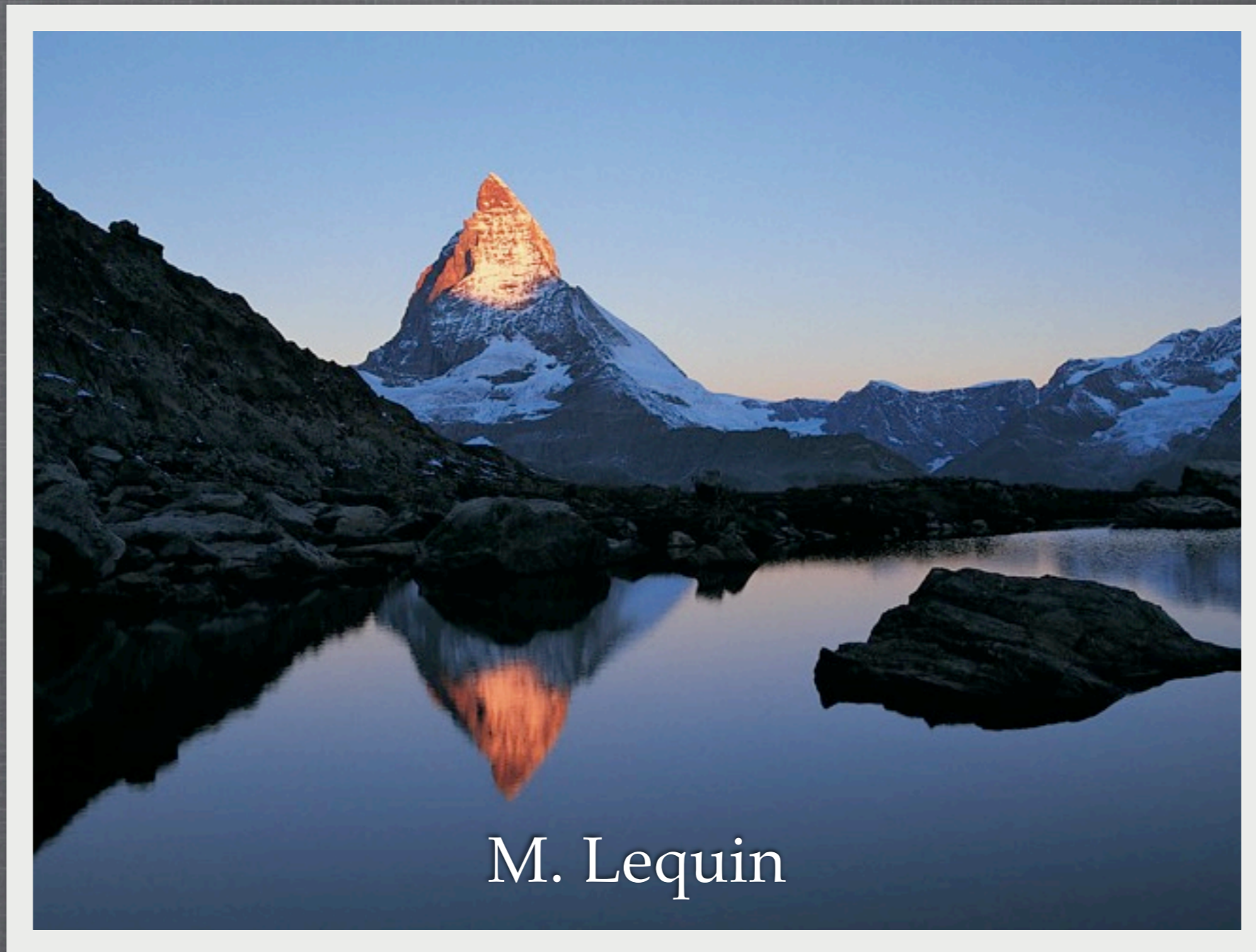


Imaging findings in CNS infections and differential diagnosis



OUTLINE

- Introduction and terminology
- Diagnosis & Differential diagnosis
- Pediatric brain infections
 - viral infections
 - Meningitis
 - Encephalitis acute / chronic
 - bacterial infections
 - Meningitis / cerebritis-abscess / empyema / TB / Lyme
 - fungal infections
 - parasitic infections
- Conclusion

Neuroimaging of Pediatric Intracranial Infection—Part 1:
Techniques and Bacterial Infections

Joshua P. Nickerson, MD, Beat Richner, MD, Ky Santy, MD, Maarten H. Lequin, MD, Andrea Poretti, MD,
Christopher G. Filippi, MD, Thierry A.G.M. Huisman, MD

Neuroimaging of Pediatric Intracranial Infection—Part 2: TORCH,
Viral, Fungal, and Parasitic Infections

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INTRODUCTION

- Pediatric brain infections are:
 1. mostly viral
 2. meningitis > encephalitis
- CNS is vulnerable to infectious agents due to
 3. lack of a true lymphatic system
 4. little resistance to infection offered by the subarachnoid space
 5. CSF facilitates infection spread the brain and into the ventricles
- Early diagnosis is important due to the risk of permanent damage in survivors

TERMINOLOGY

- CEREBRITIS

1. Focal inflammation of the brain
2. bacterial infections

- MYELITIS

3. Focal inflammation of the spinal cord

- ENCEPHALITIS

4. Diffuse inflammation throughout the brain
5. Viral infection

TERMINOLOGY

■ MENINGITIS

1. Pachymeningitis: involves the pachymeninges (dura mater), manifests usually as epidural or subdural EMPYEMA
2. Leptomeningitis: involves the leptomeninges (pia mater and arachnoid), manifests as inflammatory exudate of the pial and arachnoid membranes, more frequent than pachymeningitis

TERMINOLOGY

- ABSCESS

1. Suppurative inflammatory process with central liquefactive necrosis, encased by granulation tissue
2. Endstage of an untreated cerebritis
3. Bacterial infection

DIAGNOSIS

- How to diagnose a pediatric brain infection?
 1. clinical picture
 2. laboratory findings
 3. imaging

CLINICAL PICTURE

- Non-specific but often severely ill

- neonates

fever, lethargy, stupor, seizures,..

- older children

fever, headache, seizures, meningeal signs,..

LABORATORY FINDINGS

- CSF

1. elevated WBC (lymphocytes in viral infection)
2. elevated protein
3. positive PCR (viral: herpes, enterovirus)

- Blood

1. increased ESR
2. increased WBC (leucocytosis)

IMAGING

- MR is imaging modality of choice
- Protocol:
 1. Axial/coronal T2 FSE
 2. 3D T1 gradient echo -/+ Gd (FS)
 3. 3D FLAIR (>2 years)
 4. Axial DWI
 5. Optional: SWI, ASL and MRS

CONGENITAL BRAIN INFECTIONS

- ToRCH

1. Toxoplasmosis
2. Rubella
3. Cytomegalovirus
4. Herpes simplex virus type 2

hematogeneous transmission may occur at any time during gestation or occasionally at the time of delivery via maternal-to-fetal transfusion

- Congenital HIV

in utero, at the delivery or by breastfeeding

VIRAL INFECTIONS

- Viral meningitis (mostly enterovirus)
normal imaging findings
- Acute encephalitis
HSV and many others: CMV, EBV, VZV (chickenpox), ..
- Subacute and chronic encephalitis
Rasmussen encephalitis
subacute sclerosing panencephalitis
- Postinfectious encephalitis
ADEM

HERPES ENCEPHALITIS

- Most common encephalitis, especially in children
- HSV type 1 (>3 months)
- Fever, vomiting, headache, behavioral disturbances, lethargy and seizures
- Positive PCR in CSF

HERPES ENCEPHALITIS

- MR more sensitive than CT
- Hyperintense T2 areas in the temporal lobe, insular cortex, orbital surface of the frontal lobe and cingulate gyrus
- Petechial hemorrhages
- variable enhancement after 3 days (gyral pattern)
- DD in bilateral temporal involvement:
limbic encephalopathy, SLE, gliomatosis cerebri,
enteroviruses

VARICELLA ZOSTER ENCEPHALITIS

- Chickenpox
- Acute cerebellar ataxia often around 10 days onset of the rash
- varicella specific IgM in serum or PCR in CSF
- MRI:
 1. Acute cerebellitis, swelling and T2 hyperintensity
 2. Small vessel arteriopathy
 3. Basal ganglia infarctions due to vasculitis, often unilateral (after 1-12 months)

VIRAL INFECTIONS

- Viral meningitis (mostly enterovirus)
normal imaging findings
- Acute encephalitis
HSV and many others: CMV, EBV, VZV (chickenpox), ..
- **Subacute and chronic encephalitis**
Rasmussen encephalitis
subacute sclerosing panencephalitis
- Postinfectious encephalitis
ADEM

RASMUSSEN ENCEPHALITIS

- Progressive disease
- Age peak:6-8 yrs
- Etiology still unclear (viral?, autoimmune?)
- severe epilepsy, hemiplegia
- typical unilateral
- lesions in basal ganglia
- cerebral cortical swelling (insular) with progressive atrophy

SSP ENCEPHALITIS

- slow virus infection several years after primary measles infection (before the age of 2 years)
- rare due to vaccination
- age peak: 7-9 y
- Progressive psychoneurological deterioration → death within 3 years
- Different stages:
 1. Normal imaging 3-4 months after onset
 2. Patchy asymmetrical T2 hyperintensities in parietotemporal areas (first peripheral cortex and WM, later deep WM and CC)

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BACTERIAL INFECTIONS

- Bacterial meningitis
- Bacterial cerebritis / brain abscess
- Empyema
- Tuberculosis
- Lyme disease (neuroborreliosis)

BACTERIAL MENINGITIS

- Most common pediatric infection
- More in (premature) neonates than infants
- One of the most severe infectious processes
- Etiology agents vary with the age of the patient
- Neonates: group B streptococcus (45-50%), E coli (15-20%), Staph., Listeria, ..
- Children: H.influenzae, Neisseria meningitidis, Strept. pneumoniae, ..



BACTERIAL MENINGITIS

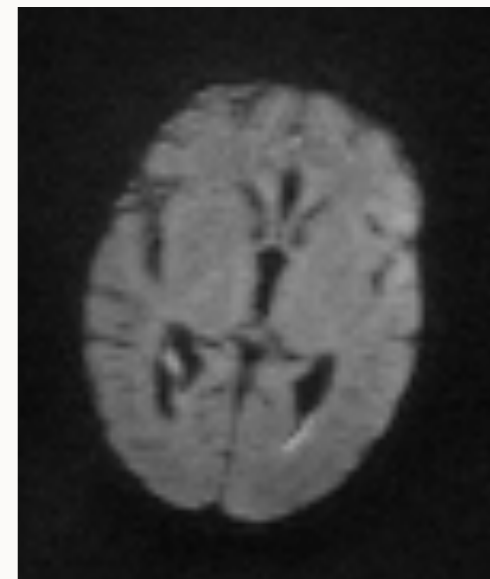
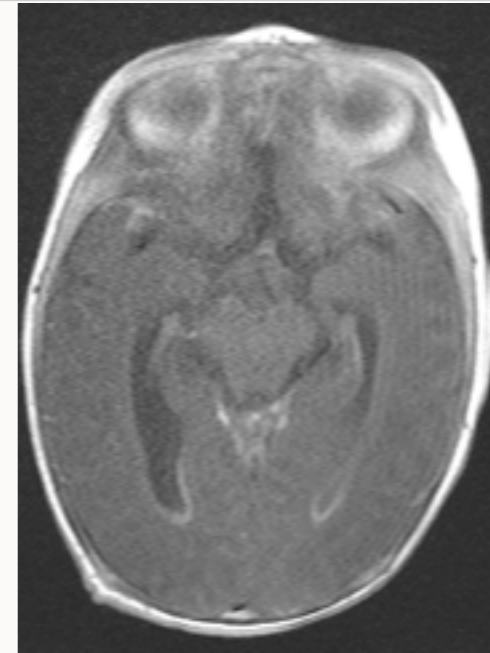
- Diagnosis using clinical signs and CSF
- MR imaging when unclear, non responsive to therapy or when complications occur
- Mechanism:
 1. Hematogenous spread (choroid plexus)
 2. Direct implantation (traumatic, CSF leak, ..)
 3. local extension (sinusitis, mastoiditis, otitis,..)
 4. Spread along the peripheral nervous system

BACTERIAL MENINGITIS

- Imaging:
- Depends on neuropathologic stage
- May rapidly change from normal to severe edema, destruction in a few days and to multiple infarcts and atrophy in a few weeks (especially in the newborns due to the vulnerability of the immature brain)

BACTERIAL MENINGITIS

- Stage 1 / 2: choroid plexitis / ventriculitis
- plexus adhesions to ventricular wall
- ependymal thickening and enhancement
- intraventricular debris
- hydrocephalus due to obstruction
- periventricular edema



BACTERIAL MENINGITIS

- Stage 3: arachnoiditis
 1. purulent exudation in the subarachnoid space covers the cranial base (*H. Influenzae*) or sometimes the cerebral convexity (pneumococcal meningitis)
 2. dural or leptomeningeal enhancement

BACTERIAL MENINGITIS

- Stage 4: vasculitis (perivascular spaces)
 1. always present in neonatal bacterial meningitis
 2. infarction preferential at the cerebral cortex and subcortical white matter but also basal ganglia and periventricular WM.
 3. Cerebral infarct are seen in up to 30% of patients with bacterial meningitis
 4. Arteritis or (thrombo)phlebitis

BACTERIAL MENINGITIS

- Stage 5: cerebral edema
 1. primarily related to vasculitis (vasogenic edema due to BBB changes) but may be complicated by cytotoxic and interstitial edema
 2. brain herniation is rare because distensibility of the neonatal vault
 3. initially vasogenic due to vasculitis and increased permeability of blood vessels

BACTERIAL MENINGITIS

- Acute stage complications:
 1. parenchymal gliosis, neuronal loss
 2. subdural effusions (sterile: toxin-induced increased permeability of capillaries and veins, resolve spontaneously)
 3. brain abscess (superimposed infection of ischemic lesions, seen in *Citrobacter*, *Proteus* and *Staph. Aureus*)

BACTERIAL MENINGITIS

- Chronic complications:

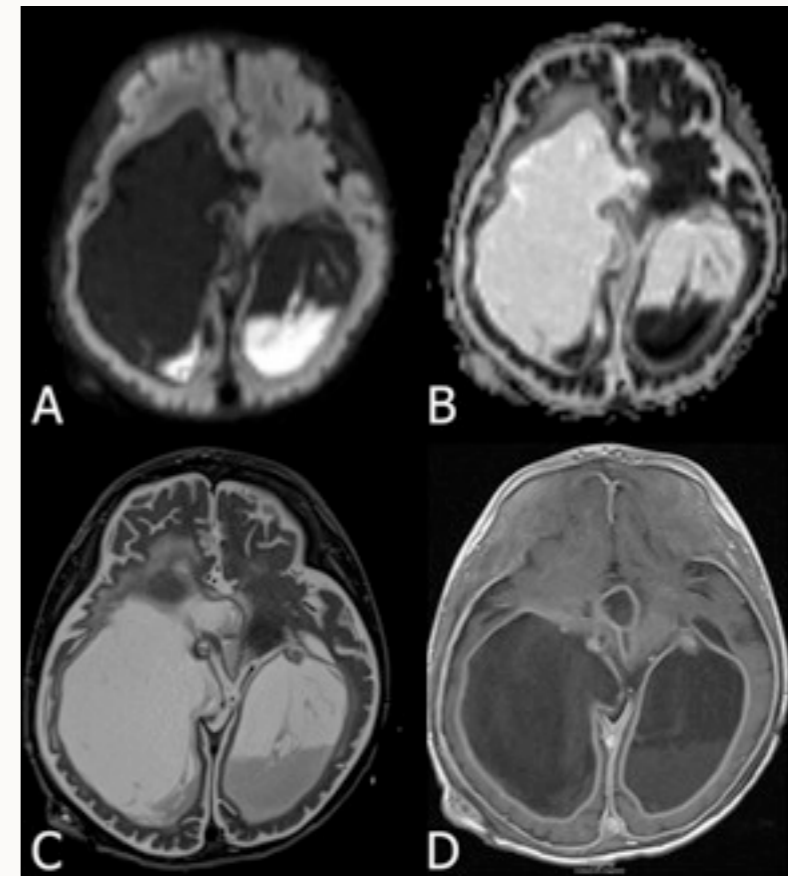
1. hydrocephalus (often communicating)

2. multicystic encephalomalacia

3. porencephaly

4. atrophy

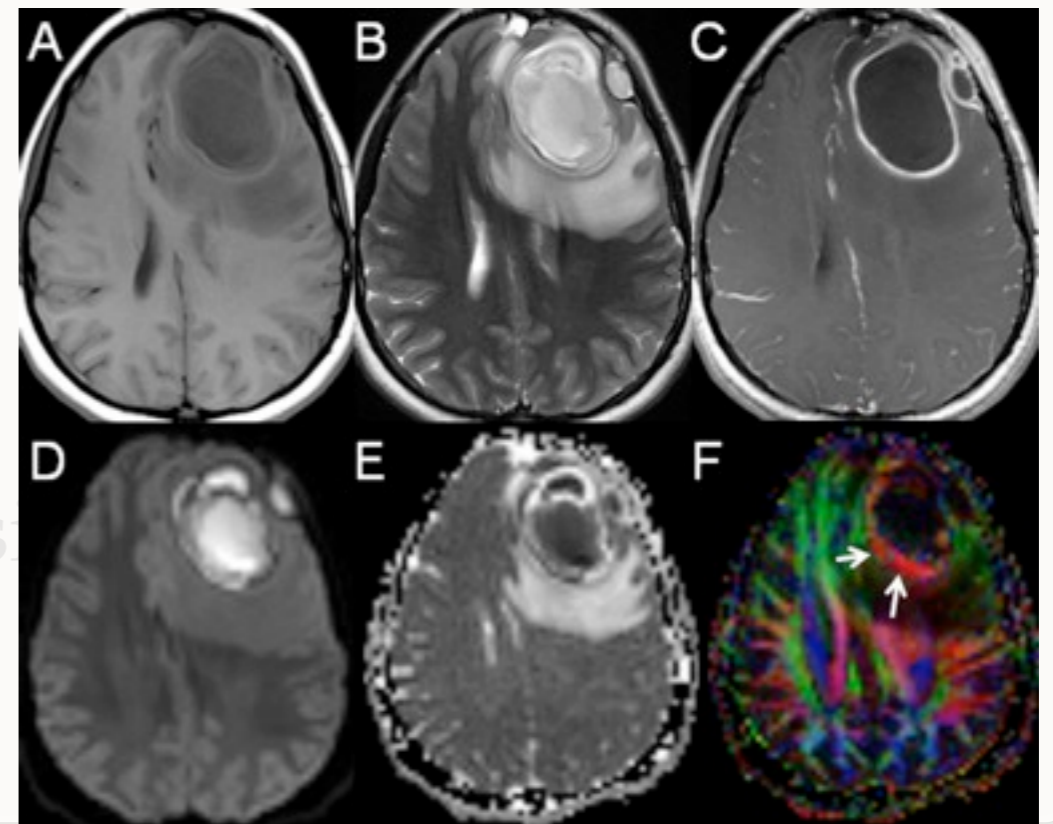
 May lead to brain death



courtesy to A. Poretti

BACTERIAL INFECTIONS

- Bacterial meningitis
- **Bacterial cerebritis / brain abscess**
- Empyema
- Tuberculosis
- Lyme disease (neuroborreliosis)



CEREBRITIS

- Uncommon
- Early stage of focal purulent brain infection
- Early cerebritis stage: ill defined area of T2 hyperintensity with patchy enhancement
- Late cerebritis stage: evolution to abscess
- Surgery contra-indicated

BRAIN ABSCESS

- uncommon in children, but often large
- 2/3 in neonates
- Citrobacter, Proteus, Pseudomonas, Serratia, Staph. aureus, Streptococcus, Pneumococcus, Candida, toxoplasmosis,..
- must be differentiated with necrotic tumors by DWI and MRS
- MRS may show lactate, lipids, acetate and succinate peaks and aminoacid peaks

EMPHYEMA

- Rare purulent extracerebral collection
- Neurosurgical emergency
- Epidural due to frontal sinusitis or mastoiditis (lentiform shape)
- Subdural after neurosurgery or trauma (crescent shape)
- No vasogenic edema, reduced diffusion
- Peripheral enhancement

BACTERIAL INFECTIONS

- Bacterial meningitis
- Bacterial cerebritis / brain abscess
- Empyema
- **Tuberculosis**
- Lyme disease (neuroborreliosis)

TUBERCULOSIS

- Tuberculous meningitis:

1. basal leptomeningitis

thick enhancing exudate obliterates the basal cisterns

often communicating hydrocephalus

infarctions (due to vessel invasion), mostly basal ganglia and thalami

2. most children have also parenchymal lesions

TUBERCULOSIS

- Tuberculomas:

mostly supratentorial

usually smaller than 2 cm

caseating tuberculous granulomas

disseminated tuberculosis

multiple small nodular enhancing lesions with edema

- Tuberculous abscess rare

BACTERIAL INFECTIONS

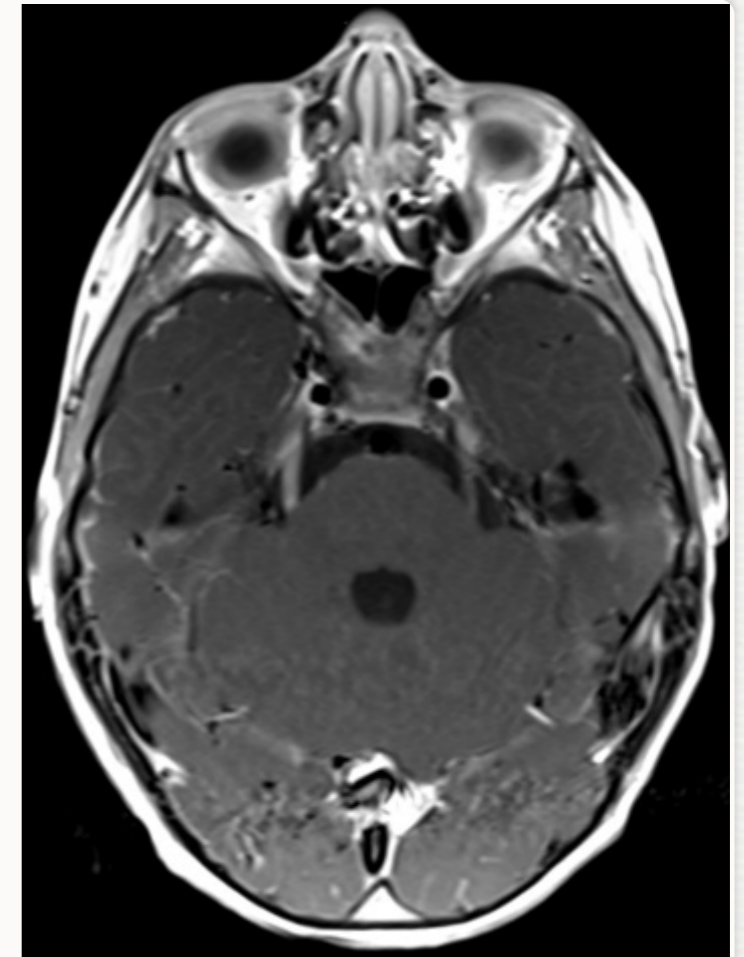
- Bacterial meningitis
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- Empyema
- Tuberculosis
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LYME DISEASE

- Borrelia (Burgdorferi)
- Neuroborreliosis = rare manifestation of late Lyme disease
- General symptoms: erythema migrans, flu-like symptoms
- Neuroborreliosis symptoms: headache, sleeping disorders, papilledema, cranial nerve abnormalities

LYME DISEASE

- MR imaging:
 1. often negative
 2. prominent Virchow-Robin spaces
 3. hyperintense WM lesions (MS-like)
 4. meningeal and cranial nerve enhancement
- Milder course in children than in adults



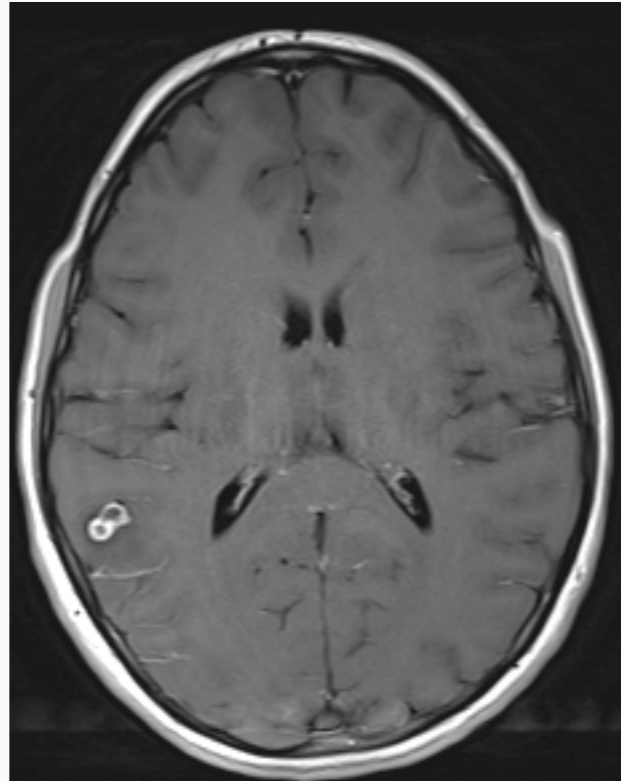
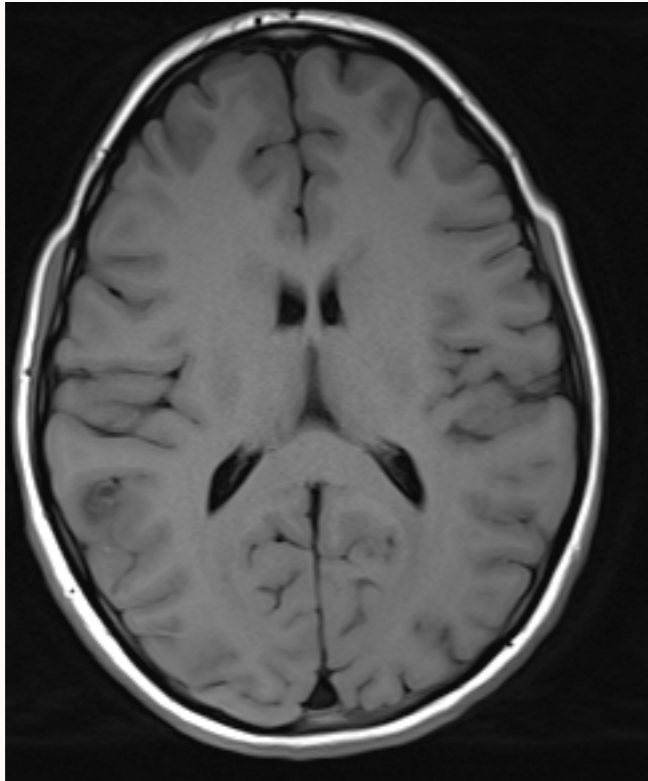
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FUNGAL INFECTIONS

- uncommon in children
- more in immunosuppressed patients
- meningitis > meningoencephalitis, abscess
- Cryptococcus: meningitis > granuloma
- Candida: meningitis, multiple micro-abscesses
- Aspergillus: often hemorrhagic abscesses (hypo on T2), ring enhancement

PARASITIC INFECTIONS

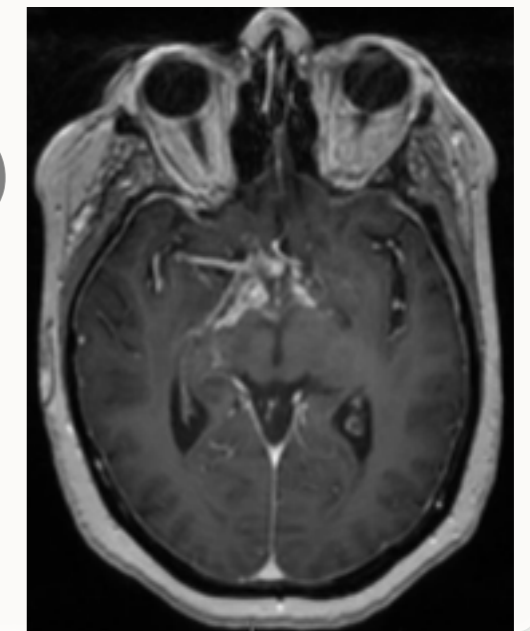
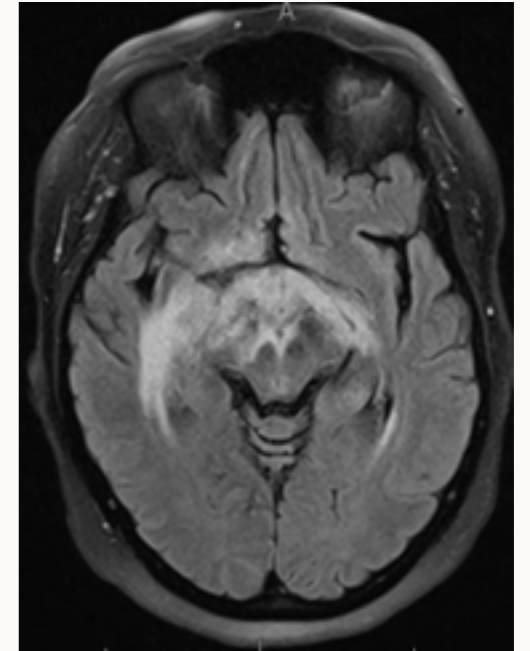


- Neurocysticercosis
- Echinococcosis



SARCOIDOSIS

- Systemic granulomatous disorder
- Unknown origin
- CNS involvement 5-10%
- Uncommon in children
- Facial nerve involvement (>N II and VIII)
- Granulomatous leptomeningitis
- Diagnosis by exclusion



CONCLUSION

- Clinical picture and laboratory findings are more important than imaging
- Differentiating infection from other pathology
- Imaging findings:
 1. depend on the age group
 2. depend on the pathogen
 3. often non-conclusive
- MR protocol should include:
 - T1 with contrast (and FS)
 - DWI