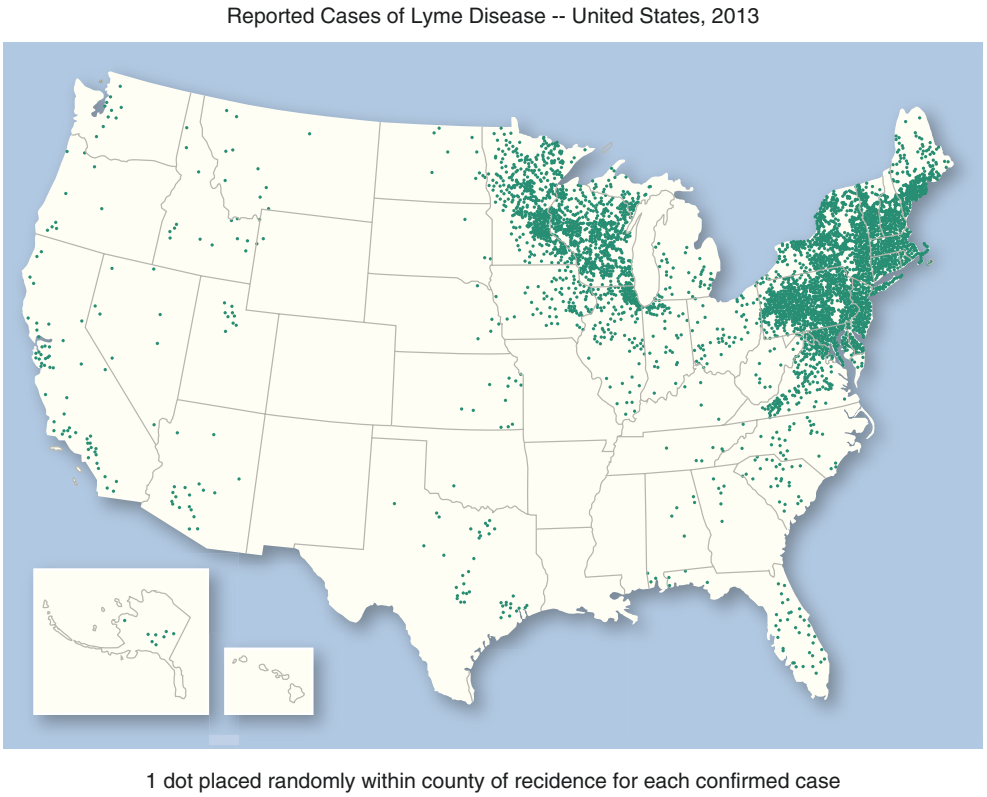

Fig. 46 Reported cases of Lyme disease in the United States, 2013. One dot represents each confirmed case. (Modified from Halperin et al. [90])

Table 80 CSF analysis Lyme disease encephalomyelitis

Test	CSF findings
Opening pressure[a]	Normal
Total leukocytes/mm^3	166 (15–700)[b]
Percent lymphocytes	93 (40–100)
Glucose, *mg/dL*[c]	49 (33–61)
Protein, *mg/dL*	79 (8–400)
IgG/albumin ratio (n = 20)	0.18 (0.9–0.44)
Oligoclonal bands (n = 4)	Present
Myelin basic protein (n = 5)	Absent
VDRL (n = 20)	Negative

Adapted from Pachner and Steere [91]; with permission
VDRL Venereal Disease Research Laboratory
[a]n = 38, except where noted
[b]Median (range)
[c]Serum glucose = 95 (87–113)

Table 81 Causes of false-positive and false-negative Lyme serologic tests

False-positive
Cross-reactive spirochetal infection (*e.g.*, mouth treponemes, syphilis, leptospirosis, relapsing fever)
Severe bacterial infections
Hypergammaglobulinemia
Epstein-Barr virus
Autoimmune disorders with high autoantibody titers
HIV infection
Unreliable assay
False-negative
Too early in the infection
Early antibiotics with blurred humoral response
Unreliable assay

Adapted from Coyle [92]

Table 82 Neurologic conditions in which Lyme disease should be considered

Central nervous system	Peripheral nervous system
Acute aseptic meningitis	Cranial neuritis (Bell's palsy)
Chronic lymphocytic meningitis	Mononeuritis simplex or multiplex
Acute meningoencephalitis	Radiculoneuritis
Acute focal encephalitis	Plexitis
Brainstem encephalitis	Distal axonal neuropathy
Progressive encephalomyelitis	Demyelinating neuropathy
Cerebral demyelination, including multiple sclerosis	Carpal tunnel syndrome
Cerebral vasculitis	Focal myositis
Dementia	
Transverse myelitis	

Adapted from Halperin et al. [90]

Parasitic Infections

Table 84 lists the major protozoan and helminthic infections of the CNS. Toxoplasmosis is the most important protozoan infection in developed countries, where it occurs in immunosuppressed individuals. Worldwide, malaria is the most important protozoan infection. Cysticercosis is probably the most important helminthic infection causing CNS disease.

Table 83 Antibiotic therapy for neurologic symptoms of Lyme disease

Manifestations	Treatment
ECM and systemic symptoms	
Adults	Doxycycline, 100 mg po bid for 14–28 d
	Amoxicillin, 500 mg po tid for 14–28 d (plus probenecid, 500 mg po tid)[a]
	Cefuroxime axetil, 500 mg po bid for 14–28 d[b]
Children (≤8 y)	Amoxicillin, 25–50 mg/kg po daily in 3 divided doses for 14–28 d
	Cefuroxime axetil, 250 mg po bid for 14–28 d[b]
Neurologic involvement	
Facial palsy alone	Oral antibiotics as for ECM
All others	
Adults	Ceftriaxone, 2 g IV daily for 14–28 d
	Cefotaxime, 2 g IV tid for 14–28 d
	Penicillin G, 20–24 million U IV daily for 10–14 d
	Doxycycline, 200 mg po bid for 14–28 d
Children	Ceftriaxone, 75–100 mg/kg IV daily for 14–28 d
	Penicillin G, 300,000 U/kg IV q 4 h for 10–14 d

Author noted need for adjustment: Make first line of treatment (*ie*. Doxycycline 100 mg…) line up with "Adults" line. The first line of Treatment for Children should remain Amoxicillin, 25–50….
ECM erythema chronicum migrans, *IV* intravenous, *po* per os (by mouth)
[a]Optional
[b]Alternative

Table 84 Major protozoan and helminthic infections of the central nervous system

Protozoan
Toxoplasmosis
Cerebral malaria
Trypanosomiasis
Amebic meningoencephalitis
Nematodes (roundworms)
Trichinosis
Eosinophilic meningoencephalitis
Angiostrongylus cantonensis
Gnathostoma spinigerum
Strongyloidiasis
Toxocariasis (visceral larva migrans)
Human filariases
Onchocerciasis (river blindness)
Dracunculiasis
Trematodes (flukes)
Schistosomiasis
Paragonimiasis
Cestodes (tapeworms)
Cysticercosis
Hydatid disease *(Echinococcus)*

Adapted from Coda [93]

Protozoa

Protozoa are small, single-cell organisms that cause diffuse more often than focal encephalitis of the nervous system. Table 85 lists protozoan infections of the nervous system. Protozoa do not cause allergic reactions and eosinophilia, as do many helminthic infections.

Toxoplasmosis

Table 86 lists clinical manifestations of toxoplasmosis. Congenital toxoplasmosis is a systemic illness causing chorioretinitis, microencephaly, seizures, mental retardation (from encephalitis), and cerebral calcifications in newborns. Cases are frequent in immunocompromised patients; toxoplasmosis is a common opportunistic infection in AIDS patients, usually occurring because of reactivation.

Figure 47 illustrates methods of transmission of toxoplasmosis. Most often *Toxoplasma gondii* infection occurs by eating undercooked meat or other foods contaminated with cat feces containing oocysts. Common-source outbreaks have occurred in families from contaminated food. Unpasteurized milk and water are also possible sources of infection. In addition to exposure to cats and eating undercooked meats, warm, humid climates and poor sanitation correlate with a greater prevalence of infection. Primary infection in the immunocompetent host is usually asymptomatic, but rarely, symptomatic, severe primary infection occurs. Usually tissue cysts persist and reactivation is prevented unless immunity wanes, as occurs in AIDS or other immunosuppressive events such as therapy for cancer or transplantation.

The complete blood count may reveal anemia, leukopenia, or leukocytosis in congenital toxoplasmosis. In most AIDS patients, disease is limited to the brain. The CSF is abnormal in about half of patients with congenital toxoplasmosis and in most patients with AIDS. Lymphocytic pleocytosis is usually mild but may be as high as several thousand cells/mm^3. The protein level is increased and the glucose level is usually normal or rarely mildly reduced. Isolation of the organism is difficult, as it requires inoculation of laboratory mice; therefore, a presumptive diagnosis can be made based on serologic tests in the appropriate clinical setting. The demonstration of IgM antibodies is most helpful for the diagnosis of congenital or acute acquired infection. In AIDS and other immunosuppressed patients, IgG, but not IgM, antibody is usually present. CSF antibodies may also be detected. Other than serologic testing, neuroimaging and PCR testing are the diagnostic studies of choice. In congenital toxoplasmosis, the skull radiograph may reveal multiple intracerebral calcifications. In AIDS patients, T1-weighted MRI or enhanced CT scans (Fig. 48) reveal multiple ring-enhancing, hypodense lesions

Table 85 Protozoan infections of the nervous system

Disease/parasite	Geographic distribution	Risk factor	Neurologic disease
Toxoplasmosis			
Toxoplasma gondii	Worldwide	Perinatal infection, immunosuppression	Diffuse, focal, or multifocal encephalitis, chorioretinitis
Malaria			
Plasmodium falciparum	Tropics and subtropics	Mosquitoes	Acute encephalopathy
Trypanosomiasis			
African			
Trypanosoma gambiense	Tropical West African forest	Tsetse flies	Chronic encephalitis
Trypanosoma rhodesiense	East equatorial Africa		Subacute meningoencephalitis
South American			
Trypanosoma cruzi	Mexico to South America	Reduviid bugs	Acute meningoencephalitis (rare)
			Chronic parasympathetic denervation of gastrointestinal tract
Amebiasis			
Entamoeba histolytica	Worldwide	Poor water and sewage, institutionalized persons, homosexuals	Brain abscess (rare)
Naegleria	Worldwide	Freshwater sports	Acute meningoencephalitis
Acanthamoeba	Worldwide	Immunosuppression	Subacute or chronic meningoencephalitis

Adapted from Johnson and Warren [94]; with permission

Table 86 Clinical manifestations of toxoplasmosis [note spelling]

Congenital disease	%	Immunocompromised host	%
Retinochoroiditis	87	Altered mental state	75
Abnormal cere-brospinal fluid	55	Fever	10–72
Anemia	51	Seizures	33
Convulsions	50	Headache	56
Intracranial calcifications	50	Focal neurologic signs	60
Jaundice	29	Motor deficits	
Fever	25	Cranial nerve palsies	
Splenomegaly	21	Movement disorders	
Hepatomegaly	17	Dysmetria	
		Visual field loss	
		Aphasia	

Adapted from Luft and Remington [95]

with surrounding edema. Toxoplasma PCR testing in the CSF is highly specific. A CSF positive test establishes the diagnosis of toxoplasma encephalitis [98].

Table 87 presents guidelines for the treatment of toxoplasma encephalitis. The prognosis is poor in the congenital form of toxoplasmosis, with death occurring within weeks of birth in more than 50% of cases. Mental retardation and other neurologic defects are common in survivors. The prognosis for reactivated infections in immunocompromised patients is also poor. In AIDS patients, empiric therapy is instituted when IgG antibody and characteristic CT findings are found. Pyrimethamine/sulfadiazine/folinic acid or trimethoprim-sulfamethoxazole are the agents of choice.

Cerebral Malaria

The symptoms and signs of cerebral malaria are primarily those of acute encephalopathy (Table 88). These neurologic manifestations usually occur in the second or third week of infection. The disease occurs most often in infants, children, and nonimmune travelers to endemic areas.

The neurologic manifestations of cerebral malaria are due to the congestion and obstruction of capillaries and venules with parasitized erythrocytes (Fig. 49). Parasitized erythrocytes are less deformable than normal erythrocytes and more adherent to vascular endothelial cells. Thrombotic occlusions, microinfarctions, microhemorrhages, and cerebral edema result. Large infarctions and hemorrhage are unusual.

Malaria is the most common human parasitic disease in the world. In 2012, there were about 219 million cases, 70% in Africa and 25% in Southeast Asia. The yearly death rate is 1 million. The disease is endemic in tropical and subtropical areas of Asia, Africa, and Central and South America. Nervous system involvement occurs in about 2% of infected patients. Most cases of cerebral malaria are caused by *Plasmodium falciparum* [102].

Diagnosis is made from the clinical presentation and by finding the organisms in the blood. The mortality rate for cerebral malaria is 15–40%, with the highest mortality rate in those patients with coma and seizures. Table 89 lists regimens of antimalarial therapy for cerebral malaria.

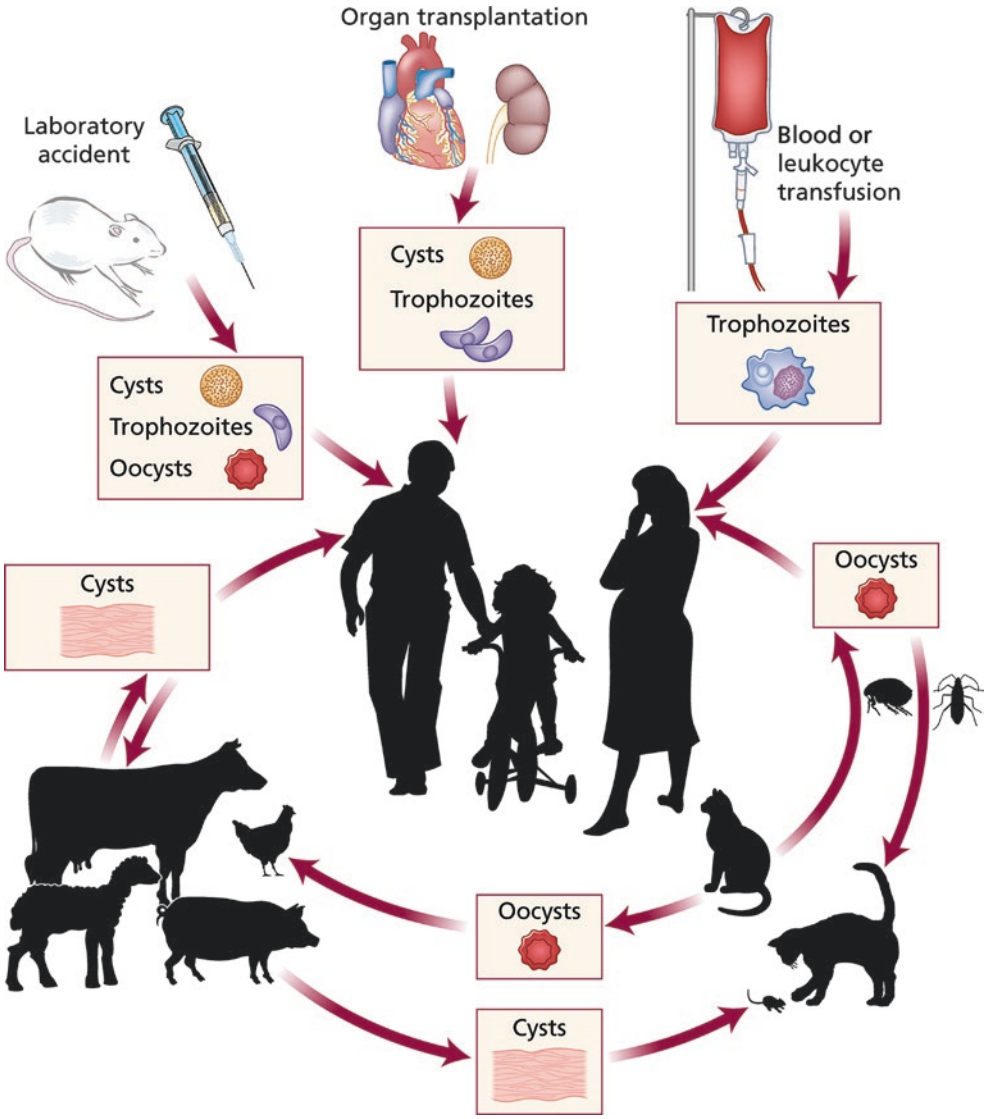

Fig. 47 Transmission of toxoplasmosis. (Adapted from Berger [96]; with permission)

Trypanosomiasis

There are two varieties of human trypanosomiasis, an African form (sleeping sickness) and a South American form (Chagas disease), which is caused by *Trypanosoma cruzi*. The African disease is of two types (Table 90): The West African form is caused by *Trypanosoma brucei gambiense* and the East African variety, by *Trypanosoma brucei rhodesiense*. The East African disease is more acute, leading to death in weeks to months.

The signs and symptoms of West and East African trypanosomiasis are basically the same, except that the East African form has a more acute course of weeks to months, whereas the West African form has a more chronic course of months to years. As shown on Table 91, these diseases pass through two stages: Stage I is the systemic illness, with organisms present in the blood; stage II is neurologic. The first stage usually passes imperceptibly into the second.

The acute stage of South American trypanosomiasis lasts about 1 month, during which trypanosomes are present in the blood. In the chronic stage, organs (including the nervous system) are involved. This disease affects about 16 million people in Central and South America, primarily children living in rural areas. The disease is transmitted by the reduviid bug, which lives in the walls of houses. Death usually occurs within a few months or years.

Anemia occurs in all forms of trypanosomiasis. The erythrocyte sedimentation rate and serum IgM may be increased. The CSF has lymphocytic pleocytosis, normal glucose level, increased protein level, and increased IgG and IgM levels. The diagnosis is established by identifying the organism in the blood, CSF, or biopsied lymph nodes.

Table 92 lists the drugs used for the various types and stages of trypanosomiasis. Except for the chronic stage of American trypanosomiasis, chemotherapy is relatively effective.

Amebic Meningoencephalitis

Amebic meningoencephalitis is caused primarily by the free-living amebae *Naegleria fowleri* and *Acanthamoeba* species (Table 93). *Entamoeba histolytica* may rarely invade the brain and cause brain abscess. *Naegleria* causes acute primary amebic meningoencephalitis (PAM), whereas *Acanthamoeba* causes subacute or chronic PAM and granulomatous amebic encephalitis (GAE). The Leptomyxida *Balamuthia mandrillaris* has also caused GAE. These infections occur worldwide. Most cases in the United States occur in the Southeast.

Figure 50 shows a case of acute PAM, with the most severe lesions in the basal meninges and adjacent cortex. *Acanthamoeba* causes subacute or chronic PAM, including

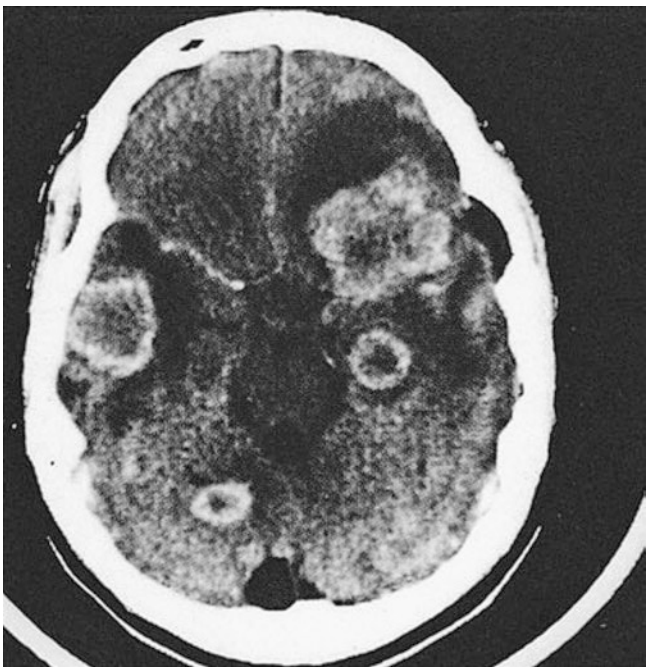

Fig. 48 Enhanced axial CT scan of toxoplasmosis in an AIDS patient, showing multiple ring and nodular enhancing lesions. (From Farrar et al. [97])

Table 88 Clinical manifestations of cerebral malaria

Common	Less common	Possible systemic manifestations
Headache, meningismus, photophobia	Monoparesis and hemiparesis	Hyperpyrexia
Seizures	Aphasia	Anemia
Behavioral and cognitive changes	Hemianopia	Hepatosplenomegaly
Delirium	Ataxia, tremor, myoclonus	Hypoglycemia
Coma	Cranial nerve palsies	Disseminated intravascular coagulation
	Papilledema	Pulmonary edema
	Blindness	Renal failure
	Deafness	Shock
	Spinal cord lesions	
	Polyneuritis	

Adapted from Berger [96] and Idro et al. [100]; with permission

Table 87 Regimens for treatment of toxoplasma encephalitis

Drugs	Immunocompetent patients with acute infection	Immunocompromised patients
Preferred treatment regimen		
Pyrimethamine (po)	50 mg every 12 h for 2 d followed by 25–50 mg daily	200 mg loading dose followed by 50 mg (<60 kg) to 75 mg (>60 kg)
Folinic acid (po)	10–20 mg daily (during and 1 wk. after therapy with pyrimethamine)	10–20 mg daily (up to 50 mg/d) (during and 1 wk. after therapy with pyrimethamine)
plus Sulfadiazine (po)	75 mg/kg (first dose) followed by 50 mg/kg every 12 h (maximum 4 g/day)	1000 (<60 kg) to 1500 mg (>60 kg) every 6 h
or Clindamycin (po or IV)	300 mg every 6 h	600 mg every 6 h (up to 1200 mg every 6 h)
Alternative treatment regimens		
Trimethoprim-sulfamethoxazole (po or IV)	10 mg/kg/d (trimethoprim component) in two to three doses	10 mg/kg/d (trimethoprim component) divided in two to three doses (doses as high as 15–20 mg/kg/d have been used)
Atovaquone (po)	1500 mg orally twice daily	1500 mg orally twice daily
Atovaquone (po)	1500 mg orally twice daily	1500 mg orally twice daily
plus Sulfadiazine (po)	1000 (<60 kg) to 1500 mg (>60 kg) every 6 h	1000 (<60 kg) to 1500 mg (>60 kg) every 6 h
or Pyrimethamine/folinic acid	Same doses as above	Same doses as above
Azithromycin (po)	900–1200 mg/d	900–1200 mg/d
and Pyrimethamine/folinic acid	Same doses as above	Same doses as above

Adapted from Montoya [99]; with permisison
IV intravenous, *po* by mouth

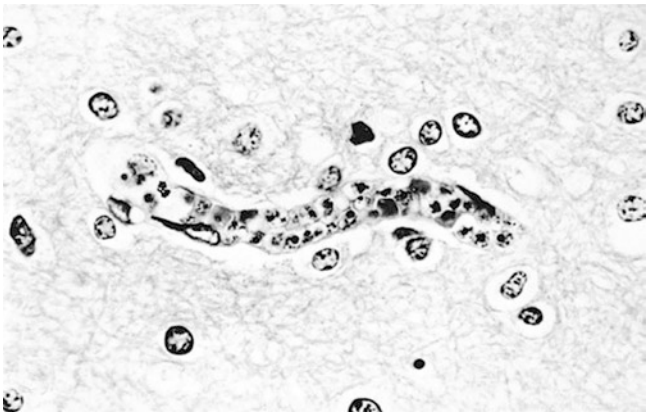

Fig. 49 A brain capillary with parasitized erythrocytes in a patient with cerebral malaria. (From Oo et al. [101]; with permission)

granulomatous amebic encephalitis (GAE), usually as an opportunistic infection in immunosuppressed patients. The respiratory tract is probably the portal of entry, resulting in systemic infection with seeding of the brain through hematogenous spread. GAE may ensue with multiple focal areas of infection (cortical, subcortical white matter, and basal ganglia).

Naegleria infections usually occur in children and young adults who have been swimming in fresh water lakes and ponds, although inhalation of dust-borne cysts occurs in arid regions. The organism does not cause a systemic infection but invades the brain through olfactory nerves.

Table 94 lists clinical manifestations of acute and subacute or chronic PAM. Acute PAM caused by *Naegleria* presents as acute meningoencephalitis after an incubation

Table 89 Antimalarial therapy for cerebral malaria[a]

Medication	Dosage
I. Artemisinin derivative	
Artesunate[b]	2.4 mg/kg IV as first dose, followed by 2.4 mg/kg at 12 and 24 h, followed by 2.4 mg/kg once daily
II. Quinine or quinidine	
Quinine dihydrochloride[c]	16.7 mg base/kg (=20 mg salt/kg) in 5% dextrose loading dose over 4 h, followed by 25 mg base/kg/day (20–30 mg salt/kg/day) divided into 2 to 3 equal administrations of 8.35 mg base/kg (=10 mg salt/kg) over 2 h at 8- or 12-h intervals (maximum 1800 mg salt/day)
Quinidine gluconate[d]	6.25 mg base/kg (=10 mg salt/kg) loading dose IV (maximum 600 mg salt) in normal saline over 1–2 h, followed by 0.0125 mg base/kg/min (=0.02 mg salt/kg/min) continued infusion for at least 24 h
PLUS[a] one of the following: Doxycycline, Tetracycline, or Clindamycin	
Doxycycline	*Adults:* 100 mg orally twice daily. *Children:* 2.2 mg/kg (up to 100 mg) orally twice daily. IV dosing acceptable if oral medication not tolerated; switch to oral dosing once patient is able to swallow. Treatment course is 7 days
Tetracycline	*Adults:* 250 mg orally 4 times daily. *Children:* 25 mg/kg/day (up to 1000 mg) divided into 4 equal doses. Treatment course is 7 days
Clindamycin[e]	*Adults and children:* 20 mg base/kg/day orally (maximum 1800 mg) divided into 3 equal doses. Treatment course is 7 days

CDC Malaria Hotline (770)488–7788 M–F 8–4:30 ET; (770)488–7100 after hours, weekends, and holidays
Adapted from Postels and Taylor [102]
ACT artemisinin combination therapy, *IV* intravenous
[a]In general, parenteral therapy is administered for severe disease. Once the patient has received at least 24 h of IV therapy and is able to tolerate oral medications, treatment should be completed orally. There are various options: (1) Parenteral artesunate followed by a 3-day oral regimen of an ACT, usually artemether plus lumefantrine, artesunate plus sulfadoxine-pyrimethamine, or dihydroartemisinin plus piperaquine. (2) Parenteral quinine (or quinidine) followed by doxycycline, tetracycline, or clindamycin (7 days oral therapy); this is common practice for patients with malaria acquired in SE Asia, if artesunate is not available. (3) Parenteral quinine (at least 33 doses) until the patient is able to swallow, followed by oral therapy with an artemisinin combination therapy (3 days oral therapy); this is common practice for children with malaria acquired in Africa, if IV artesunate is not available
[b]Artesunate can also be administered intramuscularly, orally, or via rectal suppository (100 mg for children 6 months to 6 years of age; 400 mg for children >6 years). In the United States, IV artesunate is not approved by the Food and Drug Administration (FDA) but is available for emergency use under an investigational protocol by enrollment with the Centers for Disease Control (CDC). Artesunate is unstable in solution, so it is dispensed as a dry powder of artesunic acid together with an ampule of diluents (5% sodium bicarbonate solution or sodium phosphate solution as supplied by US CDC). Once the patient has received 4 doses of IV artesunate and is able to swallow, treatment should be completed with a course of an active oral antimalarial drug, usually an ACT
[c]Quinine should be given by rate-controlled IV infusion and never by IV injection (which can be lethal). Quinine can also be administered via intramuscular injection if IV infusions cannot be given: two injections of 10 mg/kg quinine (diluted to 60 mL) should be administered 4 h apart. The anterior thigh is preferred over the gluteal region to minimize the risk of sciatic nerve damage
[d]In the United States, IV quinidine is available for treatment of severe malaria. Quinidine can cause QT prolongation and should be administered by rate-controlled IV infusion with continuous electrocardiographic and hemodynamic monitoring in an intensive care unit
[e]Clindamycin should be administered for pregnant women; doxycycline and tetracycline are contraindicated

period of several days to a week. The CSF profile is similar to that of acute bacterial meningitis, with several hundred to a thousand leukocytes (primarily polymorphonuclear leukocytes) and a low glucose level. Amebae may be seen on wet preparations or with Wright or Giemsa stains. The organisms can be cultured on special media or isolated by mouse inoculation. A serologic test is available at the Centers for Disease Control and Prevention. The disease is rapidly fatal. Amphotericin B is the drug of choice. Recently, two patients recovered after treatment with amphotericin, rifampin, and fluconazole.

Subacute or chronic PAM (including granulomatous amebic encephalitis) presents more gradually, similar to a brain abscess or tumor. The CSF pleocytosis is more often lymphocytic, with a normal or only slightly decreased glucose level. Amebae can be found in the CSF only occasionally. Neuroimaging reveals focal lesions; biopsy is usually required for diagnosis. This disease is usually fatal. In vitro, the organism is usually sensitive to pentamidine, ketoconazole, and flucytosine.

Table 90 Comparison West African and East African trypanosomiasis

	West African *(T. gambiense)*	East African *(T. rhodesiense)*
Organism	*T.b. gambiense*	*T.b. rhodesiense*
Vectors	Tsetse flies (*palpalis* group)	Tsetse flies (*morsitans* group)
Primary reservoir	Humans	Antelope and cattle
Human illness	Chronic (late CNS disease)	Acute (early CNS disease)
Duration of illness	Months to years	< 9 months
Lymphadenopathy	Prominent	Minimal
Parasitemia	Low	High
Diagnosis by rodent inoculation	No	Yes
Epidemiology	Rural populations	Tourists in game parks
		Workers in wild areas
		Rural populations

From Kirchhoff [103], with permission

Table 91 Clinical manifestations of African trypanosomiasis

Stage I—febrile or hemolymphatic stage	Stage II—lethargic or meningoencephalitic stage
Remitting fever	Headache
Circinate rash and pruritus	Irritability
Lymphadenitis	Personality change with apathy
Transient edema of face and hands	Organic mental syndrome
Hepatosplenomegaly	Insomnia or somnolence
Headache	Tremor
Asthenia	Ataxia
Arthralgia	Convulsions
Myalgia	Paralysis
Weight loss	Coma

Helminthic Infections

Nematode (roundworm) infections of the nervous system (Table 95) are no longer common in the United States or other developed countries. Trichinosis was common in the United States during the first half of the twentieth century but is now almost nonexistent because of improved sanitation and public health measures. Patients with CNS involvement should be treated with corticosteroids. Mebendazole or albendazole is used to treat tissue larvae. *Angiostrongylus* causes eosinophilic meningitis with headache, paresthesia, and a mean CSF leukocyte count of 500–600 cells/mm^3, of which the mean eosinophil count is approximately 50%. Most patients recover in 1–2 weeks without treatment. Additional causes of eosinophilic meningitis include other helminths, coccidioidomycosis, foreign bodies, drug allergies, and neoplasia. The other roundworm infections less frequently involve the nervous system.

Many species of trematodes (flukes) can infect humans, although schistosomiasis and paragonimiasis are the most common infections (Table 96). With the exception of some schistosomes, most trematodes have wild or domestic animals as definitive hosts, with humans infected accidentally. Eosinophilia is common during acute trematode

Table 92 Drugs for treatment of trypanosomiasis

	Clinical stage			
Causative agent	I – Hemolymphatic		II – Central nervous system	
Trypanosoma brucei gambiense (West African HAT)	Pentamidine (alternative: suramin)		Eflornithine (Alternative: eflornithine/nifurtimox	
Trypanosoma brucei rhodesiense (East African HAT)	Suramin (alternative: pentamidine)		Melorsoprol	
	Congenital	**Acute**	**Chronic < 18 yo**	**Chronic > 18 yo**
Trypanosoma cruzi	Nifurtimox *or* benznidazole	Nifurtimox *or* benznidazole	Nifurtimox *or* benznidazole	Unclear Unclear

Adapted from Kirchoff [103]; with permission
HAT human African trypanosoma, *yo* years old

Table 93 Species of amebae causing amebic meningoencephalitis

Taxonomy	Host	Pathogen	Disease
Order Amoebida			
Family Endamoebidae			
Entamoeba histolytica	Humans	Yes	Colitis, hepatic, lung, and brain abscess
Endolimax nana	Humans	No	None
Iodamoeba butschlii	Humans	No	None
Family Acanthamoebidae			
A. culbertsoni, A. polyphaga, A. castellani, A. astronyxis, A. palestinensis, A. rhysodes, others	Humans, mice	Yes	GAE, keratoconjunctivitis, skin lesions, mandibular bone graft infection
Order Schizopyrenida			
Family Vahlkampfidae			
Naegleria fowleri	Humans	Yes	PAM
Naegleria australiensis	Mice	Yes	Experimental PAM
Naegleria gruberi, Naegleria lovaniensis	None known	No	None known
Vahlkampfia	Humans	Unproven	? GAE or PAM
Order Leptomyxida			
Balamuthia mandrillaris	Humans, primates sheep	Yes	GAE
Leptomyxa	Unknown	No	?

Adapted from Durack [104]
GAE granulomatous amebic encephalitis, *PAM* primary amebic meningoencephalitis

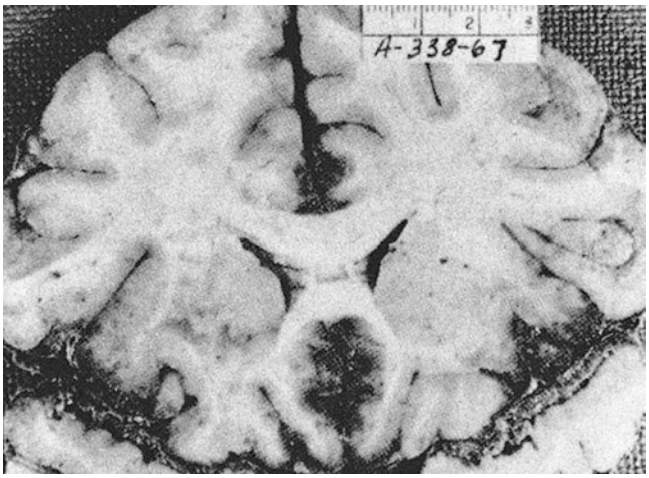

Fig. 50 Acute primary amebic meningoencephalitis (PAM), with the most severe lesions in the basal meninges and adjacent cortex. (From Durack [104], with permission)

Table 94 Clinical manifestations of PAM

Acute	Subacute or chronic, including granulomatous
Abrupt onset	Insidious onset
Fever	Chronic fever
Headache	Headache
Nuchal rigidity	Gradual onset of focal signs
Vomiting	Aphasia
Lethargy	Focal seizures
Disorientation	Hemiparesis
Seizures	Ataxia
Increased intracranial pressure	Altered mentation
Coma	Systemic manifestations
	Skin lesions
	Corneal ulcers
	Uveitis
	Pneumonitis

Adapted from Moonah and Petri [105]

infections. *Paragonimus* are lung flukes, the lungs being the final habitat. Acute purulent (meningoencephalitic) forms, chronic granulomatous (tumorous) forms, and late inactive forms are seen. In the acute meningoencephalitic form, there is fever, headache, seizures, hemiparesis and other focal deficits, and confusion. The CSF pleocytosis consists of polymorphonuclear leukocytes in the acute form and lymphocytes in the chronic form. Eosinophils occasionally appear in the CSF. Serologic tests are generally available. Diagnosis is confirmed by finding ova in the stool or sputum or by biopsy. CT scans may reveal "soap bubble" calcifications. The acute form has a 10% mortality rate; the chronic form is benign. The acute form is treated with praziquantel or bithionol with steroids; the chronic form, with surgery.

Five species of *Schistosoma* infect over 200 million people in the world (Table 97). It is estimated that over 400,000 cases exist in the United States, primarily in immigrants from infected areas (Puerto Rico, Brazil, Philippines, Middle East). Fortunately, the organism cannot be transmitted in this country because of the absence of the appropriate male intermediate host. *Schistosoma* are blood flukes; their final habitat is veins or venous plexi. The predilection for a specific region of the CNS appears to relate to the location of the adult worms when ova are released. *S. japonicum* resides in the superior mesenteric veins; it infects the CNS in about

Table 95 Nematode (roundworm) infections of the nervous system

Disease/parasite	Geographic distribution	Risk factors	Neurologic disease
Trichinella spiralis	Worldwide	Eating rare pork or bear meat	Acute meningoencephalitis myositis
Angiostrongylus cantonensis	Southeast Asia, Oceania	Eating freshwater snails, crabs, and raw vegetables	Acute eosinophilic meningitis
Gnathostoma	Japan, Thailand, Phillippines, Taiwan	Eating raw fish or meat	Hemorrhages, infarcts (rare)
Strongyloides	Tropics	Penetration of skin or gut by filariform; dissemination with immunosuppression	Meningitis (rare), paralytic ileus due to autonomic involvement
Toxocara	Worldwide	Children with pica, contamination with dog or cat feces	Small granulomas (rare), ocular granuloma
Baylisascaris procyonis	United States	Exposure to infected raccoon eggs	Acute fulminant eosinophilic meningoencephalitis
Lagochilascaris	United States, Central & South America	Ingestion of infected rodents	Meningeal parasitic lesions

Adapted from Johnson and Warren [94] and Serpa et al. [106]

Table 96 Trematode (fluke) infections of the nervous system

Disease/parasite	Geographic distribution	Risk factors	Neurologic disease
Schistosomiasis			
Schistosoma japonicum	Far East	Walking or swimming in infested waters (snails)	Cerebral granulomas
Schistosoma mansoni	South America, Caribbean, Africa		Myelitis (rare)
Schistosoma hematobium Africa, Middle East			Myelitis (rare)
Paragonimus sp.	Asia, Central Africa, central and South America	Eating infected freshwater crabs and crayfish	Cerebral granulomas

Adapted from Johnson and Warren [94]; with permission

Table 97 Species of *Schistosoma* that infect humans

	Intermediate hosts		
Species infecting humans	Primary	Secondary	Final habitat
S. Haematobium	Snails	None	Vesical plexus
S. japonicum	Snails	None	Superior mesenteric veins
S. mansoni	Snails	None	Inferior mesenteric veins
S. mekongi	Snails	None	Mesenteric veins
S. Intercalatum	Snails	None	Mesenteric veins

Adapted from Maguire [107]; with permission

3% of cases. The small eggs of this organism are able to reach the brain; ectopic worms have been found in cerebral veins. *S. mansoni* and *S. haematobium*, residing in the inferior mesenteric veins and vesical plexus, respectively, have larger eggs, which most commonly affect the spinal cord. This CNS involvement occurs less frequently than that seen with *S. japonicum*. Neurologic disease has not been well characterized for *S. mekongi* and *S. intercalatum*.

Cerebral schistosomiasis may be acute or chronic. The acute form presents as fulminating meningoencephalitis with fever, headache, confusion, lethargy, seizures, focal deficits, and coma. The presentation of the chronic cerebral form is similar to a tumor, with focal deficits, seizures, increased intracranial pressure, and papilledema. The spinal cord disease (Fig. 51) is almost always acute, presenting as incomplete transverse myelitis. There is a peripheral leukocytosis with eosinophilia except in the chronic cerebral form. The CSF shows slight to moderate pleocytosis, sometimes with eosinophilia. Cerebral lesions may be seen with CT or MRI; spinal lesions are seen with MRI or myelography. Diagnosis can be made by finding ova in the stool or urine, by using serologic tests, and by rectal mucosal biopsy. Treatment includes the use of praziquantel, corticosteroids for edema, anticonvulsants for seizure, and often decompressive laminectomy for a spinal block. Oxamniquine may need to be added for *S. mansoni* species resistant to praziquantel.

Cestode, or human tapeworm, infections can be divided into two groups. In the first, humans are the definitive host and the adult worms (*Taenia saginata* and others) live in the gastrointestinal tract and the CNS is not involved. In the second group (Table 98), humans are the intermediate host and the larvae spread to tissues that include the CNS (echinococcosis, coenurosis, and others less common).

In infection with *Taenia solium*, the pork tapeworm, humans may be either the definitive host (*T. solium*) or the intermediate host (cysticercosis). Ingestion of undercooked pork containing the encysted larvae (*Cysticercus cellulosae*; tissue larval stage) results in infection of the human intestine by the adult tapeworm (definitive host). There are usually no symptoms at this stage. The terminal gravid proglottids of the worm are excreted in the feces with thousands of ova. These ova contaminate the environment, where they are ingested

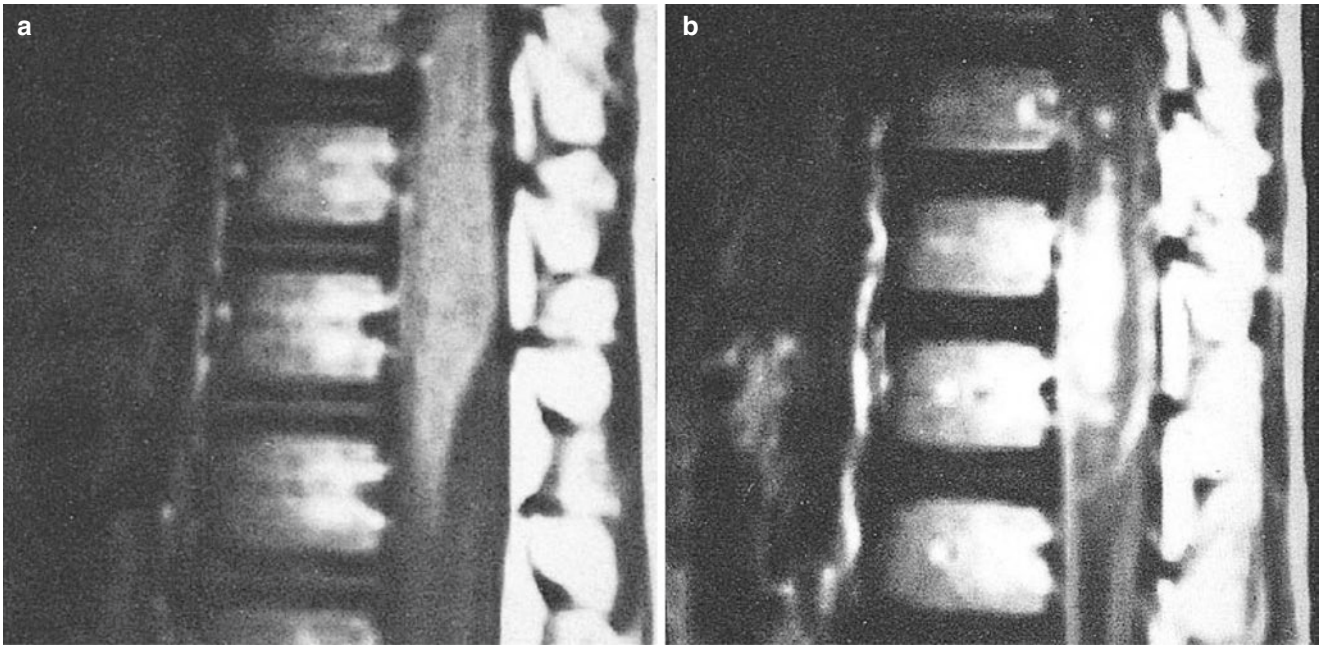

Fig. 51 T1-weighted MRI showing sagittal view of a spinal cord in a case of infection with *Schistosoma mansoni*. (**a**) Precontrast MRI scan showing increased anteroposterior diameter of the spinal cord at T11–T12. (**b**) Postcontrast MRI scan showing enhancement of the schistosomal lesion. (From Selwa et al. [108], with permission)

Table 98 Cestode (Tapeworm) infections of the nervous system

Disease/parasite	Geographic distribution	Risk factors	Neurologic disease
Cysticercosis			
Taenia solium	Central and South America, Asia, Africa, East Europe	Ingestion of eggs in human fecal contamination	Small cysts or basilar arachnoiditis with hydrocephalus; ocular lesions
Hydatid disease			
Echinococcus granulosus	Worldwide	Ingestion of eggs in canine fecal contamination	Large cysts
Coenurosis			
Taenia multiceps	Europe, Americas	Ingestion of eggs in carnivore fecal contamination	Budding cysts (rare)

Adapted from Johnson and Warren [94] and Serpa et al. [106]

by pigs or humans (intermediate hosts). The shells of these eggs are digested by gastric juices, liberating the embryos (oncospheres), which penetrate the intestinal wall, migrate to tissues, and become encysted (cysticerci). In humans, they primarily localize to the brain and CNS. Cysticercosis is clearly the most important cestode infection of humans. Coenurosis is the rare larval disease caused by the dog tapeworm, *Taenia* (*Multiceps*) *multiceps*.

The clinical manifestations of neurocysticercosis depend on the location of the lesions (Table 99). The clinical disease can be divided into four types based on the anatomic location of infection: parenchymal, subarachnoid (meningitic), intraventricular, and spinal. In the parenchymal form, the manifestations are related to the location of the cysts (Fig. 52). Focal seizures and focal neurologic deficits are seen in the

Table 99 Clinical manifestations of neurocysticercosis [109]

Symptoms and signs	Approximate frequency, %
Headache	23–98
Seizures	37–92
Papilledema	48–84
Meningeal signs	29–33
Nausea/vomiting	74–80
Altered mental status	9–47
Dementia	1–6
Psychosis	1–17
Focal sensory or motor deficits	3–36
Cranial nerve palsies	1–36
Altered vision	5–34
Ataxia	5–24
Spinal cord compression	< 1

From Serpa et al. [106]

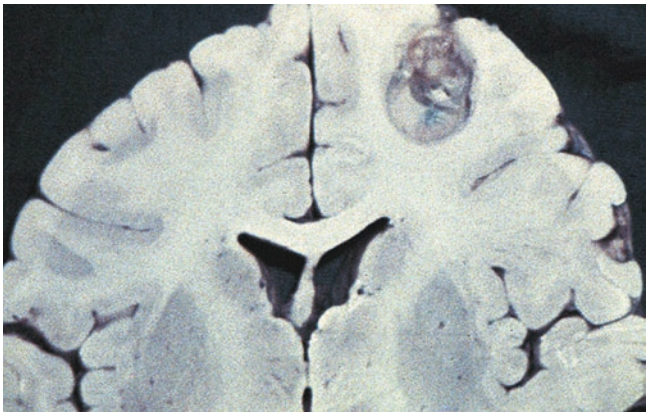

Fig. 52 Pathologic sample showing the parenchymal cysticerci that are typically found at gray-white matter junctions. The encysted larvae (cysticerci) are fluid-filled cysts that may be deposited in parenchymal CSF spaces, where they may displace or compress tissue or block CSF pathways. (From Berger [96], with permission)

parenchymal form. The meningitic form results in headache, nuchal rigidity, and communicating hydrocephalus. Intraventricular disease may result in obstructive hydrocephalus. Spinal disease may result in arachnoiditis and subarachnoid block.

The diagnosis of cysticercosis should be considered in patients who reside in endemic areas (*see* Table 99) and have seizures, meningitis, or papilledema (increased intracranial pressure). CT and MRI are especially useful, as they may demonstrate live parenchymal cysts with enhancement (diffuse or ring pattern), calcified dead cysts, hydrocephalus, and intraventricular and subarachnoid cysts with enhancement (Fig. 53). Usually the CSF shows mild pleocytosis, but it may be normal or show severe pleocytosis owing to meningitis when subarachnoid or intraventricular cysts die. There may be up to several thousand leukocytes (usually mononuclear), a low glucose level, and an elevated protein level. CSF and serum antibody tests are usually positive (80% to 98% sensitivity depending on the test).

To treat patients with symptomatic neurocysticercosis, both praziquantel and albendazole are effective (Table 100). Because dying cysticerci provoke a severe inflammatory reaction with edema, corticosteroids should be used concomitantly. Seizures usually can be controlled with anticonvulsants, but if intractable, surgical removal of cysts may be required. Ventricular shunting is usually adequate for hydrocephalus. Symptomatic ocular and spinal lesions usually require surgical excision.

Table 101 lists clinical manifestations of CNS echinococcosis (hydatid disease, hydatid cysts). Echinococciasis is the tissue infection caused by the larvae of a dog tapeworm. Most cases are caused by *Echinococcus granulosus*,

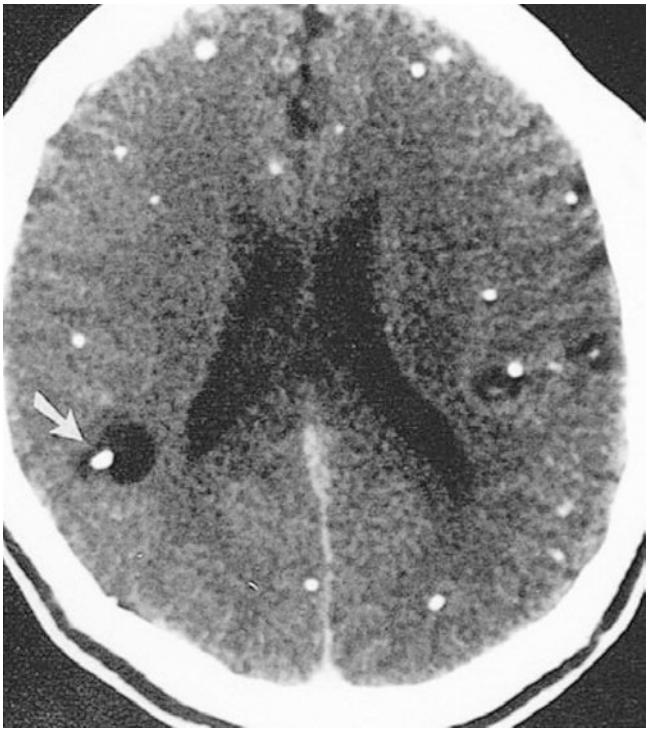

Fig. 53 Noncontrast CT scan showing numerous calcified (inactive) cysticerci and an active cyst with scolex (*arrow*) with contrast ring enhancement of active cysts in a patient with neurocysticercosis. (From Cameron and Durack [109], with permission)

Table 100 Treatment of neurocysticercosis

Medical therapy	
Praziquantel	50 mg/kg/d in 3 doses × 15 d
Albendazole	15 mg/kg/d in 2 doses × 8 d
Plus adjunctive corticosteroids	
Or	
Surgical excision	

Adapted from Serpa et al. [106]; with permission

but a few have been caused by *Echinococcus multilocularis*, *Echinococcus vogeli*, and *Echinococcus oligarthrus*. The disease primarily occurs in sheep-herding regions of Africa, South America, Eastern Europe, the former Soviet Union, and the Mediterranean. Sheep and cattle are the usual intermediate hosts. In the brain, the disease presents as a slowly expanding mass lesion.

CT and MRI scans localize hydatid cysts of the brain, which are usually single, nonenhancing, and have the density of cerebrospinal fluid (Fig. 54). Needle biopsy is usually precluded because cyst rupture may cause severe allergic reactions, including anaphylaxis. Additional cysts may be found in the lungs and liver. The enzyme-linked immunosorbent assay antibody test has a 95% sensitivity. Surgical removal of cysts is the preferred treatment. Drug treatment

Table 101 Clinical manifestations of CNS echinococcosis

Headache
Increased intracranial pressure
Nausea and vomiting
Papilledema
Seizures
Focal neurologic signs
Hemiparesis
Hemisensory loss
Aphasia
Ataxia
Cranial nerve palsies
Spinal cord compression

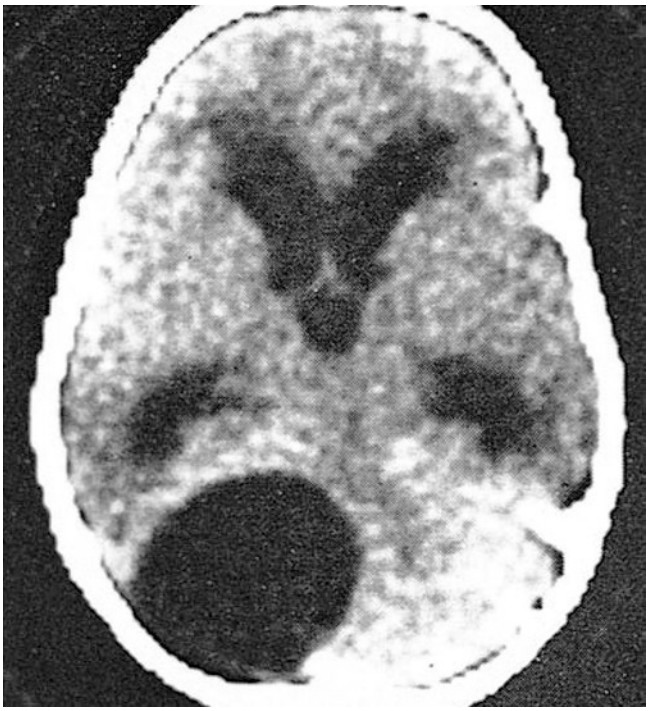

Fig. 54 CT scan of a patient with a hydatid cyst of the brain. (From Abbassioun et al. [110], with permission)

with albendazole may decrease the size of the cysts, but it should be started before surgery to prevent allergic reactions and secondary hydatidosis at the time of surgery.

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