Review Article

Viral Infections of the CNS in Children: Imaging Features

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In this paper, we review the imaging findings associated with the major viral infections of the CNS in infants and children. We approach these infections by grouping them into several categories: congenital infections in neonates, aseptic meningitis and encephalitis, acute disseminated encephalomyelitis and other postviral syndromes in older children, and HIV infection.

Imaging has various functions in children with viral CNS infection. With some agents, such as reactivated latent herpesvirus type 1, imaging may suggest the diagnosis. With others, such as congenital cytomegalovirus (CMV), imaging may suggest the presence of infection and show the extent of involvement, but immunologic and culture methods are needed to suggest the causal agent (Fig. 1). With epidemic encephalitis, such as Western equine encephalitis, imaging findings are used to exclude a bacterial process or complications. In patients with acute disseminated encephalomyelitis, imaging may show the extent of disease and suggest the nature of the process.

The wide range of clinical and imaging findings and the spectrum of agents seen with viral CNS infections in children reflect the immaturity of children's nervous and immune systems. In the fetal nervous system, the severity of the sequelae of infection tends to reflect the gestational age of the fetus at the time of exposure. Other age-related differences are seen with neonates and young children, whose immature immune system renders them susceptible to a different spectrum of viral agents with a wide range of virulence.

Congenital and Perinatal Viral Infections

The principal congenital viral infections, rubella, cytomegalovirus (CMV) infection, and herpes simplex commonly occur in the perinatal period and have been grouped with toxoplasmosis (caused by an obligate intracellular parasite) as the TORCH infections. Infection with HIV type I also occurs perinatally; however, the principal manifestations of HIV infection most often occur outside the perinatal period. Vaccination programs have diminished the prevalence of perinatal infections caused by other agents, such as measles, mumps, and varicella-zoster viruses, and reports of neonatal infection with other viral agents, such as enterovirus, are only sporadic.

In general, sequelae of an intrauterine infection reflect the agent involved and the stage in fetal development at which exposure occurred. Early infections can result in embryonic death with resorption or spontaneous abortion, intrauterine growth retardation, and developmental anomalies. Some congenital viral infections, such as rubella, CMV infection, herpes simplex, herpes zoster, and HIV infection, can persist in the neonate. The clinical features of these infections, such as encephalitis or failure to thrive, can then reflect the persistence of viral infection in addition to the effects of intrauterine exposure.

Perinatal exposure to viral agents occurs via three pathways. In utero, the placenta is generally effective in protecting the fetus; thus, most episodes of maternal viremia are not associated with placental or fetal involvement. Nevertheless, placental transgression does occur and is the usual route by which the fetus is infected. Less commonly, trans-

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mission involves ascending infection via the cervix. Exposure also may occur during delivery, either as the infant descends through the vaginal canal or by direct contact with the monitor's electrodes [1].

Radiologic manifestations of this group of infections are similar, with differences stemming from the time of exposure during gestation and the age of the child when the diagnosis is made. In general, the later the diagnosis is made, the more difficult it is to identify the causal agent. Often, antibody titers indicating exposure to a specific agent are the only way to confirm a specific diagnosis. Imaging in the young infant is complicated by incomplete myelination of white matter, with its lower density on CT scans and hyperintensity on T2-weighted MR images, which can obscure abnormalities (or result in overdiagnosis of cerebral edema).

Cytomegalovirus Infection

CMV, a DNA virus of the herpesvirus group, is the most frequent cause of congenital viral infections and is reported to be present in 1% of neonates, although only 10% of infected neonates are symptomatic. Most significant congenital infections (with clinically apparent sequelae) occur by placental transgression during the primary episode of maternal infection; the prevalence may be as high as 58%. Conversely, asymptomatic infection, whether congenital or perinatal, is more common if maternal viremia results from reactivation of a latent infection or if neonatal exposure occurs via cervical secretions or infected breast milk [2].

CNS sequelae associated with congenital CMV infections include seizures, mental retardation, optic atrophy, sensorineural hearing loss, and hydrocephalus. Pathologically, cerebellar hypoplasia, periventricular calcifications, cerebral atrophy, porencephaly and subependymal cysts, polymicrogyria, and delayed myelination have been described [2]. CMV may remain latent and be shed during asymptomatic periods. Reactivation can occur, most commonly in those who become immunocompromised, as has been reported in an infant with human T-cell leukemia virus type 3 [3].

Either MR imaging or CT can be used to assess the extent of disease. Calcifications are better evaluated with CT, whereas the extent of parenchymal disease is more accurately shown with MR imaging [4]. MR findings in one group of 10 children included dilated lateral ventricles in 10, large subarachnoid spaces in eight, oligogyria and pachygyria in eight, delayed myelination in seven, paraventricular cysts in six, and intracranial calcification in one [5]. Intracranial calcification (Figs. 1 and 2), reported in up to 40% of affected children, is typically periventricular but can also be found in basal ganglia and subcortical and cortical regions [2]. Subependymal periventricular cysts, usually in the occipital lobe, are thought to be associated with necrosis and gliosis. Such cysts can also be diagnosed with sonography. Similar cysts have been associated with rubella, bacterial ventriculitis, and intraventricular hemorrhage. Associated microgyria is a frequent neuropathologic finding but may appear on imaging studies as oligogyria or pachygyria [6]. This focal cerebral dysplasia (Fig. 3) is thought by some to result from congenital vascular insufficiency [7]. Cerebral atrophy, indicated by an increase in the size of ventricles and subarachnoid spaces, can be shown with MR imaging, CT, or sonography; however, MR is more sensitive for the detection of delayed or pathologic myelination [5].

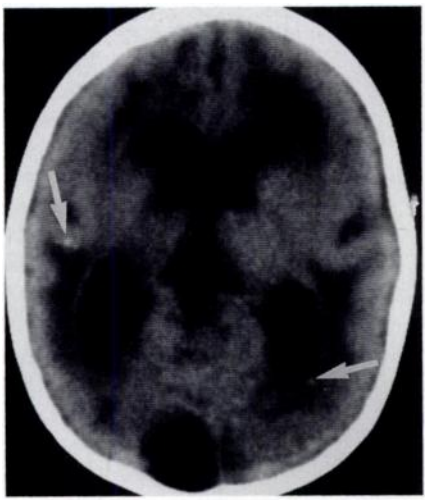

Fig. 1.—10-month-old child with developmental delay and microcephaly. Presumptive diagnosis was cytomegalovirus (CMV) encephalitis. Axial CT scan shows hydrocephalus, hypodensity, volume loss, and punctate calcifications (*arrows*) in a predominantly periventricular distribution. Most likely cause is intrauterine infection by *Toxoplasma*, rubella virus, CMV, or herpesvirus. Serum assays for rubella, toxoplasmosis, and herpes simplex were negative. It was not possible to test a child of this age for infection with CMV.

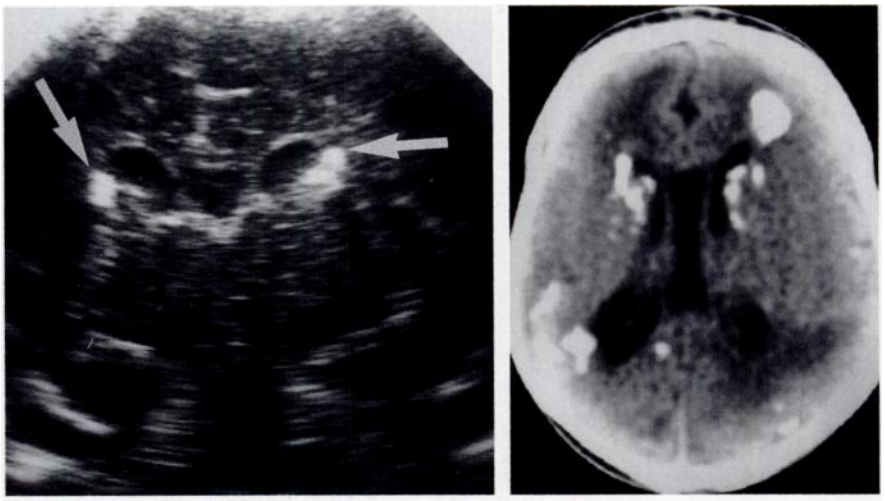

Fig. 2.—1-month-old child whose mother was infected by cytomegalovirus (CMV) during pregnancy. Presumptive diagnosis was CMV encephalitis.

***A*, Coronal sonogram shows hydrocephalus with bilateral, highly echogenic periventricular foci (*arrows*). This appearance is highly suggestive of an intrauterine infection.**

***B*, Axial CT scan through body of lateral ventricles shows hydrocephalus and prominent periventricular calcifications. This appearance is typical for a neonate who had a severe early intrauterine infection. Calcifications are better shown on unenhanced CT scans than on MR images.**

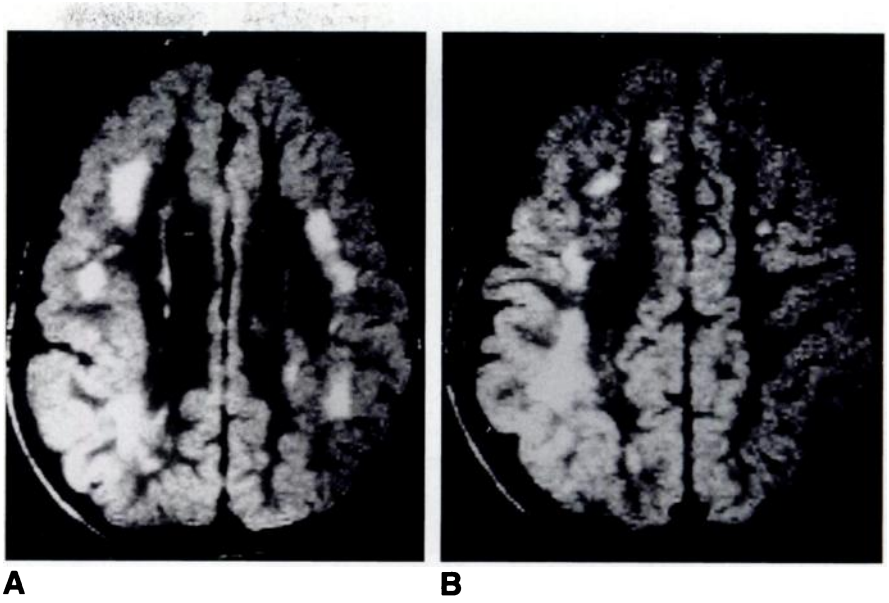

Fig. 3.—Congenital cytomegalovirus (CMV) encephalitis.

***A* and *B*, Axial MR images through bodies of lateral ventricles (*A*) and centrum semiovale (*B*) show dysplastic cortex in right frontal lobe and areas of increased T2 signal scattered through white matter. Calcifications were present in corresponding areas on CT scan. (Courtesy of A. J. Barkovich, San Francisco, CA.)**

Herpes Simplex

Herpes simplex types I and II are also caused by DNA viruses of the herpesvirus group. Either type can be perinatal; however, type 2 accounts for 80–90% of neonatal and almost all congenital herpesvirus infections. Fetal herpes simplex is relatively rare, but CNS sequelae of such infection are generally severe. In one series of 13 infants infected in utero, 12 had skin lesions, seven had microcephaly, five had hydrocephalus, two had microphthalmia, and eight had chorioretinitis [8]. Unlike the case in other perinatal infections, intrapartum transmission via direct contact rather than transplacental transgression is the origin of most neonatal herpesvirus infections; the reported prevalence is between one in 200 and one in 5000 deliveries. Diagnosis is difficult because the mother may not have a history of genital herpes or evidence of active infection. Furthermore, neonatal herpetic skin lesions may be absent (or misdiagnosed) [9].

Classically, neonatal herpetic infections are divided into three clinical categories: (1) skin, eye, and mouth; (2) disseminated; and (3) CNS infections. Cutaneous infections are the most common (43%) and the mildest form; nevertheless, without treatment, the infection will progress to disseminated or CNS disease in 75% of infected children. Disseminated disease tends to manifest by 10–11 days after birth, with signs and symptoms that suggest severe bacterial sepsis. CNS manifestations are present in approximately half of the cases. In disseminated herpes simplex, the mortality rate is almost 80% in untreated infants and usually more than 50% in those who are treated. Isolated CNS herpesvirus infection manifests in neonates 2–4 weeks after birth as fever and lethargy followed by seizures [10]. Pathologically, all cells of the CNS can be infected, yet the predilection is involvement of endothelial cells, which can result in vascular thrombosis and hemorrhage [9].

CT scans and MR images may show focal evidence of cerebral edema, but either can show normal findings during the initial episode of encephalitis. Thus, neither CT nor MR findings should be used to exclude diagnosis. The most frequent initial finding on CT scans is widespread, patchy areas of low attenuation in the cerebral cortex and white matter (Fig. 4), which Noorbehesht et al. [11] found in 12 of 15 infants. The earliest reported diagnosis was in a 1-week-old neonate. On MR images, patchy areas of increased T2 signal are seen in the cerebral hemispheres and the basal ganglia, thalamus, and cerebellum. Neonatal infections do not have the temporal lobe predilection seen in herpesvirus infections in older children and adults [12]. Encephalomalacia, which develops rapidly, may be visible within the first 2–3 weeks. Foci of hemorrhage and dystrophic calcification occur in the basal ganglia and periventricular white matter, although hemorrhage has been seen more often on pathologic examinations than on imaging studies. A linear gyriform pattern of increased attenuation on non–contrast-enhanced CT has been reported and attributed to the presence of calcification [11, 13], to changes in local vascularity, or to prolonged retention of contrast material in regions where the blood-brain barrier is disrupted [14] (Fig. 4). We have also occasionally observed a linear gyriform pattern of hyperintensity on T1-weighted images. Some have speculated the underlying disease relates to cortical laminar necrosis. CT early in the course of infection is not a good predictor of outcome, although findings on later scans are more accurate indicators of prognosis [11]. Sonography in neonates with herpesvirus infection may show linear thalamic echogenicities, thought to reflect vasculopathy [15].

Rubella

Placental transmission of the rubella virus occurs at the time of primary maternal infection. If this occurs during the first trimester, the risk of fetal infection may approach 85%. Gestational age at the time of infection is the most important factor in ultimate outcome. The infection can kill the fetus or have no apparent effect. Infections in the first 2 months of gestation are associated with cataracts and cardiac abnormalities. In 10–20% of affected infants, an acute meningoencephalitis is present at birth, which can be correlated with motor and mental retardation. In the remainder of young

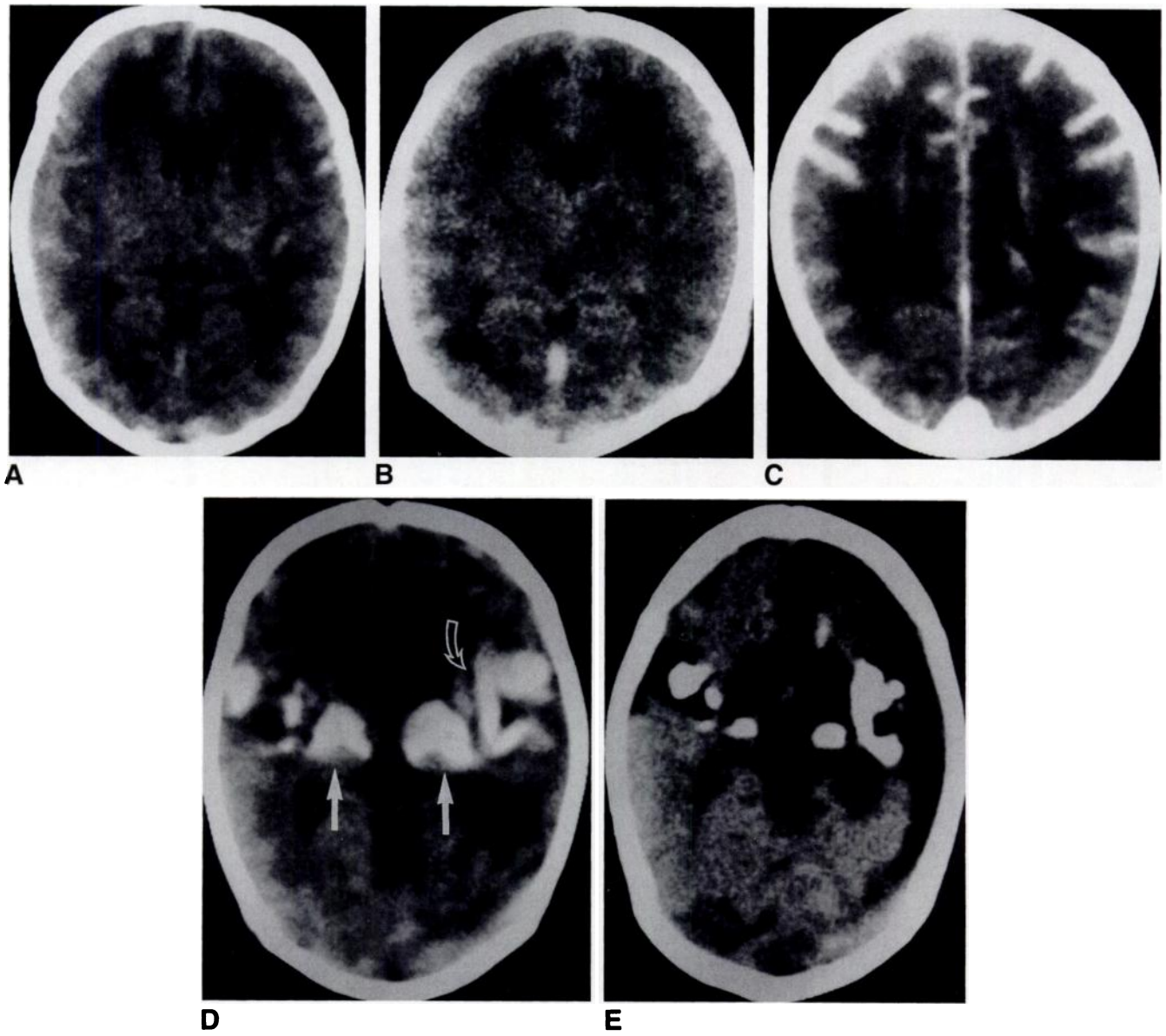

Fig. 4.—2-week-old child who had had a seizure. Presumptive diagnosis was herpes simplex.

***A*, Initial unenhanced axial CT scan shows patchy areas of low attenuation throughout both hemispheres. Sulcal pattern is difficult to discern.**

***B* and *C*, Axial CT scans, obtained 1 week after *A*, without (*B*) and with (*C*) IV contrast material show patchy areas of low attenuation throughout white matter. Ventricles are somewhat smaller than normal, suggestive of underlying edema. On *C*, note gyral pattern of enhancement in cortex and along edges of ventricles.**

***D*, Axial CT scan obtained when child was 1 month old. IV contrast material had been given 12 hr before this scan. Patchy areas of low attenuation remain scattered throughout white matter, while striking, gyriform pattern of increased density is present in both ganglia (*solid arrows*), right frontal operculum, and left insula (*open arrow*). Areas of high attenuation, which can represent calcification, local hemorrhage, or delayed clearance of IV contrast material, can develop quite rapidly in children.**

***E*, Unenhanced CT scan (obtained 1 month after *D*) shows marked periventricular and parenchymal calcification; marked encephalomalacic change with loss of tissue in both frontal lobes, more so in left one than in right one; and marked dilatation of both lateral ventricles.**

infants, rubella may be subclinical [16]. Deafness, often not detected until the infant is older, is the most common feature of congenital rubella. Congenital rubella has been implicated as the cause of a chronic progressive panencephalitis similar to subacute sclerosing panencephalitis associated with measles [17, 18]. The pathologic appearance of rubella is characterized by a generalized vasculitis with relatively little cellular necrosis [19].

Microcephaly and intracranial calcifications are seen with congenital rubella. Of five patients with congenital rubella who had CT, four had areas of low density in the centrum semiovale and periventricular white matter, and two had calcified nodules [20]. The white matter changes may have reflected the delayed myelination described in pathologic studies [19]. Because of the widespread use of vaccination, few descriptions of neonatal rubella have been published.

HIV Infection

A characteristic dysmorphic syndrome associated with congenital HIV infection has been reported [21]. The primary features included growth failure and microcephaly. This has not, however, been consistently observed, and the imaging features of the syndrome have not been described. More commonly, the CNS abnormalities associated with HIV infection become manifest during infancy and early childhood [22].

Acute Meningitis or Encephalitis

Acute viral infection of the CNS commonly causes meningitis or encephalitis, whether in children or adults. Most viruses are pantropic, able to produce either meningitis or encephalitis. Because most viral meningitides are benign and self-limited, exclusion of other, particularly bacterial, infections that may require active medical intervention is often the main clinical issue. Enteroviruses (echoviruses, coxsackieviruses) are thought to be responsible for 50–80% of all cases of viral meningitis. Other viral agents include mumps virus, Epstein-Barr virus, and arbovirus, although in any particular case, the specific organism usually is not identified [23]. Clinically, patients have headache, fever, and signs and symptoms of meningeal irritation.

Encephalitis occurs when the brain parenchyma is invaded by the virus and clinically should be suspected if the patient has seizure, delirium, and focal neurologic signs. Viral encephalitis may occur sporadically (nonepidemic) or in epidemics; the season, timing, and geographical distribution generally reflect the vector mechanism [24].

Imaging findings in patients with viral meningitis are generally normal. Viral meningitis does not produce the meningeal enhancement seen with contrast-enhanced CT or gadolinium-enhanced MR imaging in some cases of severe bacterial meningitis. Unless encephalitis is also present, the brain parenchyma is also normal, and even with some viral encephalitides, such as that caused by enterovirus, the CT or MR appearance remains normal. Other organisms such as herpesvirus may produce a necrotizing or hemorrhagic infection that is visible on CT or MR.

Epidemic Encephalopathies

The most common viral encephalitides are spread by arthropods (ticks and mosquitoes). The causal agents have previously been classified as arboviruses, although more recently this classification has been reorganized. Those commonly encountered in North America include Eastern equine encephalitis, Western equine encephalitis, and Venezuelan equine encephalitis, all of which occur as sporadic epidemics most severely affecting the young and elderly. Mortality in those more than 50 years old who have clinically evident and diagnosed Eastern equine encephalitis may reach 80%, and survivors less than 10 years old have significant sequelae. Yet in patients 15–55 years old, the disease may be mild or inapparent. Western equine encephalitis has a similar clinical picture but is more prevalent in those less than 1 year old. Venezuelan equine encephalitis tends to be a rather mild infectious syndrome; encephalitis symptoms are seen in 4% of young patients and only 0.4% of adults infected. Pathologically, in those dying, both gray and white matter can be involved with perivascular inflammation and formation of inflammatory nodules. Patchy areas of demyelination may be seen in the white matter. In these entities, CT findings generally have not been useful for diagnosis, and little information on MR findings has been reported [24].

Herpes Simplex

Herpesvirus is thought to be the most frequent cause of nonepidemic encephalitis. It is common in children and adults; 33% of patients in the National Institutes of Health trial of acyclovir vs vidarabine treatment of herpes simplex were less than 20 years old [25]. Most cases of herpes simplex that occur outside the neonatal period are due to herpesvirus type I infection. Unlike many viral encephalitides that represent a primary infection, encephalitis caused by herpes virus I occurs as a reactivation of latent virus within the trigeminal ganglion. Encephalitis results from retrograde transport of virus into the CNS. Although the infection rapidly disseminates throughout the brain, characteristically, the temporal lobes are involved first.

The earliest CT findings, which reflect this initial temporal lobe localization (Fig. 5), have low density in the temporal lobes associated with hemorrhage and streaky contrast enhancement [26]. Localized or generalized edematous changes can progress ultimately to atrophy, multicystic encephalomalacia, and gyriform high attenuation (Fig. 5). This gyriform high density is more commonly seen in children (and neonates) than in adults [13]. MR similarly shows edema with mass effect and increased T2 signal within the temporal lobe. Rarely, herpesvirus encephalitis can be manifested as diffuse brainstem encephalitis without alteration of the level of consciousness [25]. In general, the imaging appearance with CT does not accurately reflect the clinical course, which is significant because early treatment with antiviral agents, most recently acyclovir, has improved the otherwise 67% mortality associated with herpesvirus encephalitis [9]. MR is more sensitive than CT for detecting the presence of infection and has been used to show response to antiviral therapy [27].

Mumps

Mumps virus previously was the single most common agent producing aseptic meningitis and mild encephalitis. Immunization has markedly diminished the incidence and subsequent complications of mumps, although the vaccine is successful in only 75–90% of patients. In the CNS, mumps produces meningism in more than half the cases. Associated encephalitis is much rarer but also has a significant mortality and morbidity. Pathologically, mumps produces areas of perivascular inflammation and demyelination scattered throughout the CNS [28]. Not unexpectedly, MR has been reported to be more sensitive than CT in delineating these lesions; however, not many imaging studies have been done [29]. Some think that mumps encephalitis is similar to other postinfectious encephalitides [28].

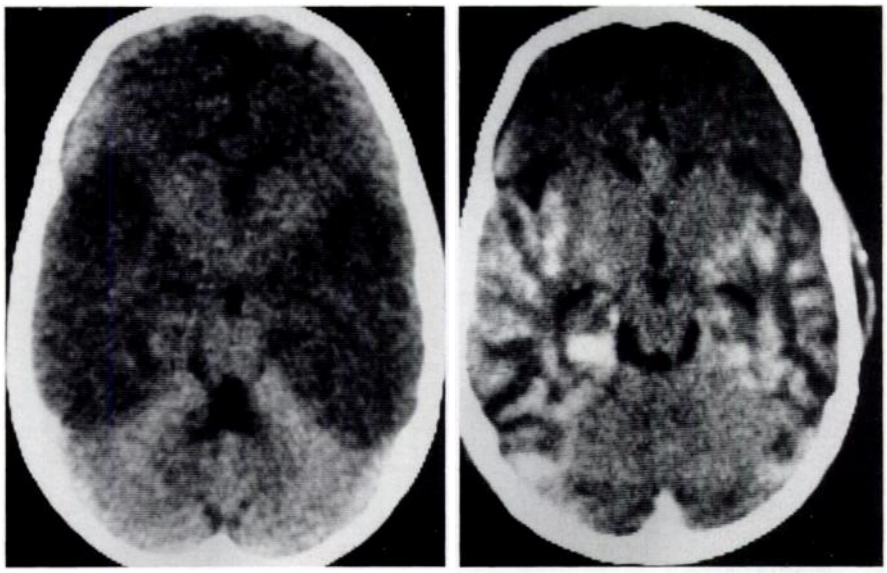

Fig. 5.—18-month-old child with clinical evidence of encephalitis. Presumptive diagnosis was herpes simplex.

***A*, Initial unenhanced CT scan shows areas of low attenuation within both temporal lobes, compression of both temporal horns and both lateral ventricles, and extension of this process into the parietooccipital regions bilaterally. Accompanying scan obtained after injection of contrast material (*not shown*) showed no abnormal enhancement.**

***B*, Axial CT scan obtained 1 week after *A*. IV contrast material has been administered. Mass effect is diminished, basal cisternal and ventricular structures are larger than normal, and gyral pattern of enhancement is present throughout both temporal lobes. This pattern of temporal lobe involvement is classic for herpetic infection outside the perinatal period. Herpes simplex is commonly thought to result from reactivation of virus residing within trigeminal ganglia.**

Rubella, Measles, and Chickenpox

The common viral infections of childhood occasionally can involve the CNS at the time of the acute infection. Chickenpox (varicella) is associated with an acute meningoencephalomyelitis, and encephalitis has been reported with German measles (rubella). Before immunization became widespread, encephalitis as a complication of measles occurred in about one per 1000 cases. It is now seen only rarely in immunologically normal children. Measles encephalitis pathologically resembles subacute sclerosing panencephalitis.

Subacute sclerosing panencephalitis, which can occur years after a primary infection with measles, continues to have an unclear pathogenesis. Some think that it represents reactivation of a latent infection, infection with a variant of the measles virus that is behaving as a "slow virus," or an immunologic response to a previous infection with measles virus. CT findings in a patient with subacute sclerosing panencephalitis may be normal or may show patchy low density, mainly in the white matter. These lesions may enhance with IV contrast material [30]. MR imaging shows patchy areas of increased T2 and decreased T1 signal intensity in the white matter and basal ganglia, which may represent inflammation, demyelination, gliosis, or some combination of these [31].

Acute Disseminated Encephalomyelitis

Acute disseminated encephalomyelitis commonly occurs as a sequela to another process, such as measles, rubella, varicella-zoster, smallpox, mumps, and upper respiratory infections. Considered to have a similar pathogenesis are the encephalitides that occur after vaccination for smallpox, measles, or rabies. With the reduced use of vaccination for smallpox and the development of vaccines for the common childhood exanthems, most episodes of acute disseminated encephalomyelitis are now related to viral infections of the upper respiratory tract.

Acute disseminated encephalomyelitis is thought to be an immunologic reaction to the viral infection, less commonly a reaction to a viral toxin. Virus has not been isolated from patients with this syndrome. The pathologic appearance suggests loss of myelin, sparing of axons, perivascular lymphocytic and mononuclear infiltration, edema, and endothelial proliferations. Lesions can be located throughout the CNS, including cerebrum, cerebellum, brainstem, and spinal cord. Although acute disseminated encephalomyelitis is mainly a white matter process, lesions can be found in the gray matter. Acute hemorrhagic leukoencephalitis is thought to be an aggressive form of acute disseminated encephalomyelitis in which microscopic areas of hemorrhage occur.

MR is more sensitive than CT for the diagnosis. CT findings in patients with the clinical diagnosis of acute disseminated encephalomyelitis may be normal or the scans may show areas of patchy low attenuation in the white matter accompanied by focal or more diffuse cortical enhancement. In general, lesions seen on CT tend not to correspond to the extent or pattern of clinical disease [32]. However, on T2-weighted MR images, multiple areas of increased signal are found throughout the CNS and correspond to the patient's clinical deficits (Fig. 6). As in multiple sclerosis, in acute disseminated encephalomyelitis, T2-weighted images are more sensitive than T1-weighted images for detection of the abnormalities [33]. In three patients, Atlas et al. [34] found clear abnormalities on T2-weighted images and no abnormalities on T1-weighted images (Fig. 7). Others [35] have seen similar abnormalities and found similar insensitivity of CT compared with MR imaging, although the exact imaging sequences used were less well defined. Contrast enhancement has been seen in lesions of acute disseminated encephalomyelitis in animal models [36].

Children with acute disseminated encephalomyelitis can have a subacute process that reflects the areas of the CNS involved. Common signs and symptoms include headache, diplopia, ataxia, hemiparesis, seizures, dysarthria, and coma [35]. Treatment with steroids is used to minimize the residual neurologic deficits [33].

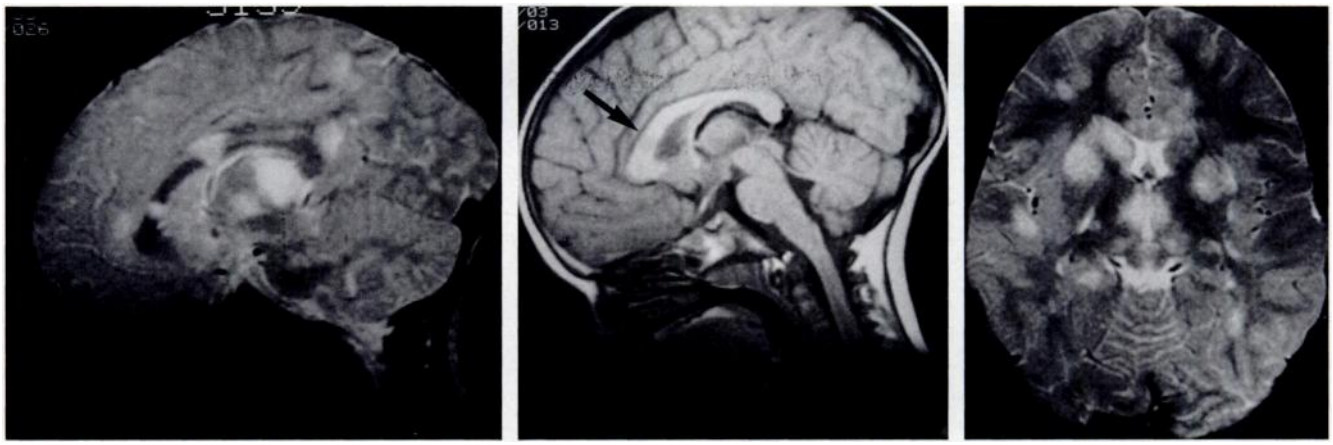

Fig. 6.—2-year-old who was lethargic and had had a viral infection of upper respiratory tract 3 weeks earlier. Presumed diagnosis was acute disseminated encephalomyelitis.

***A*, Paramedian sagittal T2-weighted MR image shows multiple areas of increased signal throughout both gray and white matter. Lesions are present in all compartments, including posterior fossa and brainstem. Lesions are present in corpus callosum (white matter) and thalamus (gray matter) also.**

***B*, Sagittal T1-weighted MR image shows an area of relatively low signal intensity (*arrow*) in anterior body of corpus callosum, which corresponds to an area of increased signal on T2-weighted images. However, most lesions seen on T2-weighted images are inapparent on T1-weighted images.**

***C*, Axial T2-weighted MR image shows multiple areas of increased signal in both gray and white matter, including right caudate nucleus, bilateral lentiform nuclei, and both thalami. Unlike lesions of multiple sclerosis, those of acute disseminated encephalomyelitis can occur in gray matter or white matter tracts.**

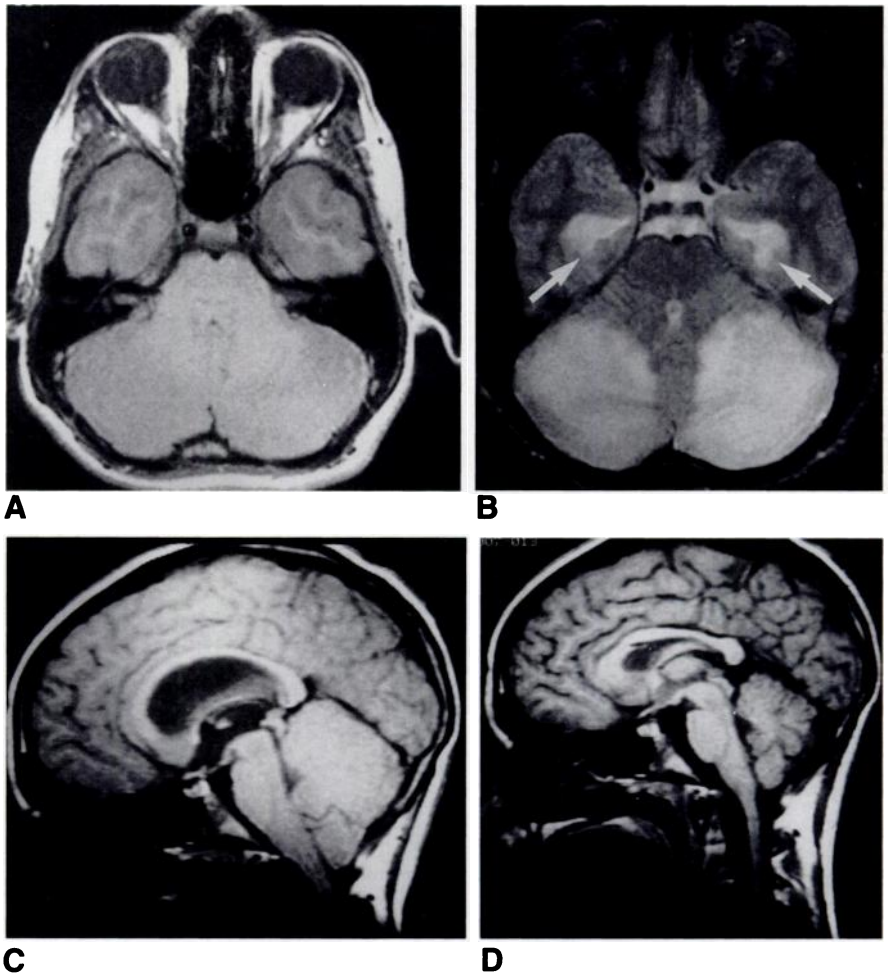

Fig. 7.—9-year-old boy with headache and cerebellar findings 3 weeks after an infection of upper respiratory tract. Presumed diagnosis was acute disseminated encephalomyelitis.

***A*, Axial T1-weighted MR image shows compression of fourth ventricle, effacement of cerebellar folia bilaterally, and a suggestion of lower signal intensity in both cerebellar hemispheres.**

***B*, Axial T2-weighted MR image at same level as *A* shows large areas of increased signal intensity in both cerebellar hemispheres. Extent of involvement is shown better on T2- than on T1-weighted MR images. Patient has acute hydrocephalus with dilated temporal horns and periventricular transudation of CSF (*arrows*).**

***C*, Sagittal T1-weighted MR image shows swollen cerebellar hemispheres, compression of fourth ventricle, compression of brainstem, and downward displacement of cerebellar tonsils.**

***D*, Sagittal T1-weighted MR image obtained 3 weeks later shows resolution of process within cerebellum. Fourth ventricle is slightly enlarged, cerebellar folia are well seen, and brainstem and cerebellar tonsils have returned to a normal position.**

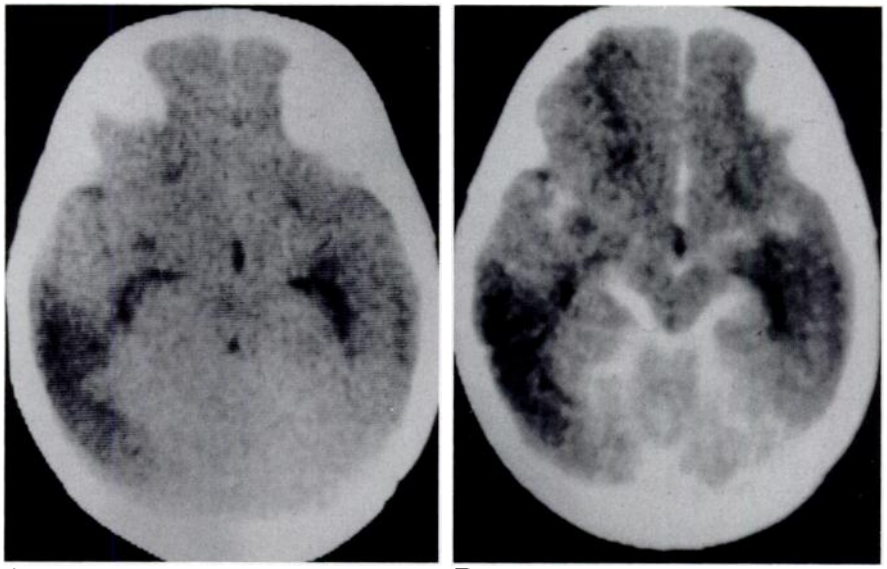

Fig. 8.—1-year-old child who had a fever and lethargy and whose mother was seropositive for HIV. *Pneumococcus* was cultured from CSF. Presumed diagnosis was pneumococcal meningitis.

***A*, Axial CT scan shows obscured cisterns, hydrocephalus, and an area of low attenuation in posterior temporal lobe on right side, suggestive of an area of infarction. Relative obscuring of cisterns suggests either a highly aggressive process or hemorrhage within basal cisterns.**

***B*, Contrast-enhanced axial CT scan shows marked enhancement of all basal cisternal structures. As on *A*, an area of infarction in posterotemporal lobe on right side is not enhanced. This scan epitomizes one of the problems in HIV-positive children: Those children who have CNS infections tend to have severe manifestations of common diseases rather than opportunistic infections.**

HIV Infection in Infants and Children

Infants and children infected with HIV are particularly at risk for neurologic complications. Most childhood exposure to HIV results from transmission from an infected mother (transplacental exposure), exposure to maternal blood during delivery, or ingestion of virus during breast feeding [22]. Diagnosis of HIV may be difficult in infants because passively transmitted maternal antibodies may be present in children up to 15 months after birth. Thus, early diagnosis requires culture of virus, demonstration of viral antigens, evidence of immunodeficiency, or the presence of a characteristic symptom complex. The number of children who have acquired HIV from transfusions or from contaminated blood products is somewhat smaller; however, these children were infected early in the course of the epidemic and do not form a significant proportion of new cases. A separate classification for HIV infection in children less than 13 years old has been established by the Centers for Disease Control [37].

In children, neurologic manifestations of HIV infection tend to have typical clinical features, including failure to reach developmental milestones, apathy, and spastic paraparesis [22]. In a study by Belman et al. [38], 61 of 68 infants and children had CNS dysfunctions as a manifestation of HIV infection. Neurologic signs included microcephaly, developmental delay, cognitive deficits, bilateral pyramidal tract signs, mild-to-moderate spastic diparesis or paraparesis, movement disorders, and ataxia. Seizures were uncommon.

Opportunistic infections are exceedingly unusual in infants and children who have AIDS, although sporadic cases of CNS lymphoma have been reported. Infectious complications include severe manifestations of more common diseases, such as those caused by Epstein-Barr virus, *Streptococcus pneumoniae*, and *Hemophilus influenzae* (Fig. 8). Disseminated CMV encephalitis has been seen at autopsy and *Candida* infections have been reported. Also occurring in children are episodes of intracranial hemorrhage associated with immune thrombocytopenia [38, 39].

Most imaging findings in HIV-positive children have been obtained with CT. In one study [40], 23 of 25 patients with a subacute progressive course had atrophy associated with decreased attenuation in the white matter. Also seen were bilateral symmetric calcification in 10 and calcification in the frontal lobes in two. In patients who had serial studies, progressive atrophy was found in 16 of 17. Of 12 patients with a more static course, five had atrophy, and two had basal ganglia calcification [37]. In another study [41] of 14 patients, both MR and CT showed central volume loss in eight patients and peripheral volume loss in seven, old hemorrhage in one, multifocal abnormal signal in one, and cervical lymphatic hypertrophy in four. CT was better than MR for showing striatal thalamic calcification (one), whereas only MR showed delayed myelination (one). Despite this, and because of the greater ease of obtaining CT scans, CT may be the study of choice.

Summary

Children are susceptible to a wide variety of viral infections that involve the CNS, in greater frequency than adults. Particularly vulnerable is the developing fetus. Imaging of neonates revealing periventricular calcification, cerebral atrophy, or microcephaly should raise the spectrum of congenital or perinatal TORCH infections. Although a specific diagnosis will generally be established by immunologic techniques, some findings in association can suggest a more specific identity; such as pachygyric-appearing brain consistent with the microgyria of CMV, or the linear gyriform cortical pattern of increased attenuation on CT scans (or hyperintensity on T1-weighted MR images) seen with perinatal herpes.

Imaging of uncomplicated viral meningitis will generally be unremarkable. Children, however, are more susceptible to complication than adults. Evidence of focal brain parenchymal edema in this setting suggests concomitant encephalitis.

A hemorrhagic process, especially involving the temporal lobes, is highly suggestive of herpes encephalitis; although CT or MR imaging should not be used to absolutely exclude this entity early in its course.

Areas of hyperintensity on T2-weighted MR images after a systemic viral infection or vaccination raise the spectre of acute disseminated encephalitis, although a definite cause is likely to remain elusive. CT is less sensitive for showing the pathologic changes.

Subacute presentations of CNS dysfunction associated with evidence of atrophy, decreased white matter attenuation, and basal ganglia calcification in this day raise the possibility of HIV infection.

REFERENCES

1. Klein JO, Remington JS. Current concepts of infections of the fetus and newborn infant. In: Remington JS, Klein JO, eds. *Infectious disease of the fetus and newborn infant.* Philadelphia: Saunders, **1990**:1–14
2. Bale JF Jr. Human cytomegalovirus infection and disorders of the nervous system. *Arch Neurol* **1984**;41:310–320
3. Post MJD, Curless RG, Gregorios JB, Scott GB, Sheldon JJ. Reactivation of congenital cytomegalic inclusion disease in an infant with HTLV-III associated immunodeficiency: A CT-pathologic correlation. *J Comput Assist Tomogr* **1986**;10:533–536
4. Holland BA, Kucharcyzk W, Brant-Zawadzki M, Norman D, Haas DK, Harper PS. MR imaging of calcified intracranial lesions. *Radiology* **1985**;157:353–356
5. Boesch Ch, Issakainen J, Kewitz G, Kikinis R, Martin E, Boltshauser E. Magnetic resonance imaging of the brain in congenital cytomegalovirus infection. *Pediatr Radiol* **1989**;19:91–93
6. Bignami A, Appicciutolo L. Micropolygyria and cerebral calcification in cytomegalic inclusion disease. *Acta Neuropathol* **1964**;4:127–137
7. Marques-Dias MJ, Hartmant-van Rijckevorsel G, Landrieu P, Lyon G. Prenatal cytomegalovirus disease and cerebral microgyria: Evidence for perfusion failure, not disturbance of histogenesis, as the major cause of fetal cytomegalovirus encephalopathy. *Hippokrates* **1984**;15:18–24
8. Hutto C, Arvin A, Jacobs R, et al. Intrauterine herpes simplex virus infections. *J Pediatr* **1987**;110:97–101
9. Whitley RJ. Herpes simplex virus infections. In: Remington JS, Klein JO, eds. *Infectious disease of the fetus and newborn infant.* Philadelphia: Saunders, **1990**:282–301
10. Herman TE, Cleveland RH, Kushner DC, Taveras JM. CT of neonatal herpes encephalitis. *AJNR* **1985**;6:773–775
11. Noorbehesht B, Enzmann DR, Sullender W, Bradley JS, Arvin AM. Neonatal herpes simplex encephalitis: correlation of clinical and CT findings. *Radiology* **1987**;162:813–819
12. Benator RM, Magill HL, Gerald B, Igarashi M, Fitch SJ. Herpes simplex encephalitis: CT findings in the neonate and young infant. *AJNR* **1985**;6:539–543
13. Taccone A, Gambaro G, Chiorzi M. Computed tomography (CT) in children with herpes simplex encephalitis. *Pediatr Radiol* **1988**;19:9–12
14. Junck L, Enzmann DR, DeArmond SJ, Okerlund M. Prolonged brain retention of contrast agent in neonatal herpes simplex encephalitis. *Radiology* **1981**;140:123–126
15. Ben-Ami T, Yousefzadeh D, Backus M, Reichman B, Kessler A, Hammerman-Rozenberg C. Lenticulostriate vasculopathy in infants with infections of the central nervous system sonographic and Doppler findings. *Pediatr Radiol* **1990**;20:575–579
16. Preblud SR, Alford CA Jr. Rubella. In: Remington JS, Klein JO, eds. *Infectious disease of the fetus and newborn infant.* Philadelphia: Saunders, **1990**:196–224
17. Townsend JJ, Baringer RB, Wolinsky JS, et al. Progressive rubella panencephalitis: late onset after congenital rubella. *N Engl J Med* **1975**;292:990–993
18. Weil ML, Itabashi HH, Cremer NE, Oshiro LS, Lennette EH, Carnay L. Chronic progressive panencephalitis due to rubella virus simulating subacute sclerosing panencephalitis. *N Engl J Med* **1975**;292:994–998
19. Rorke LB, Spiro AJ. Cerebral lesions in congenital rubella syndrome. *J Pediatr* **1957**;70:243–255
20. Ishikawa A, Murayama T, Sakuma N, et al. Computed cranial tomography in congenital rubella syndrome. *Arch Neurol* **1982**;39:420–421
21. Marion RW, Wiznia AA, Hutcheon RG, et al. Fetal AIDS Syndrome Score: correlation between severity of dysmorphism and age at diagnosis of immunodeficiency. *Am J Dis Child* **1987**;141:429–431
22. Haney PJ, Yale-Loehr AJ, Nussbaum AR, Gellad FE. Imaging of infants and children with AIDS. *AJR* **1989**;152:1033–1041
23. Ratzan KR. Viral meningitis. *Med Clin North Am* **1985**; 69:399–413
24. Weiner LP, Fleming JO. Viral infections of the nervous system. *J Neurosurg* **1984**;61:207–224
25. Robb L, Butt W. Brain stem encephalitis due to herpes simplex virus. *Aust Paediatr J* **1989**;25:246–247
26. Enzmann DR, Ranson B, Norman D, Talberth E. Computed tomography of herpes simplex encephalitis. *Radiology* **1978**;129:419–425
27. Lester JW, Carter MP, Reynolds TL. Herpes encephalitis: MR monitoring of response to acyclovir therapy. *J Comput Assist Tomogr* **1988**;12:941–943
28. Donohue WL, Playfair FD, Whitaker L. Mumps encephalitis: pathology and pathogenesis. *J Pediatr* **1955**;47:395–412
29. Tarr RW, Edwards KM, Kessler RM, Kulkarni MV. MRI of mumps encephalitis: comparison with CT evaluation. *Pediatr Radiol* **1987**;17:59–62
30. Modi G, Campbell H, Brill P. Subacute sclerosing panencephalitis. *Neuroradiology* **1989**;31:433–434
31. Tsuchiga K, Yamanchi J, Furui S, Suda Y, Takenaka E. Mr imaging vs. CT in subacute sclerosing panencephalitis. *AJNR* **1988**;9:943–946
32. Lukes SA, Norman D. Computed tomography in acute disseminated encephalomyelitis. *Ann Neurol* **1983**;13:567–572
33. Sheldon JJ, Siddharthan R, Tobias J, Sherenata WA, Soila K, Viamonte M. MR imaging of multiple sclerosis: comparison with clinical and CT examinations in 74 patients. *AJR* **1985**;145:957–964
34. Atlas SW, Grossman RI, Goldberg HI, Hackney DB, Bilaniuk LT, Zimmerman RA. MR diagnosis of acute disseminated encephalomyelitis. *J Comput Assist Tomogr* **1986**;10:798–801
35. Dunn V, Bale JF, Zimmerman RA, Perdue Z, Bell WE. MRI in children with postinfectious disseminated encephalomyelitis. *Magn Reson Imaging* **1986**;4:25–32
36. Kuharik MA, Edwards MK, Farlow MR et al. Gd-enhanced MR imaging of acute and chronic experimental demyelinating lesions. *AJNR* **1988**;9:643–648
37. Classification for human immunodeficiency virus (HIV) infection in children under 13 years of age. *MMWR* **1987**;36:225–236
38. Belman AL, Diamond G, Dickson D, et al. Pediatric acquired immunodeficiency syndrome: neurologic syndromes. *Am J Dis Child* **1988**;142:29–35
39. Bradford BF, Abdenour GE Jr, Frank JL, Scott GB, Beerman R. Usual and unusual radiologic manifestations of acquired immunodeficiency syndroms (AIDS) and human immunodeficiency virus (HIV) infection in children. *Radiol Clin North Am* **1988**;26:341–353
40. Price DB, Jacobs J, Haller JO, et al. Pediatric AIDS: neuroradiologic and neurodevelopmental findings. *Pediatr Radiol* **1988**;18:445–448
41. Chamberlain MC, Nichols SL, Chase CH. Pediatric AIDS: Comparative cranial MRI and CT scans. *Pediatr Neurol* **1991**;7:357–362