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Pediatric Neurological Emergencies

2022 WRHEPC Pediatric Emergency Preparedness

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Objectives

- Highlights of relevant history and neurological exam in pediatric neurological emergencies
- Hemorrhage (NAT; SDH, SAH)
- Seizure disorders (febrile, neonatal, status epilepticus, epilepsy)
- Neuropharmacology
- Closed head injury/trauma (herniation, concussion, HA)
- Infection/inflammatory (meningitis, encephalitis, ADEM, GBS)
- Vascular (stroke, sinus venous thrombosis), FNDs
- Ingestions and Genetic/Metabolic diseases
- Imaging and diagnostics
- Take Home Points

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Comprehensive Neurological History and Physical Exam

- History-taking; timelines, descriptors, numbers, collateral!
- Physical exam:
  - Mental status
  - Cranial Nerve (including fundoscopy)
  - Motor (strength, bulk, tone), sensory, DTRs, cerebellar, gait/ambulation
- Medications currently taking (if relevant)
- Differentials based on H&P!

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Case #1

- 2 years old male presents to ED with decreased PO intake.
- On observation, he is fussy and makes poor eye contact.
- Multiple scattered bruises noted on face, legs and buttocks (all different colors and stages of healing) that mom associates with him being a “wild boy”.
- Small, circular, well circumscribed lesions on dorsum of hands b/l.
- Mom denies infectious symptoms.

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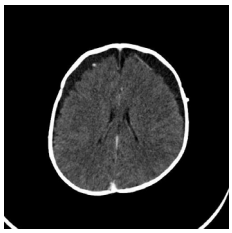
Non-Accidental Trauma (NAT)

- Child abuse and neglect occur in approximately 9.2 of every 1000 children, with the highest rates in children <1 year
- Increased susceptibility to shearing forces in younger infants; spinal cord risk of stretch or subluxation injury
- Present with variety of symptoms: lethargy, decreased PO/UOP, seizures (SE)
- Workup: BGT, CBC, CMP, Mg, PO4, UA, +/- Cxs, NCHCT, **skeletal survey,** comprehensive physical exam with **fundoscopy** (look for retinal hemorrhages)



Roselyn A. et al.; *Pediatrics* March 2021
Gunda, D. et al., *Radiographics*,2018

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Non-Accidental Trauma (NAT)

- Inconsistent history of injury
- Delay in presentation
- Reported mechanism insufficient or inappropriate to explain injury
- Caregivers can appear in a variety of ways – hostile vs. indifferent

Risk Factors	
Care Giver Factors	• Criminal History • Mental Health History • Substance Abuse • Young/Single Parent • Former Victims of Abuse/neglect
Child Factors	• Young Age • Behavioral Problems • Chronic Illness or Disability • Non-biologic Relationship to Caretaker • Prematurity/low Birth weight
Family and Environmental Factors	• High local unemployment • Intimate partner violence in the home • Poverty • Social Isolation • Lack of social supports

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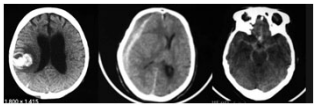
Hemorrhage



- Subdural (SDH)
  - Tearing of bridging veins d/t shearing forces
  - Retinal hemorrhages
- Epidural
  - Direct trauma
- Subarachnoid (SAH)
  - Trauma or spontaneous

Hart, R. et al., Stroke, 2012

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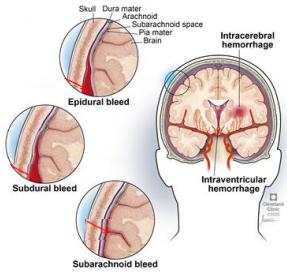
Pediatric Intracranial Hemorrhage



Boulouis, G. et. Al, Stroke, 2019
Preboth M. Am Fam Physician. 1999

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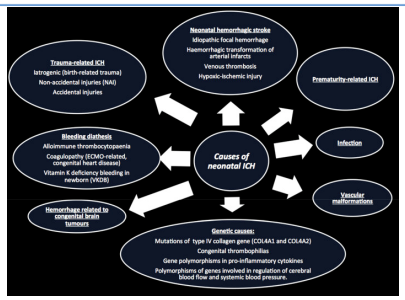
Causes of neonatal ICH



Tan, A.P., et al. *European Journal of Pediatric Neurology*, 2018

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Seizures: Introduction

- A paroxysmal disorder of the CNS characterized by an abnormal neuronal discharge resulting from excessive hypersynchronous discharges of the cortical neurons in the gray matter associated with a change in function of the patient.
- 5%-8% of pediatric-aged patients; highest risk occurring during infancy and early childhood.
- *Epilepsy* is a chronic seizure disorder characterized by recurrent (**at least more than 2**) unprovoked (or reflex) seizures >24h apart, usually in a person who has a predisposition.
  - Posttraumatic epilepsy - occurs in ~25% to 30% of pediatric victims of moderate/severe traumatic brain injury (TBI)

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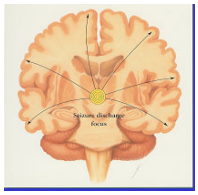
Categorization of Epilepsy

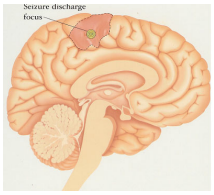
GENERALIZED

- Begin in both hemispheres



PARTIAL

- Begin in 1 or more foci



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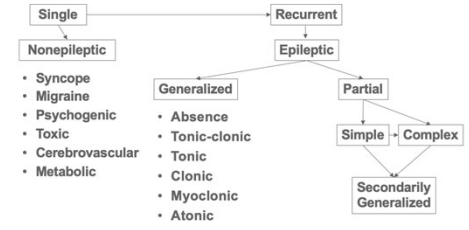
Types of Seizures



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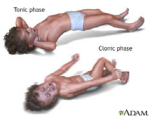
Febrile Seizures

- Febrile seizures are the most common type of pediatric seizure and occur in patients between 6 months and 5 years of age.
- Simple: Most common, No focal findings, 1x/24h
- Complex: >15 minutes, >1/24h, total duration in a series >30 minutes, focal findings, paresis
- 33% risk of recurrence (younger, lower temp with first episode)
- <5% develop epilepsy
- Labs/diagnostics: source of infection, generally no CTH indicated
- Consider LP: 6-12mo, s/p abx, complex, AMS, infectious appearing



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Neonatal Seizure

- First few days of life (<28d)
- The most common cause is hypoxic-ischemic injury (60%-70%).
- congenital anomalies, hemorrhage, hypoglycemia, hypocalcemia, infection, drug withdrawal, pyridoxine deficiency
- Brief and subtle: blinking excessively, mouth/tongue movements, “bicycling motion” with extremities
- Autonomic changes (HR, BP)
- EEG more predictable with MRI
- Epilepsy: Benign Familial, Ohtahara
- Diag: U/S -> MRI -> CT

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Case #2

- 8yo M who is presenting with seizure-like activity. Mom said that he ate dinner and was completely fine. Around 8pm, he was sitting on the couch watching TV and mom noticed that his head seemed to fall back; his eyes rolled back and he was not responsive. B/L UE made a jerking movement, repeatedly, and his b/l LE seemed to stiffen. Lasted <5 mins and self-resolved. He was confused after and just when mom thought he was coming to, his eyes rolled back again and his whole body stiffened. He started making grunting sounds, so she called 911 and he was brought to the ED immediately…

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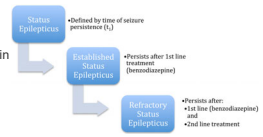
Status Epilepticus



The *underlying disorder* causes the morbidity and mortality seen in SE rather than the timing of seizure.

- The goal of treating prolonged seizures is to prevent morbidity and mortality.
- In older children **(>5 years old)** refers to **≥5** minutes of:
  - continuous seizure OR
  - two or more discrete seizures between which there is incomplete recovery of consciousness.

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Status Epilepticus

- Common pediatric neurologic emergency estimated to affect between 25,000 to 50,000 children annually, and 40% of all instances will occur in children under age 2.
- Overall mortality of up to 3% and survivors have an increased risk of subsequent epilepsy, reported to be between 13% and 74%.
- Recurs in approximately 20% of cases within 4 years of initial presentation, with most recurrences occurring during the first 2 years.
- Can become refractory (RSE)
- ~2% of total admissions to UB PICU.

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Neurophysiology

- Status epilepticus may be divided into two stages:
  - First stage (within first 30 minutes) - Increase in neuronal metabolic demand occurs with a compensatory increase in CBF and brain oxygenation. Increased autonomics: hypertension, tachycardia, hyperglycemia, diaphoresis, and hyperpyrexia.
  - Second stage - Homeostatic mechanisms are unable to keep up with the sustained increase in cerebral metabolic demand leading to failure in autoregulation. Multiorgan involvement: decreased CBF, increased ICP, hypotension and respiratory failure (hypoxemia, hypercarbia).

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Etiology

- Seizures and status epilepticus recurrence are influenced by the underlying etiology, with structural or metabolic lesions associated with the highest risk

BOX 67.1 Common Causes of Seizures in the Pediatric Intensive Care Unit

Stroke/arteriovenous malformation/ hemorrhage	Hypoxia and ischemia
Tumor	Fever and febrile seizures
Meningitis/encephalitis/abscess	Drug toxicity and withdrawal
Vasculitis	Renal/hepatic dysfunction
Traumatic brain injury	Metabolic: ↑↓ glucose
Preexisting epilepsy	↑↓ Sodium
Antiepileptic agent withdrawal or change	↑↓ Calcium
Postoperative craniotomy	↑↓ Serum osmol
Genetic CNS disorders	Hypertensive encephalopathy
Cerebral malformation	Neurocutaneous syndromes

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Evaluation

- EEG: measures extracellular electrical activity generated by cortical neurons via standard array of scalp electrodes and presented for visual display onto a paper or digital record.
- Provides real-time information regarding brain activity permitting direct correlation between patient behavior and neuronal activity.
- Abnormal waveforms on EEG can be divided into two categories:
  - Epileptiform abnormalities: EEG Seizures; abnormal discharges associated with an increased risk of seizures, including sharp waves, spikes, polyspikes, and spike and slow wave discharges.
  - Nonepileptiform abnormalities - Suggestive of CNS dysfunction.

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Evaluation

- Additional patterns:
  - Burst suppression - characterized by brief bursts containing a mixture of spikes, sharp waves, and slow waves alternating with periods of very low voltage.
  - Isoelectric EEG - continuous low-voltage record without any discernable cortical activity.
- Seen in patients in a coma (or other severe disorder of consciousness) and may carry a poor prognosis in certain clinical situations.
- In RSE, these patterns are often medically induced end point for treatment with high-dose barbiturates or benzodiazepines.

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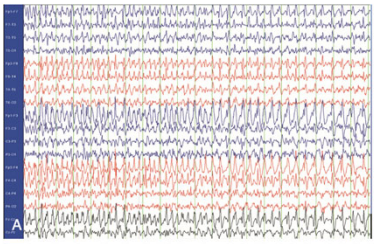

- Generalized seizures are characterized by widespread bilateral rhythmic epileptiform discharges.

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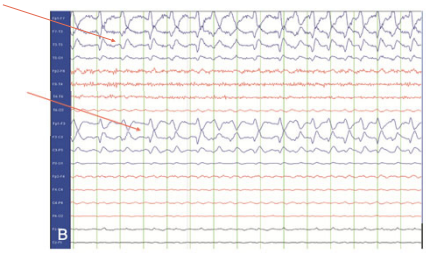

- Focal seizures are characterized by rhythmic epileptiform discharges that are confined to one brain region.

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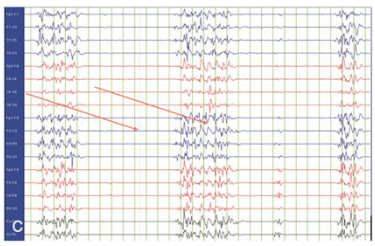

- Burst-suppression pattern in a patient treated with a midazolam infusion for refractory SE.

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Evaluation

- Nonconvulsive status epilepticus (NCSE) should be considered in patients who do not quickly return to their baseline; incidence of NCSE in pediatrics is currently unknown.
- Presents with AMS and absent or subtle motor findings (eg, finger twitch) and is therefore defined by EEG criteria.
- Ictal episodes must be continuous or recurrent for at least 30 minutes without improvement in the patient's clinical state.
- Routine EEG recording will fail to identify most children who go on to develop seizures, justifying the need for **continuous video EEG monitoring** to accurately diagnose seizures and quantify seizure burden, when appropriate.

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Evaluation

- Diagnostic testing in children and adolescents with status epilepticus varies among centers, likely reflecting the limited evidence supporting most diagnostic approaches.
- Lab work:
  - Serum glucose.
  - Serum electrolytes (sodium, calcium, and magnesium).
  - Liver function tests.
  - Arterial blood gas.
  - Urine toxicology.
  - Antiepileptic levels.
  - +/- Blood cultures and lumbar puncture

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Management

- ~75% are self-limited and stop in less than 5 minutes - reasonable to assume that most children who arrive at the ED or PICU have been seizing for a significant length of time.
  - The new operational status epilepticus definition suggests the administration of medication for seizures lasting longer than 5 minutes (used to be 20 minutes)
- Respiratory depression on arrival: consider Diastat (rectal), Valtoco (nasal), Versed (nasal) administration by EMS/family members
- Simultaneous evaluation and management
- Therapeutic goals for SE: general supportive care (ABCs), termination of status epilepticus, prevention of seizure recurrence, correction of precipitating causes, prevention and treatment of potential complications.

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Management

- In current practice, there is substantial variability in the initial management of SE
- First-line: benzodiazepines (lorazepam, diazepam, and midazolam).
- Second-line: phenytoin, fosphenytoin, levetiracetam, and phenobarbital
- Common errors in management: insufficient drug dosages, delay in advancing to a second-line drug, and inadequate supportive care.

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Pharmacotherapy

- Lorazepam is used more often due to minimal side effects (less lipophilic than diazepam causing a slower onset of action)
  - Advantage: prolonged antiepileptic effect of >6 hours vs. <1 hour for diazepam.
- Midazolam may be used as a continuous infusion for RSE.
  - Advantage: short-acting BZD with duration of effect shorter than lorazepam.
- All of the benzodiazepines have the potential to cause respiratory depression and hypotension.
  - Decreased anti-seizure activity if multiple dosages required.
  - Repeated doses of BZDs will have additive sedating effects.

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Benzodiazepines (BZD)

- All three benzodiazepines have an onset of action of less than 5 minutes and same MOA (inhibitory neurotransmission by binding to a specific BZD site on the GABA-R)
- Diazepam and lorazepam were compared in a study funded by the National Institutes of Health (NIH) and coordinated by the Pediatric Emergency Care Applied Research Network (PECARN) to determine which drug is safer and more effective.
  - Neither was superior for pediatric SE of at least 5 minutes in duration.
  - Both were effective in more than 70% of cases and had rates of severe respiratory depression of less than 20%.

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Fosphenytoin

- Fosphenytoin, (water-soluble disodium phosphate ester of phenytoin), is converted in plasma to phenytoin; both are preferred second-line, (longer-acting) AEDs for the treatment of SE.
  - effect by stabilizing the neuronal membrane and achieve therapeutic effect at ~20 minutes.
  - compatible with most IV solutions, is devoid of propylene glycol
    - administered at a faster rate and without the CV risks or deleterious effects on tissue as seen with phenytoin (extravasation), nor does it cause respiratory depression or sedation.

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Phenobarbital (PB)

- Phenobarbital is an effective anti-epileptic drug, commonly used to treat neonatal seizures and status epilepticus.
- Potential side effects: respiratory depression, hypotension, bradycardia, and prolonged sedation.
- Prolonged sedation can impair neurologic assessment and is a significant disadvantage of PB when compared to fosphenytoin and phenytoin.
- Additionally, the combination of a BZD and PB often necessitates endotracheal intubation because of respiratory depression.
- Dose: 20 mg/kg/ load followed by maintenance 5 mg/kg/day, divided by 2 doses

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Levetiracetam (Keppra)

- Mechanisms of Action: Binds to a presynaptic vesicle glycoprotein (sv2A) to act as a transporter for presynaptic P/Q type voltage-dependent calcium channels.
- It has been considered a potentially useful agent for SE because, in comparison with other IV AEDs, it has few known side effects, including a low risk of sedation, cardiorespiratory depression, or coagulopathy, and thus it is potentially useful in critically ill children.
- Clearance is dependent on renal function and completely avoids hepatic metabolism.
- Dose in SE: 40-60 mg/kg/dose, followed by maintenance
- Common Side effect in children: behavioral difficulties

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Valproic acid (VPA)

- Valproic acid is a common antiepileptic drug with case series describing the use of intravenous VPA for treatment of SE and RSE.
- Possible mechanisms of action include an increase in CNS GABA levels by increased synthesis and decreased catabolism, blockade of T-type Ca++ currents, and enhancement of Na+ channel inactivation.
- Dose in SE: 40 mg/Kg/loading dose followed by daily maintenance
- Monitor: LFT, Ammonia, rare risk of pancreatitis

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Status Epilepticus Protocol

Immediate management
- Noninvasive airway protection and gas exchange with head positioning
- Intubation if needed
- Monitoring O_2 saturation, blood pressure, heart rate, temperature
- Finger stick blood glucose
- Peripheral IV access
- Medical and neurologic examination
- Labs: BMP, magnesium, phosphate, CBC, LFT, coagulation tests, ABG, anticonvulsant levels

Emergent initial therapy (given immediately)
- IV: Lorazepam 0.1 mg/kg IV (max 4 mg)—may repeat if seizures persist
- No IV:
  - Diazepam 2–5 years 0.5 mg/kg, 6–11 years 0.3 mg/kg, 12 years 0.2 g/kg (max 20 mg)
  - Midazolam IM If 13–40 kg then 5 mg. If >40 kg then 10 mg
    Intranasal 0.2 mg/kg
    Buccal 0.5 mg/kg
- Consider whether out-of-hospital benzodiazepines have been administered when considering how many doses to administer

Urgent management
- Additional diagnostic testing as indicated: LP, CT, MRI, toxicology labs, inborn errors of metabolism
- Consider EEG monitoring (evaluate for psychogenic status epilepticus or persisting EEG-only seizures)
- Neurologic consultation

Urgent control therapy
- Phenytoin 20 mg/kg IV (may give another 10 mg/kg if needed)—may cause arrhythmia, hypotension, purple glove syndrome
- OR Fosphenytoin 20 PE/kg IV (may be given another 10 PE/kg if needed)
- OR consider phenobarbital, valproate sodium, or levetiracetam

If <2 years, consider pyridoxine 100 mg IV

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Status Epilepticus Protocol

Refractory status epilepticus

If seizures continue after benzodiazepines and a second antiseizure medication, the patient is in refractory status epilepticus regardless of elapsed time

Continue management and make plans for ICU admission/transfer. Expect need for continuous EEG monitoring once clinically evident seizures terminate to evaluate for persisting EEG-only seizures

Administer another urgent control anticonvulsant or proceed to pharmacologic coma
- Levetiracetam 20–60 mg/kg IV
- Valproate sodium 20–40 mg/kg IV—contraindicated if liver disease, thrombocytopenia, or possible metabolic disease
- Phenobarbital 20–40 mg/kg IV—may cause respiratory depression and hypotension

Pharmacologic coma medications
- Midazolam 0.2 mg/kg bolus (max 10 mg) and then initiate infusion at 0.1 mg/kg/hr. Titrate up as needed
- Pentobarbital 5 mg/kg bolus and then initiate infusion at 0.5 mg/kg/hour. Titrate up as needed
- Other options: Isoflurane

Pharmacologic coma management
- Titrate to either seizure suppression or burst suppression based on EEG monitoring
- Continue pharmacologic coma for 24–48 hours
- Modify antiseizure medications so additional seizure coverage is in place for infusion wean
- Continue diagnostic testing and implementation of etiology-directed therapy

Add-on options
- Medications: phenytoin, phenobarbital, levetiracetam, valproate sodium, topiramate, lacosamide, ketamine, pyridoxine
- Other: epilepsy surgery, ketogenic diet, vagus nerve stimulator, immunomodulation, hypothermia, electroconvulsive therapy

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Case #3

- Patient is a 13yo F with PMH asthma, who presented with severe HA.
- She was at her baseline last week and then in gym class, she was changing and slammed her head into the locker door as she was getting up from a bent forward position.
- She denies LOC, but she fell forward to the floor, vision got blurry, and she was a bit "out of it" for a while. She attempted to return to school the next day but was unable to focus and had HA throughout the entire day, with pain fluctuating between 5-8/10 in severity.

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Closed head injury/Structural Emergencies (herniation, concussion, headache)

- Headache
- Scalp injury
- Skull fracture (basilar)
- Concussion
- Contusion
- Hematoma
- Penetrating injury
- Diffuse axonal injury
- "Who ya gonna call?" → Trauma/SGY, NSGY!

Jessica Klein, *Pediatr Review*, 2020

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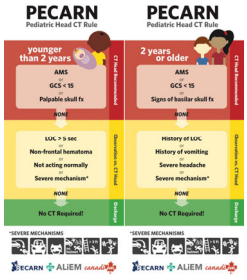
PECARN



Kuppermann N, Lancet. 2009

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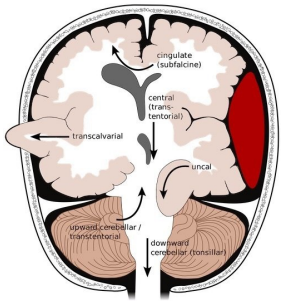
Herniation Syndromes



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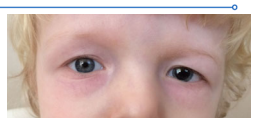
ICP/CHI



- **CPP = MAP – ICP**
- Symptoms of ICH: headache, nausea, vomiting, AMS
- Cushing triad (HTN, bradycardia, irregular respiration/apnea)
  - **Transtentorial (uncal):** LOC w/ ipsilateral pupillary dilation and contralateral hemiparesis (ascending arousal pathways, CN (III), and corticospinal tract)
  - Hypertonic saline (HTS) is the drug of choice for pediatric raised ICP
    - rule of 3's: 3mL/kg over 3 minutes.
  - Mannitol is administered as 0.5–1 g/kg intravenous (IV) bolus through a peripheral intravenous line and may be repeated every 4–6 h if serum osmolality is monitored [19]; no therapeutic benefit is appreciable with osmolality >320 mOsm/kg.

Stevens RD, et al, *Neurocrit Care*. 2015

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Case #4

- 18mo M presents with fever for 2 days. The fever has been "high grade fever" and he is inconsolable. This morning, mom endorsed a tonic-clonic seizure lasting 4-5 minutes.
- Since then, he has been lethargic with poor PO intake.
- On exam, T 102.5, hypertonic, neck stiffness with closed AF. Of note, mom mentioned that he missed most of his vaccinations in infancy.

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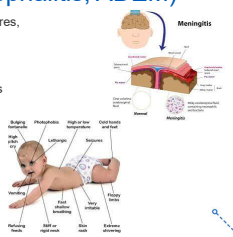
CNS Infection (meningitis, encephalitis, ADEM)

- CNS disease – Headache, nausea, vomiting, lethargy, seizures, paralysis/paresis in the context of a febrile illness
- Meningitis
  - Bulging AF, neck rigidity, Kernig's and Brudzinski's signs
  - Bacterial and viral predominant
  - Viral meningioencephalitis (e.g HSV)



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Infection/Inflammation

- Risk factors: unvaccinated, immunodeficient (nephrotic synd.), nasopharyngeal colonizers, chronic otitis media, meningiomyelocele
- General physical, neurological physical, ophthalmoscopy!

	Bact. Meningitis	Viral Meningitis
WBCs	> 1000 cmm	< 1000 cmm
Predominant differential cell	PMN	
Protein	↑↑↑	Normal or ↑
Glucose (better CSF / serum ratio)	↓	Normal

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Table 1. Most Common Bacterial Pathogens According to Age

Age Group	Bacterial Pathogens
0-1 mo (neonate)	GBS (*Streptococcus agalactiae*) *Escherichia coli* *Listeria monocytogenes*
1-3 mo	GBS *E coli* *L monocytogenes* *Streptococcus pneumoniae* *Neisseria meningitidis*
3 mo-3 y	*S pneumoniae* *N meningitidis* GBS *E coli* *L monocytogenes*
3-10 y	*S pneumoniae* *N meningitidis*
10-19 y	*N meningitidis*

GBS: group B streptococcus. Source: References 2, 4, 5.

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Post Infectious/ Inflammation

- ADEM (Acute Disseminated Encephalomyelitis) – inflammatory demyelinating disease with encephalopathy and multifocal brain lesions
  - 3yo-7yo, 0.2-0.4/100,000 annually
  - Monophasic, good recovery
  - Autoimmune, possibly post-infectious (measles, rubella, VZV, flu, EBV, HSV, enterovirus, coxsackie, mycoplasma, borrelia, GAS, COVID-19(?)

Yosha-Orpaz N, et al., *Journal of Child Neurology*. 2019
Wang, C.X.: *Pediatr Drugs*, 2021

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Vascular – Pediatric Stroke

- Affects 1/4,000 newborns + >2,000 pediatric patients per year
- Priority is confirmation of stroke rather than a stroke mimic, stroke pathogenesis, pathophysiology of the injury, and evaluation of recovery potential
- Most common sx: HA (same in SVT), emesis, focal neurological deficit – very difficult to emergently recognize (weakness, sensory change, vision loss or diplopia, speech changes, ataxia), seizure (neonates)
- Obtain true last known normal, Wt, BG, NIHSS
- Initial Imaging:
  - MRI DWI/FLAIR (<10 minutes), Non-contrast head CT (NCHCT), CT Angiogram (CTA), CT Perfusion (CTP)
  - Additional cerebral vessel imaging – MRA/MRV Head/Neck

DeLaroche, A.M. M.B.B.S., et al., Pediatric Neurology, 2018

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Vascular – Pediatric Stroke

- General delays in presentation and excluding stroke mimics results in patient outside of tPA window (<4.5 hours)
  - If <4.5 hours: page Neurology/Stroke resident, r/o contraindications, true last known "normal" (baseline), NIHSS → Admit to PICU/NICU/NSICU
  - Support ABCs, normotension, normovolemia, normoglycemia, normal O2, CO2, and pH, normothermia, seizure control (if suspected)
  - NPO, start 2 IVs, obtain CBC, BMP, coags, T&S
  - 0.9 mg/kg, with the first 10% given as a bolus
    - Study showing possibility that the most effective dose of tPA for children may be >0.9 mg/kg

Donahue, M MD. et al., Stroke, 2019
Wharton, J.D. M.D. et al., The Journal of Pediatrics, 2020
Parmer, M. Clin Lab, 2006

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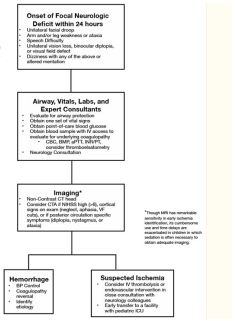
Management of pediatric stroke flowchart



Hollist et al, Aging Dis. 2021 J

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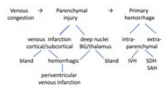
Vascular – Cerebral Venous Sinus Thrombosis (CVST)



- incidence of childhood CSVT varies between 0.4 and 0.7 per 100,000 children per year.
- Sx: HA (most common), AMS, n/v, seizures, papilledema, ataxia
- Risk factors: fever, infection (mastoiditis, otitis media), dehydration, anemia, chronic medical conditions
- Superficial > deep
- Tx: supportive care (correction of dehydration and hypovolemia, antibiotics for cases involving infection, control of seizures with anticonvulsants, and medical and surgical measures aimed at decreasing intracranial pressure), anticoagulation (older infants and children)
  - No randomized data on thrombolysis, thrombectomy or surgical decompression
  - AC: parenteral unfractionated heparin (preferred acutely d/t easy reversal), LMWH, warfarin

Diamini, N. et al., . Neurosurgery Clinics of North America, 2010

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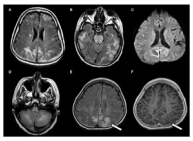
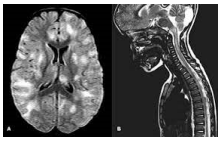
Pediatric disorders causing FNDs

- Posterior reversible encephalopathy [leukoencephalopathy] syndrome (PRES) – headache, confusion, visual symptoms, and seizures.
  - MRI: vasogenic edema in subcortical white patter and posterior hemispheres (usually b/l)
- ADEM – monophasic, associated with multifocal neuro sx and encephalopathy (preceded by infection in 75% cases)





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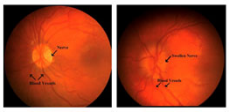
Pediatric disorders causing FNDs

- Idiopathic Intracranial HTN (IIH/pseudotumor cerebri) – child-bearing age F w/ HA, papilledema, *pulsatile tinnitus, diplopia
  - MRV: empty sella, flat posterior globe, distension of perioptic subarachnoid space, transverse sinus stenosis



- Acute cerebellar ataxia (ACA) – sudden onset, usually as gait disturbance, nystagmus, slurred or garbled speech, vomiting, irritability, dysarthria, or headache.

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"One pill can kill" – Neurological Sx in Common Ingestions

- Sulfonylureas – asx. to overt coma
- Ca channel blockers – seizures, bradycardia, hypotension, dizziness, acidosis
- Toxic etOH - (ethylene glycol > methanol > isopropanol) – AMS, ataxia, hallucinations, obtundation, vision loss
- Opioids – AMS, hyporeflexia, lethargy, coma, dizziness, euphoria, n/v
- Central α agonist – apnea, opioid-like toxidrome
- TCAs – seizures, coma, anticholinergic-like toxidrome
- Salicylate – seizures, lethargy, coma, CV collapse
- Local anesthesia – seizures, coma, ventricular dysrhythmias (benzocaine– AMS, sz, n/v)
- Antimalarials – seizures, coma, HA, n/v

Schillie SF et al. *Am J Prev Med.* 2009

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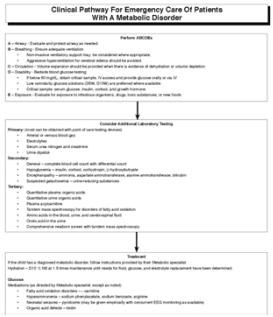
Acute Metabolic Disorder: Clinical Pathway

Typical Presentation
Lethargy
Vomiting
Seizures
Metabolic Acidosis
Hyper-amonemia



MacNeill, Emily C. *Emergency Medicine Clinics,* 2018

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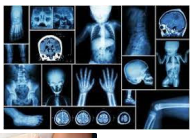
Imaging Diagnostics (CT, MRI, EEG)



- EEG
  - Suspected new onset seizure
  - Recurrent seizures of unknown etiology
  - AMS
  - SE/NCSE
  - PNES
  - Brain death
- MR > CT, contrast enhancement
  - CT: radiation, bone/blood/contrast

Ünal, A. K. Ç. A., et al. *Journal of Experimental and Clinical Medicine* 2022.
Luetje, Maureen, et al. *Pediatric Emergency Care* 2019
Lee-Jayaram, Jannet J et al., *Pediatric Emergency Care* 2020
Gunawardena, Sanuri, et al. *The American Journal of Emergency Medicine*, 2022

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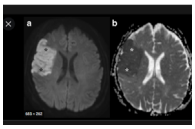
MRI

- DWI: Diffusion Weighted Imaging: Measure of water diffusion in tissues
  - Restriction of diffusion quantified by apparent diffusion coefficient (ADC)
  - RD is high intensity signal on DWI, corresponding to reduced ADC is consistent with cellular damage and infarct core, whereas tissue beyond this region but exhibiting hypoperfusion describes ischemic penumbra



Ünal, A. K. Ç. A., et al. *Journal of Experimental and Clinical Medicine* 2022.
Luetje, Maureen, et al. *Pediatric Emergency Care* 2019
Lee-Jayaram, Jannet J et al., *Pediatric Emergency Care* 2020
Gunawardena, Sanuri, et al. *The American Journal of Emergency Medicine*, 2022

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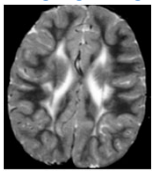
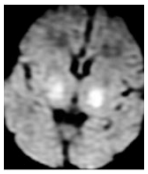
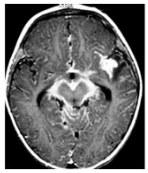
Imaging Diagnostics



T2 MR PVL



MR DWI: HIE



Post-con T1 MR: bac. mening.

Ünal, A. K. Ç. A., et al. *Journal of Experimental and Clinical Medicine* 2022.
Luetje, Maureen, et al. *Pediatric Emergency Care* 2019
Lee-Jayaram, Jannet J et al., *Pediatric Emergency Care* 2020
Gunawardena, Sanuri, et al. *The American Journal of Emergency Medicine*, 2022

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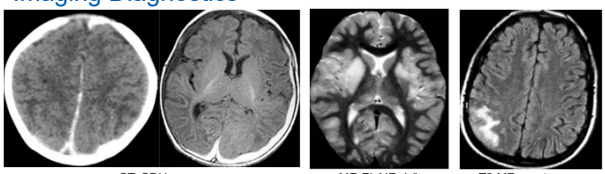
Imaging Diagnostics



CT: SDH

MR FLAIR: b/l BG (ADEM)

T2 MR: post. Circ.infarct (MELAS)

Ünal, A. K. Ç. A., et al. *Journal of Experimental and Clinical Medicine* 2022.
Luedje, Maureen, et al. *Pediatric Emergency Care* 2019
Lee-Jayaram, Jannet J et al., *Pediatric Emergency Care* 2020
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Useful References For Us All!

- MDCalc
- EMRA.org
- UpToDate
- NeuroBytes
- Pediatric Emergency Triage, Assessment and Treatment, WHO (88 pgs)
- PEARS reference card (AHA, AAP)
- Learningeeg.com

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Take Home Points ☺

- Comprehensive neurological exam in a child
- Hemorrhage – recognition, subspecialties, CPS when necessary
- Seizure disorders, SE and emergency management
- Closed head injury/trauma – appropriate diagnostics
- Infection/inflammatory profiles
- Vascular emergencies, acute neurological deficits
- Ingestion and Genetic/Metabolic diseases – approach and type of monitoring
- Imaging and diagnostics – when to use what
- Useful references for ALL…not just neurologists ;)

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References

- *Fuhrman & Zimmerman's Pediatric Critical Care*, by Bradley P. Fuhrman et al., 5th ed., Elsevier, 2017, pp. 1069–1087.
- Roselyn A. et al.; Improving Evidence-Based Non-Accidental Trauma Screening in a Pediatric Emergency Department. *Pediatrics* March 2021; 147 (3_MeetingAbstract): 153. 10.1542/peds.147.3MA2.153a
- Gunda, D. et al. 2018, Pediatric Central Nervous System Imaging of Nonaccidental Trauma: Beyond Subdural Hematomas, *Radiographics*, https://doi.org/10.1148/rg.2019180084
- Hart, R. et al., Intracranial Hemorrhage in Atrial Fibrillation Patients During Anticoagulation with Warfarin or Dabigatran, 2012, Stroke. 2012;43:1511–1517
- My.clevelandclinic.org/brain-bleed-intracranial-hemorrhage;
- Boulouis, G. et. Al., Nontraumatic Pediatric Intracranial Hemorrhage, Oct 2019; Stroke. 2019;50:3654–3661
- Preboth M. AAFP and AAP issue a practice parameter on the management of minor closed head injury in children. Am Fam Physician. 1999 Dec;60(9):2698, 2700, 2703-5. PMID: 10606000
- Boulouis, G., Stricker, S., Benichi, S., Hak, J., Gariel, F., Alias, Q., de Saint Denis, T., Kossorotoff, M., Bajolle, F., Garzelli, L., Beccaria, K., Paternoster, G., Bourgeois, M., Garcelon, N., Harroche, A., Mancusi, R. L., Boddaert, N., Puget, S., Brunelle, F., Blauwblomme, T., & Naggara, O. (2021). Etiology of intracerebral hemorrhage in children: cohort study, systematic review, and meta-analysis. *Journal of Neurosurgery: Pediatrics*, *27*(3), 357-363.
- Tan, A.P., et al. Intracranial hemorrhage in neonates: A review of etiologies, patterns and predicted clinical outcomes, *European Journal of Pediatric Neurology*, 22(4), 690-717
- www.dravetfoundation.org/what-is-dravet-syndrome.html
- University at Buffalo Translational Neuropharmacology Group, https://www.buffalo.edu/tpnc/section-2/TNG.html
- Jessica Klein, Thomas Koch; Headache in Children. *Pediatr Rev* April 2020; 41 (4): 159–171. https://doi.org/10.1542/pir.2017-0012
- Stevens RD, Shoykhet M, Cadena R. Emergency Neurological Life Support: Intracranial Hypertension and Herniation. *Neurocrit Care*. 2015;23 Suppl 2(Suppl 2):S76-S82. doi:10.1007/s12028-015-0168-z

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References

- Kuppermann N, Holmes JF, et al.; Pediatric Emergency Care Applied Research Network (PECARN). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet. 2009 Oct 3;374(9696):1160-70. doi: 10.1016/S0140-6736(09)61558-0. Epub 2009 Sep 14. Erratum in: Lancet. 2014 Jan 25;383(9914):308. PMID: 19758692.
- Yosha-Orpaz N, Aharoni S, Rabie M, Nevo Y. *Atypical* Clinical Presentations of Pediatric Acute Immune-Mediated Polyneuropathy. *Journal of Child Neurology*. 2019;34(5):268-276. doi:10.1177/0883073818825213
- Wang, C.X. Assessment and Management of Acute Disseminated Encephalomyelitis (ADEM) in the Pediatric Patient. *Pediatr Drugs* **23,** 213–221 (2021). https://doi.org/10.1007/s40272-021-00441-7
- Volpe, JJ. Perinatal brain injury: from pathogenesis to neuroprotection. Ment Retard Dev Disabil Res Rev 2001; 7:56
- Gummin DD, Mowry JB, Spyker DA, Brooks DE, Osterthaler KM, Banner W. (2018). 2017 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 35th Annual Report. *Clin Toxicol (Phila)*. 2018;56(12):1213-1415.
- Schillie SF, Shehab N, Thomas KE, Budnitz DS. Medication overdoses leading to emergency department visits among children. *Am J Prev Med*. 2009;37:181-187.
- MacNeill, Emily C., and Chantel P. Walker. "Inborn errors of metabolism in the emergency department (undiagnosed and management of the known)." *Emergency Medicine Clinics* 36.2 (2018): 369-385.
- Ünal, A. K. Ç. A., et al. "MRI utilization in pediatric emergency department: An analysis over 5 years." *Journal of Experimental and Clinical Medicine* 39.1 (2022): 75-79.
- Luetje, Maureen, et al. "Utility of Neuroimaging in Children Presenting to a Pediatric Emergency Department With Ataxia." *Pediatric Emergency Care* 35.5 (2019): 335-340.
- Lee-Jayaram, Jannet J., Lee N. Goerner, and Loren G. Yamamoto. "Magnetic resonance imaging of the brain in the pediatric emergency department." *Pediatric Emergency Care* 36.12 (2020): 586-590.
- Gunawardena, Sanuri, et al. "Utility of electroencephalogram in the pediatric emergency department." *The American Journal of Emergency Medicine* (2022).

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Thank you!

Questions?

Comments?