Pediatric Traumatic Brain Injury – Stabilization and Management

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Disclosures

- None

Goals

- Overview of the spectrum of pediatric TBI
- Review the initial stabilization, medical, and surgical management of pediatric brain injury
- Unique clinical presentations and pathophysiology of various traumatic injuries

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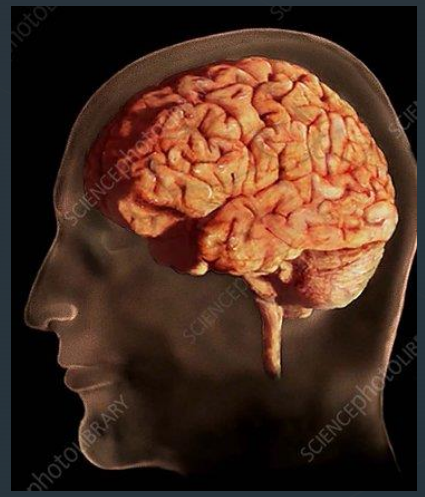
Traumatic Brain Injury

- Mild injuries with extremely low mortality
  - 80% pediatric head injuries are “mild”
- Moderate injuries with potential for improvement with aggressive medical management
- Severe injuries with 10% mortality, lower than in adults



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Outline

- Traumatic Brain Injury (TBI)
  - **Epidemiology**
  - Assessment
  - Management
    - Mild
    - Moderate
    - Severe

Epidemiology

- Among 0-14 year olds in US (annual)
  - 3,000 Deaths
  - 29,000 Hospitalizations
  - 435,000 ED visits
- More deaths than nearly all other causes
- Contributes $20 billion to annual health care costs

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Epidemiology

- Death rate is higher for children <4y
  - At least 24% TBI admissions <2y are victims of abusive head trauma (AHT)
- Mechanism:
  - <4 years old – Falls, AHT, MVC
  - 4-8y – Falls, MVC
  - 15-18y – MVC is responsible for more deaths than all other causes combined.

Outline

- Traumatic Brain Injury (TBI)
  - Epidemiology
  - **Assessment**
    - *Clinical*
    - *Radiographic*
  - Management
    - Mild
    - Moderate
    - Severe

TBI and Graded Risk

- Initial assessment can predict likelihood of significant intracranial injury and need for intervention

Assessment

Primary Physical Exam

Very Important to Examine Prior to Sedation

- ***ABC + Trauma Protocol***
- Level of Consciousness
- Vital Signs
- Cranial Nerves
  - Pupils
  - Eye Opening
- Extremity Movements

theneuroblast

Glasgow Coma Scale

EYE OPENING		VERBAL RESPONSE		MOTOR RESPONSE	
					
Spontaneous	4	Oriented	5	Obeys commands	6
To sound	3	Confused	4	Localising	5
To pressure	2	Words	3	Withdrawal	4
None	1	Sounds	2	Abnormal flexion	3
		None	1	Extension	2
				None	1

Glasgow coma scale scoring

Mild	Moderate	Severe
13-15	9-12	3-8

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- Mild (GCS 13-15)
  - 80% pediatric head injuries
  - Low mortality risk
- Moderate (GCS 9-12)
  - high potential for improvement
- Severe (GCS 3-8)
  - 10% mortality, lower than in adults

Categorization of Traumatic Brain Injury	Mild TBI / Concussion	Moderate TBI	Severe TBI
Glasgow Coma Scale (GCS)	13 - 15	9 - 12	3 - 8
Post Traumatic Amnesia (PTA)	< 24 hours	24 hours - 7 days	> 7 days
Loss of Consciousness (LOC)	0 - 30 mins	30 mins - 24 hours	> 24 hours
Medical Imaging	Typically unremarkable	Some findings	Significant findings

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Assessment

- History
  - Mechanism of injury
  - Loss of consciousness – before or after event
  - Seizure
- Exam
  - GCS
  - Focal Deficit
- Medications

Assessment

Secondary Physical Exam

- Detailed cranial nerve exam
- Skull and scalp
- Basilar Skull Fracture
  - Hemotympanum, Battle's, Raccoon Eyes, CSF leak
- Mandible fracture/carotid injury
- Spine exam

Raccoon Eyes

Battle's sign

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Mild TBI

Radiologic Assessment

CMAJ RESEARCH

CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury

Martin H. Osmond MD CM, Terry P. Klassen MD, George A. Wells PhD, Rhonda Correll RN, Anna Jarvis MD, Gary Joubert MD, Benoit Bailey MD, Laurel Chauvin-Kimoff MD CM, Martin Pusic MD, Don McConnell MD, Cheri Nijssen-Jordan MD, Norm Silver MD, Brett Taylor MD, Ian G. Stiell MD; for the Pediatric Emergency Research Canada (PERC) Head Injury Study Group

Box 1: Canadian Assessment of Tomography for Childhood Head injury: the CATCH rule

CT of the head is required only for children with minor head injury* and any one of the following findings:

High risk (need for neurologic intervention)

1. Glasgow Coma Scale score < 15 at two hours after injury
2. Suspected open or depressed skull fracture
3. History of worsening headache
4. Irritability on examination

Medium risk (brain injury on CT scan)

5. Any sign of basal skull fracture (e.g., hemotympanum, "raccoon" eyes, otorrhea or rhinorrhea of the cerebrospinal fluid, Battle's sign)
6. Large, boggy hematoma of the scalp
7. Dangerous mechanism of injury (e.g., motor vehicle crash, fall from elevation ≥ 3 ft [≥ 91 cm] or 5 stairs, fall from bicycle with no helmet)

Note: CT = computed tomography.
*Minor head injury is defined as injury within the past 24 hours associated with witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (more than one episode) or persistent irritability (in a child under two years of age) in a patient with a Glasgow Coma Scale score of 13–15.

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Clinical classification

likelihood of intracranial injury

Low Risk – No Image, No Admit

- No alteration of consciousness
- No neurologic symptoms
- Low energy mechanism
- May have scalp laceration
- Reliable observer
- Availability if new symptoms develop

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Clinical classification

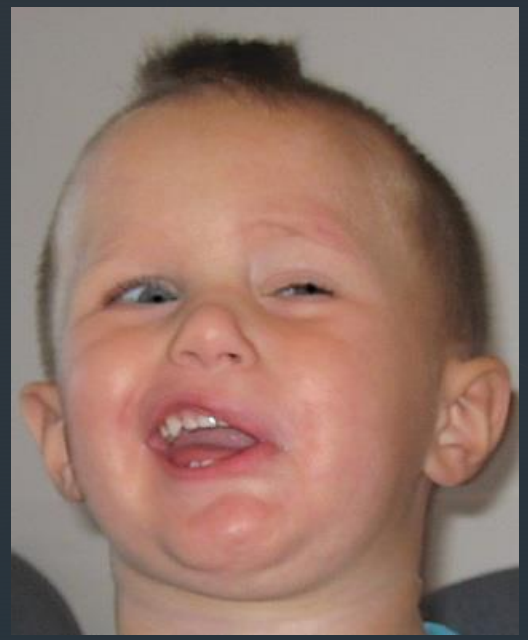
likelihood of intracranial injury

Moderate Risk – Image, Admit

- Change in consciousness
- Amnestic to event
- Progressive headache
- Emesis
- Post-traumatic seizure
- Unreliable history
- Symptoms of basilar skull fracture
- Serious facial or polytrauma

Clinical classification

likelihood of intracranial injury



High Risk – Image, Admit

- Altered, LoC
- Focal neurological findings
- Penetrating injury
- Depressed fracture on clinical exam

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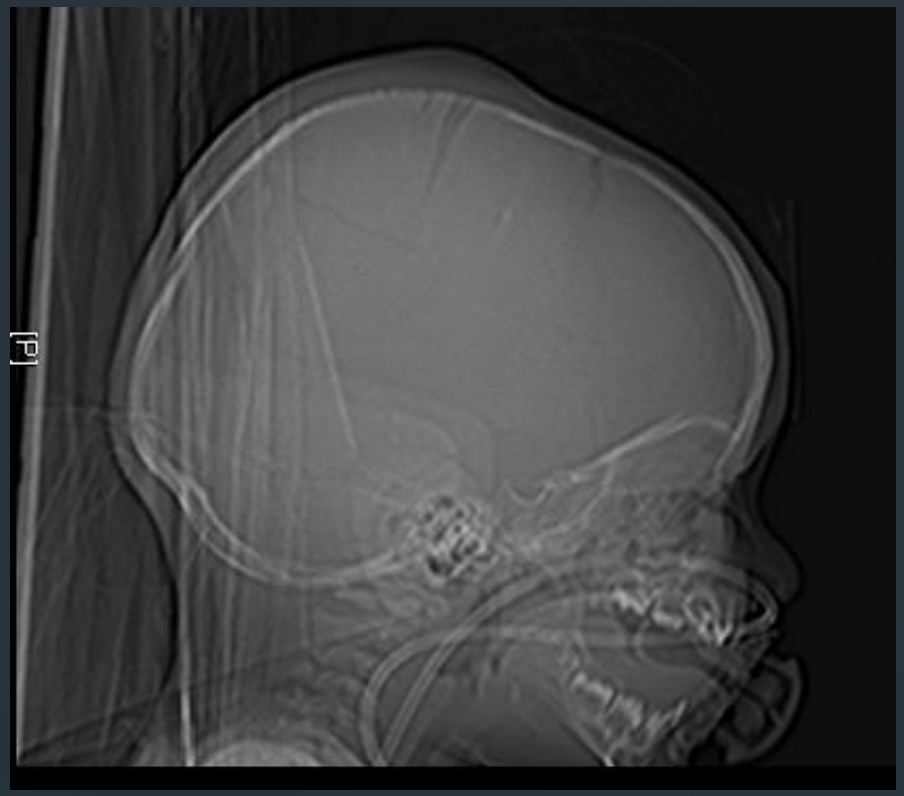
    - ***Radiographic***
  - Management
    - Mild
    - Moderate
    - Severe

imaging

Skull X-rays

- Little Acute Utility
- Fracture poorly predictive of underlying injury



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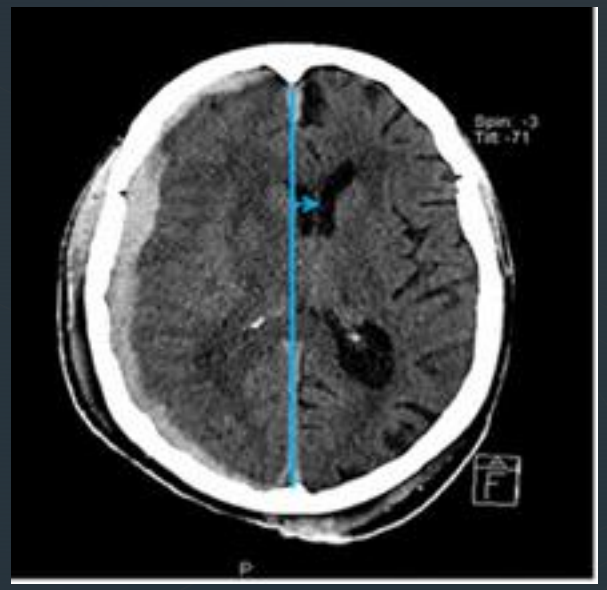
Imaging Non-contrast Head CT

Standard for Acute Management

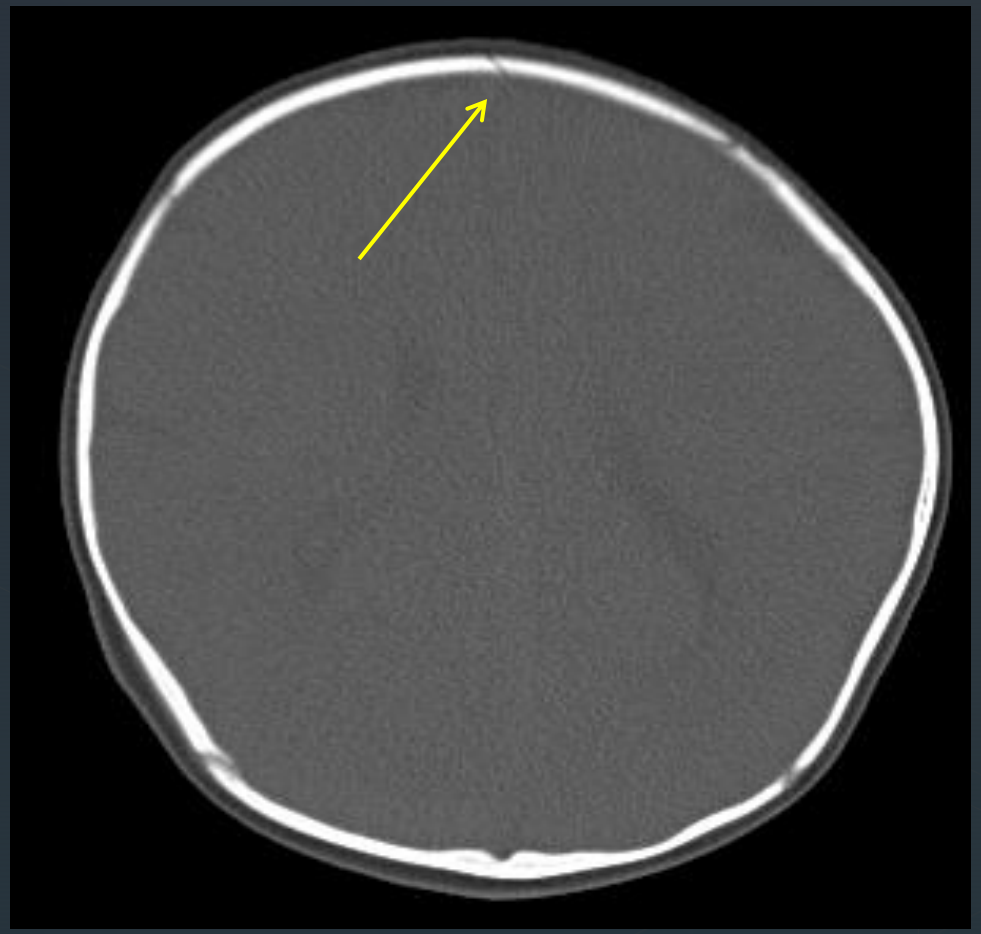
- Normal CT + Normal LOC
  - Low likelihood injury requiring treatment
- Normal CT + Neuro impairment
  - Diffuse injury, hypoxia, or ischemia
- Findings associated with increased risk irrespective of clinical exam:
  - Midline shift
  - Large mass
  - Compressed basal cisterns
  - Diffuse swelling



Imaging

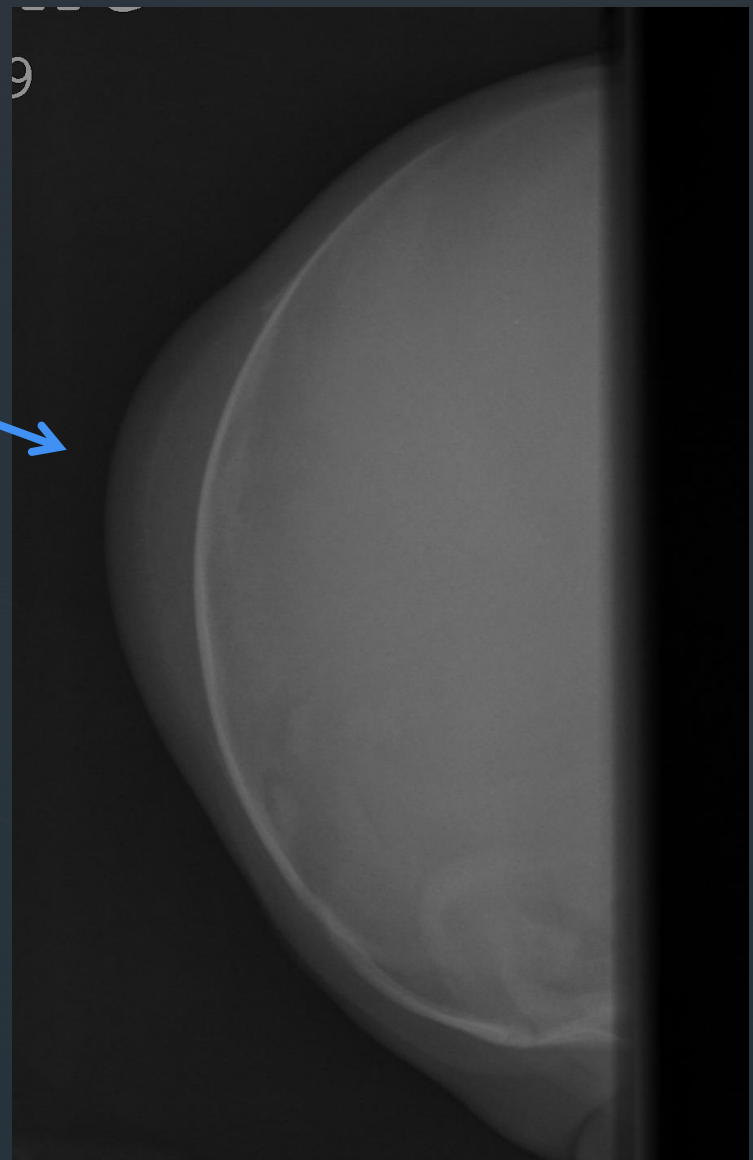
Linear Skull Fracture

- Most common
  - esp <1 year
- Falls from bed, changing table, or adult's arms
- Overlying scalp swelling



imaging

Linear Skull Fracture

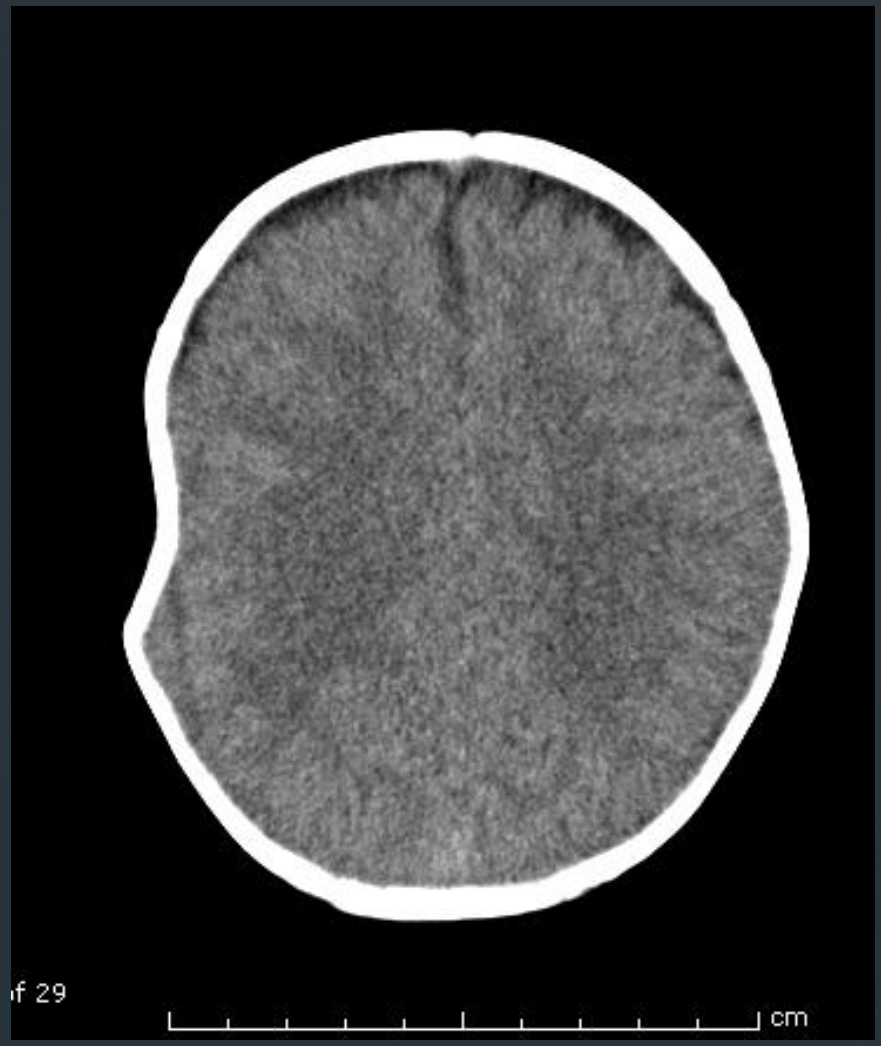


- Cephalohematoma
  - May cause anemia

Imaging

Depressed Skull Fracture

- Fracture itself not significant
  - location (cosmesis)
- Often associated w concussion
  - overnight obs or admit



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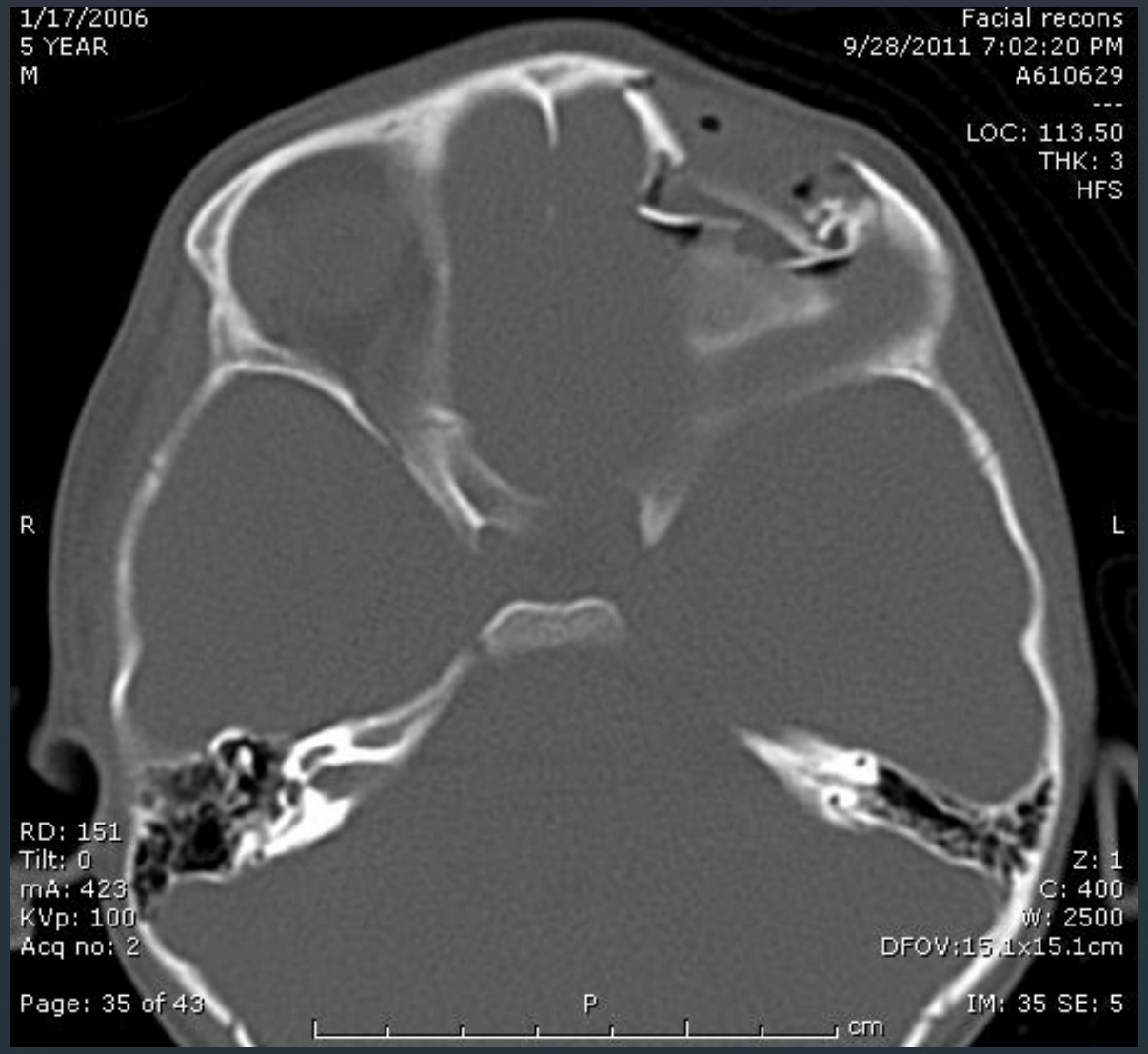
Skull Fracture

Cosmetic Reconstruction



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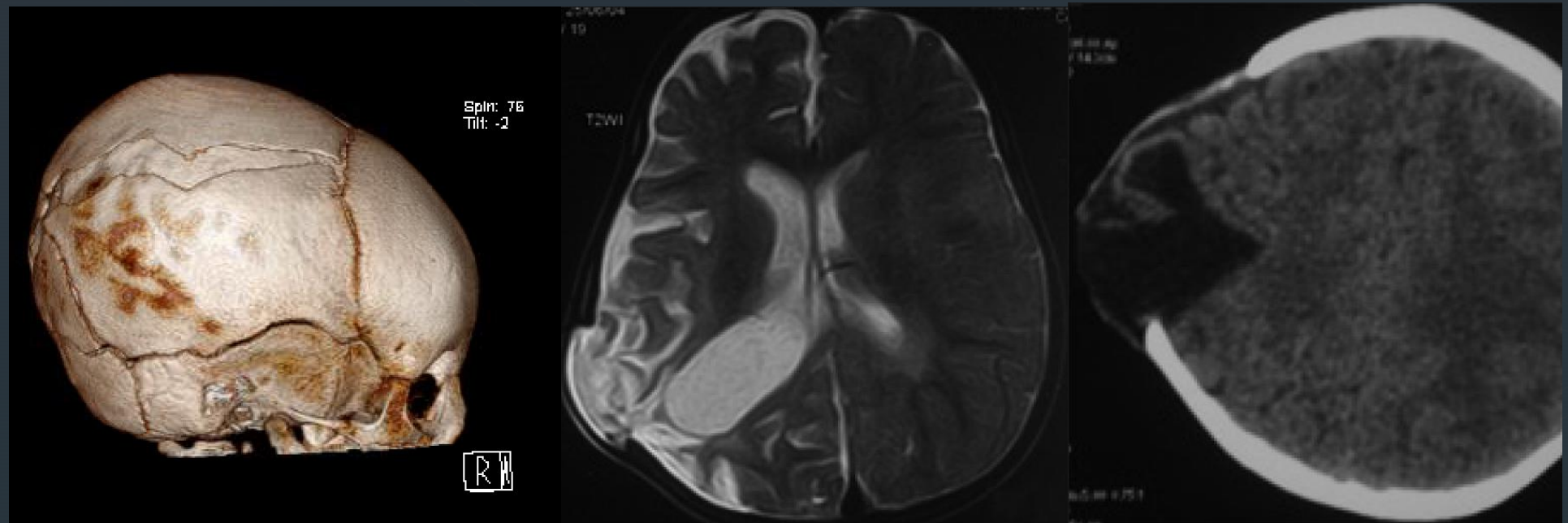
Growing skull fracture

- Late effect after skull fracture in small children
- AKA: lepto-meningeal cyst
- Brain and CSF pushes through dural rent
  - Enlarges skull defect
- Rapidly growing brain (<18 mo old)



Outline

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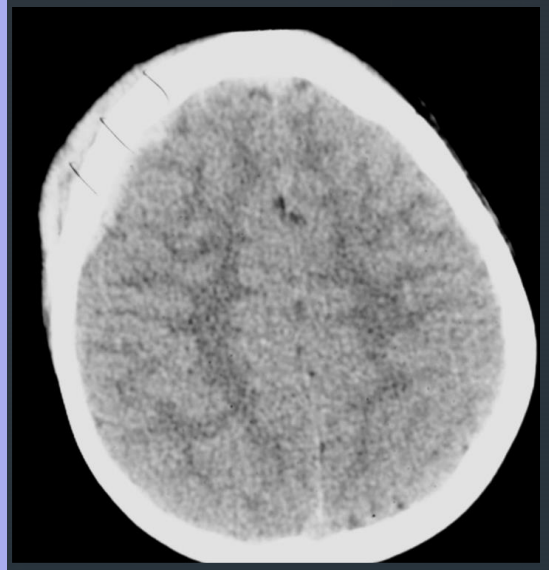
    - **Moderate**
    - **Severe**
      - **Abusive Head Trauma (AHT)**

TBI Management

Moderate injury

- Admit/Observe
  - *Goal is to confirm no deterioration over time*
- +/- Seizure prophylaxis
- Cervical collar
- Euvolemia
- Nutrition
- Neurosurgery Consult
  - *Surgery for some hematomas*



Initial CT

2 hours later

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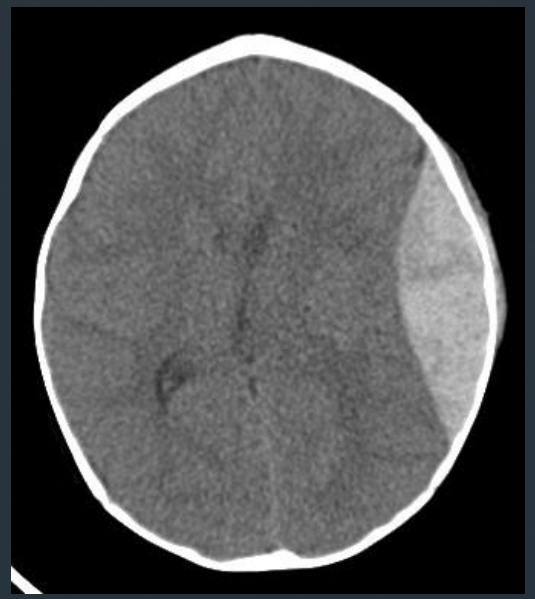
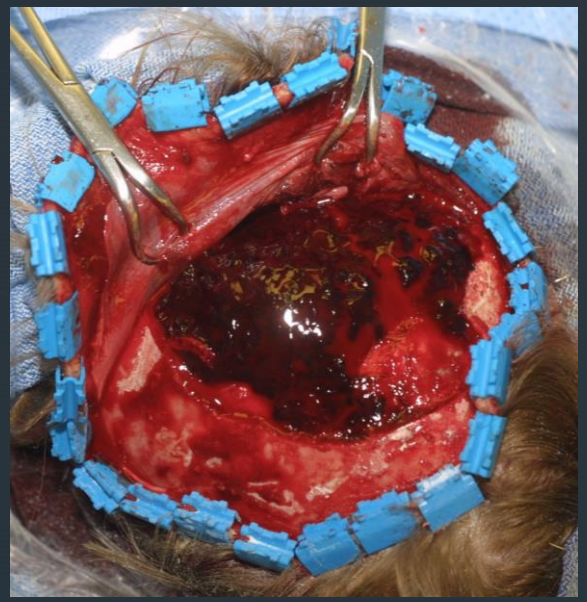
TBI Management

Severe injury

- Goals
  - Early identification and evacuation of surgical lesions
  - Prevention of secondary injury





Primary vs. Secondary

Primary Brain Injury

- Energy Dissipation on the Brain
  - Contusion
  - Laceration
  - Axonal disruption
  - Hemorrhage
- Inflicted prior to medical care
- ***Prevention***

Secondary Brain Injury

- Further damage to traumatized brain
  - Hypotension
  - Hypoxia
  - ICP
- ***Focus of TBI care***

Primary Injury

Treatment

- 14 randomized, multi-institutional trials
  - Mostly adult
  - **None positive**
  - Hundreds of millions of dollars
  - Steroid, Cooling, Progesterone etc.

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Primary injury

Treatment = Prevention

Secondary Injury

Guidelines for the Acute Medical Management
of Severe Traumatic Brain Injury in Infants, Children, and Adolescents-Second Edition

Pediatr Crit Care Med 2012 Vol. 13, No. 1 (Suppl.)

Hypoxia Guideline

- Avoid hypoxemia
- Avoid hypercarbia (goal of normal CO2)
- Universal supplemental oxygen

  - A single episode of hypoxia, cyanosis or apnea is independently associated with mortality in head injury (in adults)
    - SaO2 >90: 19% dead or severely disabled
    - SaO2 <90, >60: 55% dead or severely disabled
    - SaO2 <60: 100% dead or severely disabled

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Secondary Injury

Guidelines for the Acute Medical Management
of Severe Traumatic Brain Injury in Infants, Children, and Adolescents-Second Edition

Pediatr Crit Care Med 2012 Vol. 13, No. 1 (Suppl.)

Hypotension guideline

- Hypotension (<5% of norm for age) should be identified and rapidly corrected
- Timely administration of isotonic fluid (not hypotonic)
- Goal of euvolemia.

- Option:
  - Systolic blood pressure at or above median for age

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Intracranial pressure Management

- Concern for elevated Intracranial pressure is high when patients are unresponsive or have unreliable neurologic exam
- If GCS around 8-9, we often need ICP monitoring
- But how do we help reduce ICPs prior to transfer?

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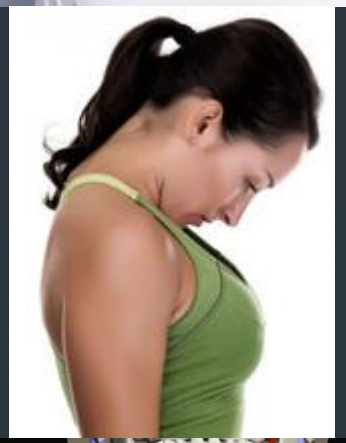
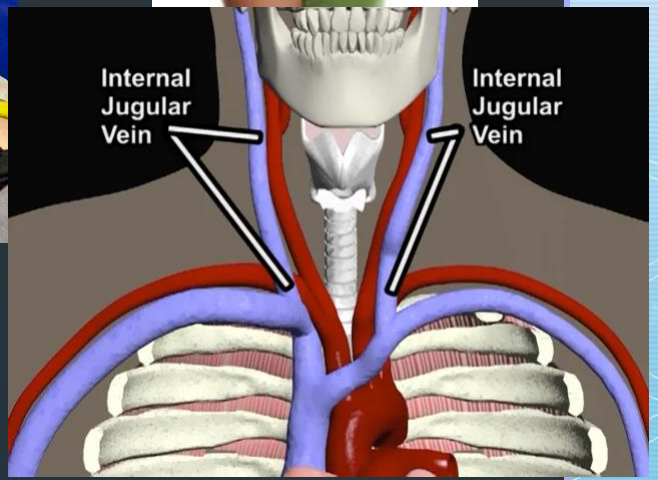
ICP Management – Simple stuff first





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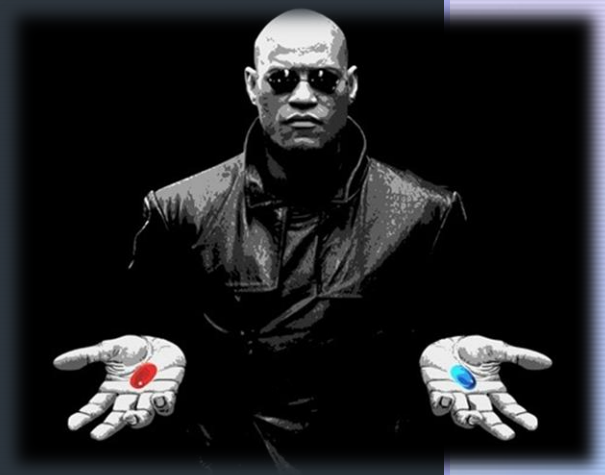
ICP Management - medications



- **Hypertonic saline** – 3%
- **Mannitol** 1 g/kg
- Historically, we have given both and retrospective data have shown them to be equally effective.
- But are they…

JAMA Network | Open

Original Investigation | Pediatrics

Comparison of Intracranial Pressure Measurements Before and After Hypertonic Saline or Mannitol Treatment in Children With Severe Traumatic Brain Injury

Patrick M. Kochanek, MD; P. David Adelson, MD; Bedda L. Rosario, PhD; James Hutchison, MD; Nikki Miller Ferguson, MD; Peter Ferrazzano, MD; Nicole O'Brien, MD; John Beca, MD; Ajit Sarnaik, MD; Kerri LaRovere, MD; Tellen D. Bennett, MD, MS; Akash Deep, MD; Deepak Gupta, MCH, PhD; F. Anthony Willyerd, MD; Shiyao Gao, PhD; Stephen R. Wisniewski, PhD; Michael J. Bell, MD; for the ADAPT Investigators

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ICP Management - Mannitol

- Mannitol has its limits:
  - Initially effective (in the very acute phase)
  - But can have rebound elevated ICPs as it eventually crosses BBB
- Mannitol can cause hypotension (so avoid in hemorrhagic shock)
  - Also would avoid in setting of neurogenic shock (spinal cord injury)
- Mannitol requires good kidney function – Would avoid in setting of renal injury or poor creatinine function
- Avoid in pulmonary edema or congestion, heart failure, dehydration

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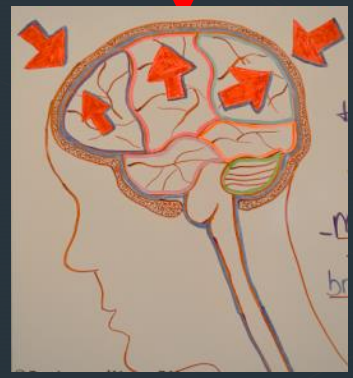
Hyperventilation?

- Yes, but only in last resort on the way for surgery
- We work with ICP vs. MAP to get perfusion in the brain
  - Hyperventilation decreases MAP in order to decrease ICP… a problem!

Elevated MAP

Hyperventilation = Decreasing pCO_2



Elevated ICP!

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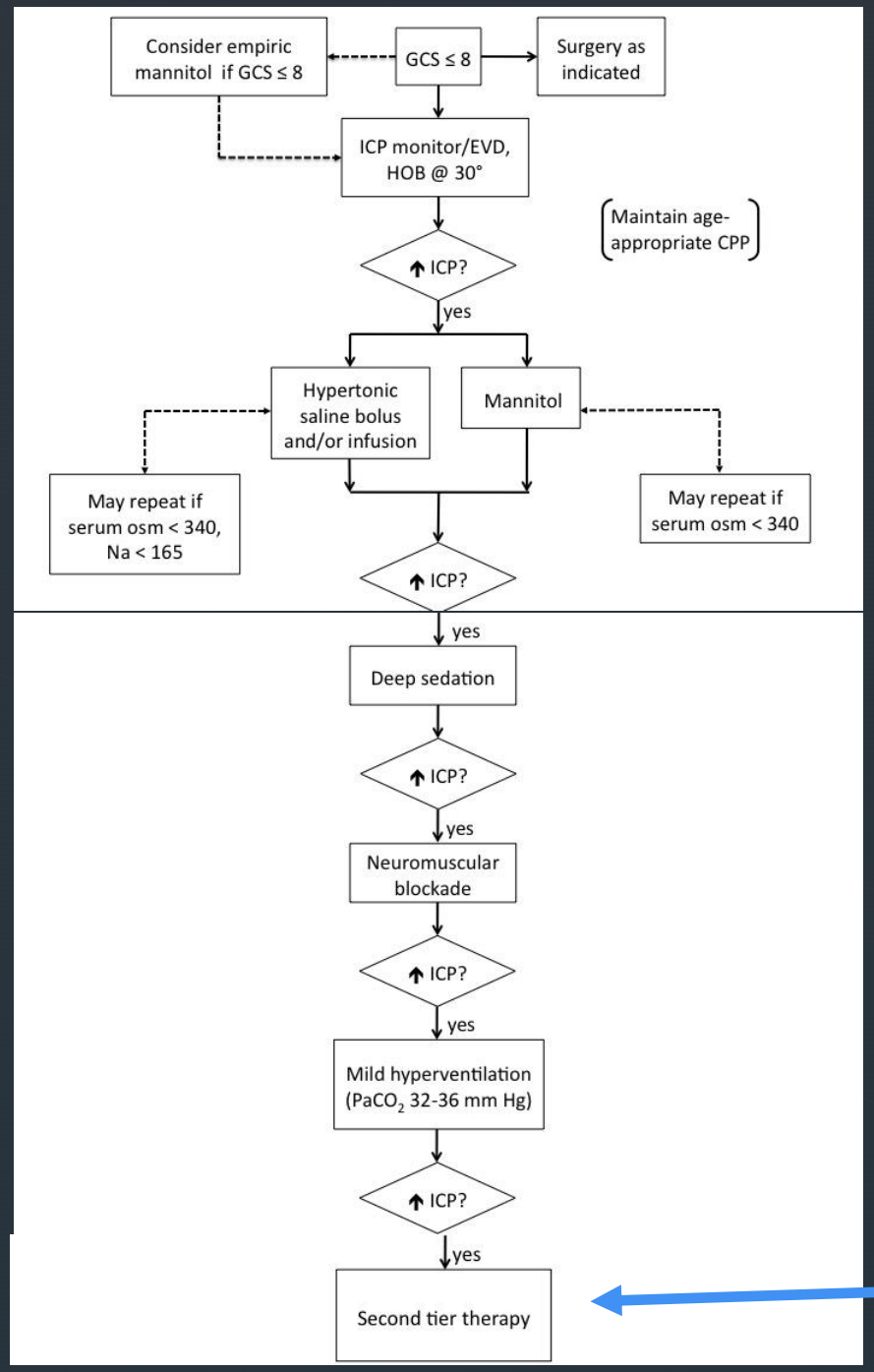
Consider empiric mannitol if GCS ≤ 8
GCS ≤ 8
Surgery as indicated
ICP monitor/EVD, HOB @ 30°
Maintain age-appropriate CPP
↑ ICP?
yes
Hypertonic saline bolus and/or infusion
Mannitol
May repeat if serum osm < 340, Na < 165
May repeat if serum osm < 340
↑ ICP?
yes
Deep sedation
↑ ICP?
yes
Neuromuscular blockade
↑ ICP?
yes
Mild hyperventilation ($PaCO_2$ 32-36 mm Hg)
↑ ICP?
yes
Second tier therapy

Second Tier

- Salvage therapies for intractable ICP
  - Barbiturate coma
  - Hemicraniectomy

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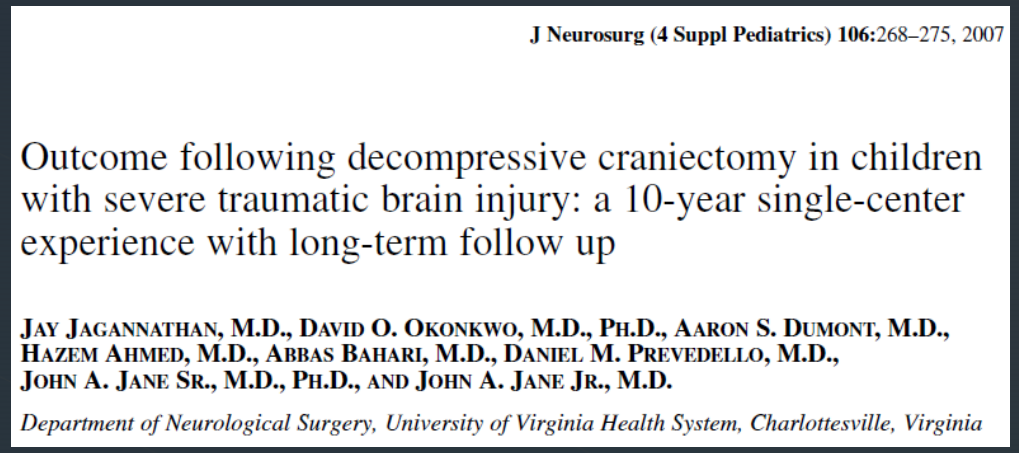
Decompressive Craniectomy

- 23 Children, mean GCS 4.6, mean ICP 30
- ICP controlled in 19 (83%)

- 7 deaths (30%)
- 3 dependent
- 13 returned to school



J Neurosurg (4 Suppl Pediatrics) 106:268–275, 2007

Outcome following decompressive craniectomy in children with severe traumatic brain injury: a 10-year single-center experience with long-term follow up

JAY JAGANNATHAN, M.D., DAVID O. OKONKWO, M.D., PH.D., AARON S. DUMONT, M.D., HAZEM AHMED, M.D., ABBAS BAHARI, M.D., DANIEL M. PREVEDELLO, M.D., JOHN A. JANE SR., M.D., PH.D., AND JOHN A. JANE JR., M.D.

Department of Neurological Surgery, University of Virginia Health System, Charlottesville, Virginia

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Decompressive Craniectomy

Rescue ICP Trial

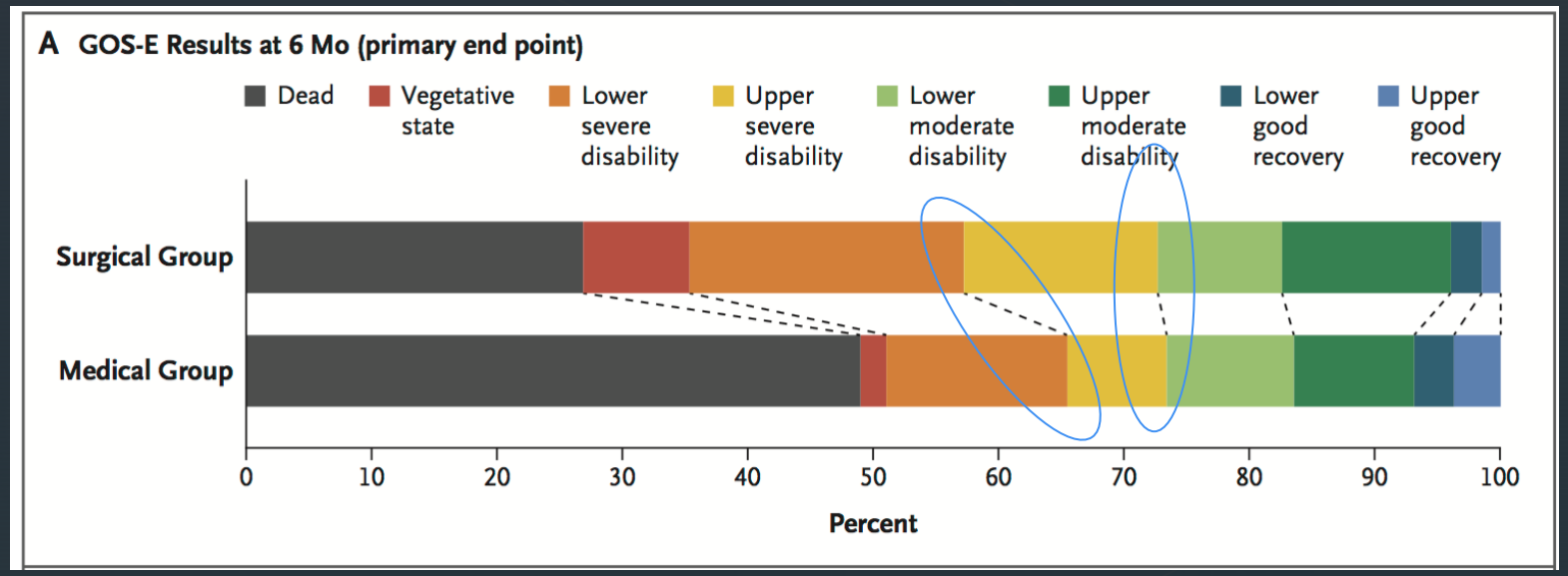
- Multicenter European RCT
  - Last Tier Therapy
- 408 pts:
  - age 10-65y
  - ICP >25mmHg
  - DC vs Medical Management
- Outcome: GOS-E (extended) @ 6m

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension

P.J. Hutchinson, A.G. Kolias, I.S. Timofeev, E.A. Corteen, M. Czosnyka, J. Timothy, I. Anderson, D.O. Bulters, A. Belli, C.A. Eynon, J. Wadley, A.D. Mendelow, P.M. Mitchell, M.H. Wilson, G. Critchley, J. Sahuquillo, A. Unterberg, F. Servadei, G.M. Teasdale, J.D. Pickard, D.K. Menon, G.D. Murray, and P.J. Kirkpatrick, for the RESCUEicp Trial Collaborators*



Severe injury

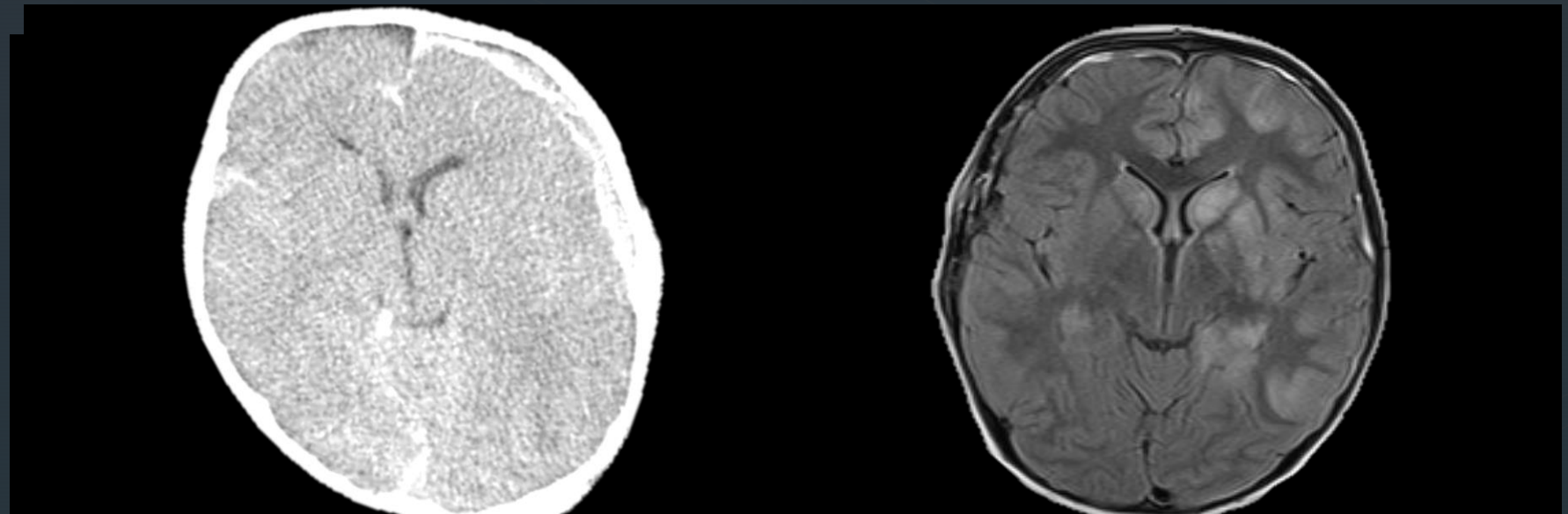
Focal Lesions

Surgical *(potentially)*

- Epidural Hematoma
- Subdural Hematoma
- Intracerebral Hemorrhage

Non-surgical *(usually)*

- Contusion
- Diffuse Axonal Injury



CASE

Epidural Hematoma

- Timely evacuation of surgical lesions:
  - 4yo skied into a tree at 2:30p
  - Crying → somnolent (about 30 min)
  - Intubated prior to helicopter evac.
  - CHCO @ 4:30p
  - Stabilized by trauma team
  - Sedated with little neuro exam.
    - Pupils equal and reactive.
  - To CT

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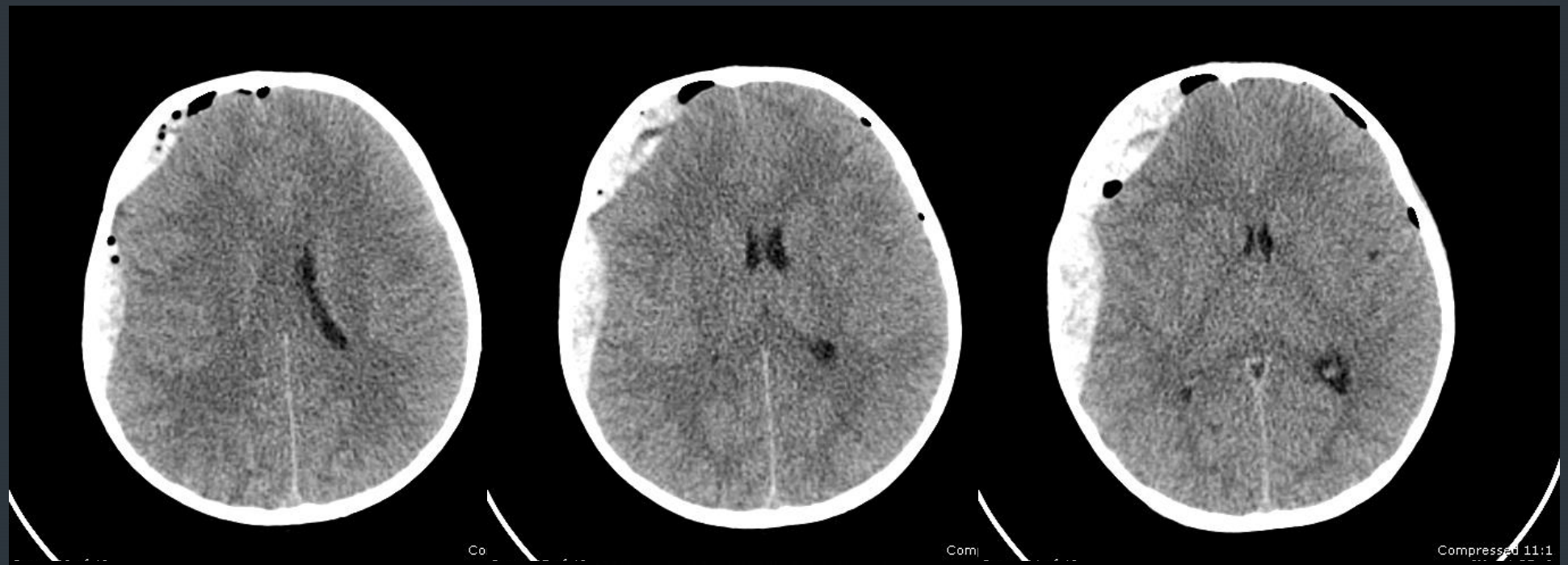
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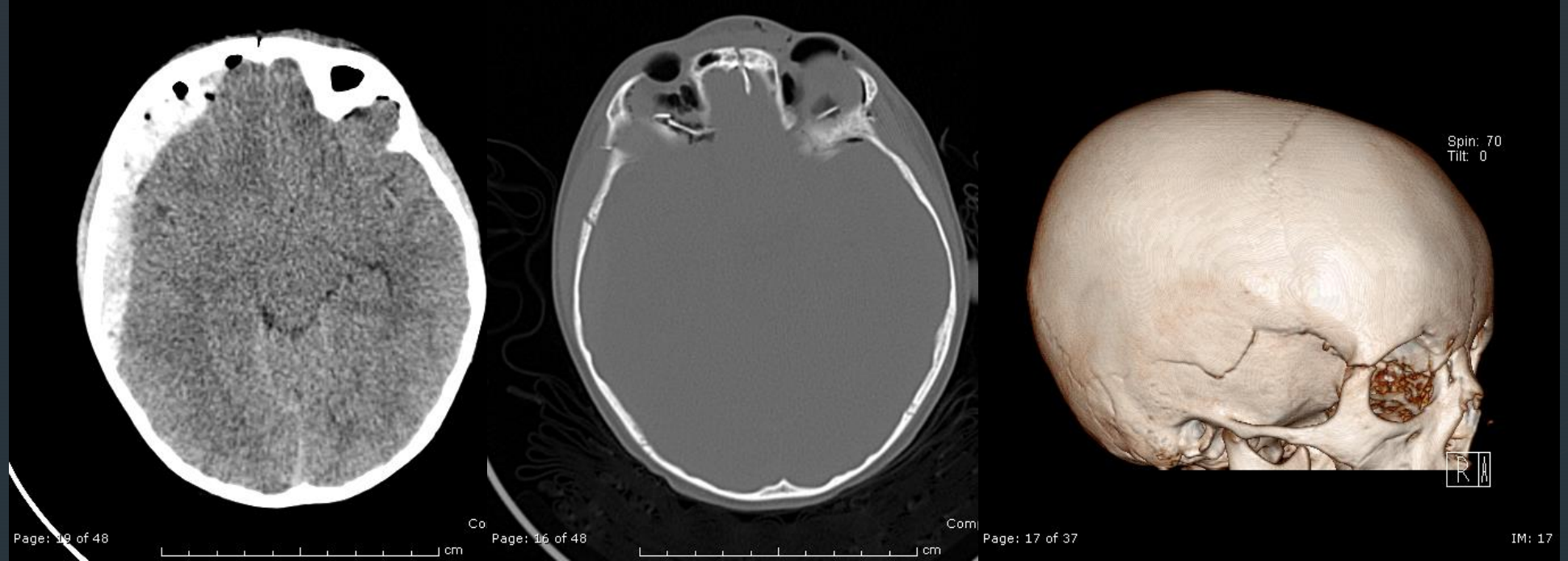
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Tilt: 0
Page: 17 of 37
IM: 17

CASE

Epidural Hematoma

- OR w/in 1 hour of arrival
- Discharged to home 6 days post-injury, without deficit

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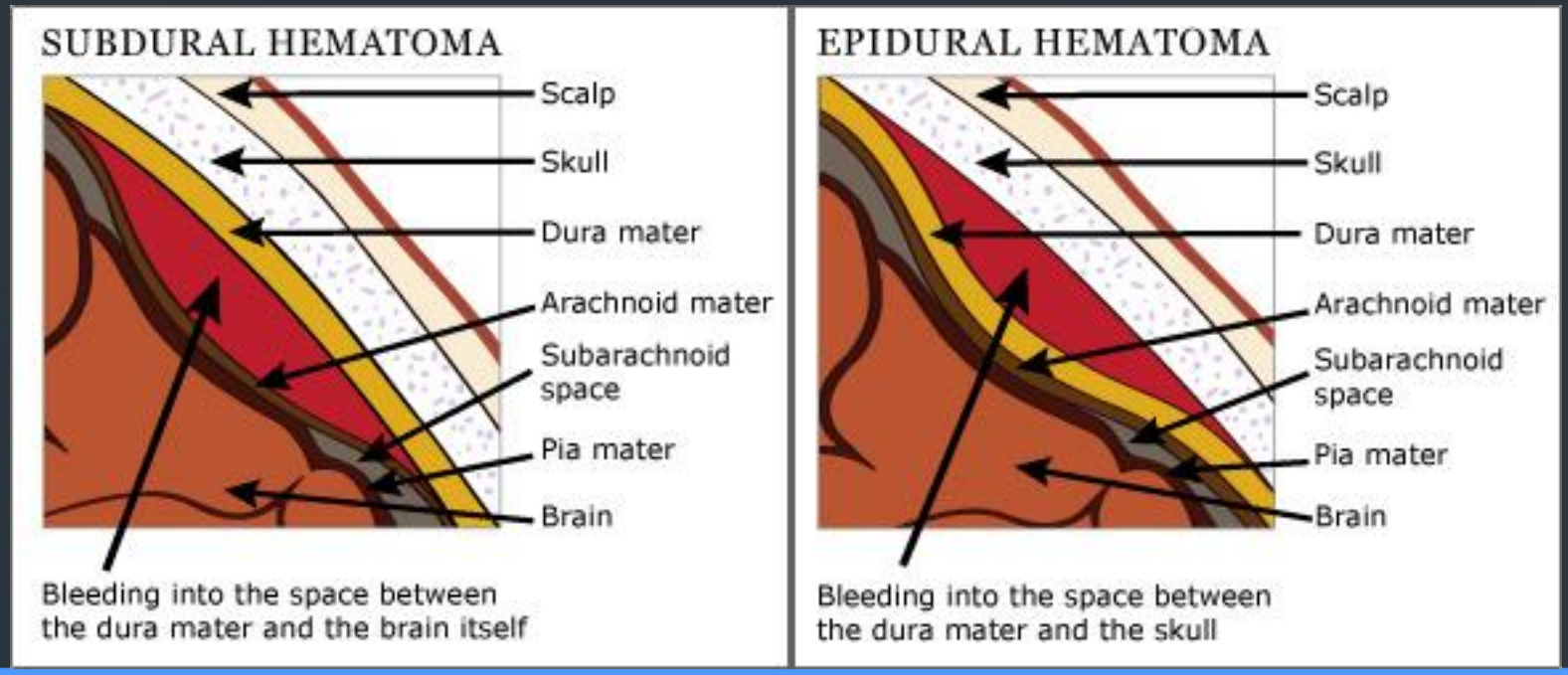
Extra-axial Hematoma

Subdural vs. Epidural

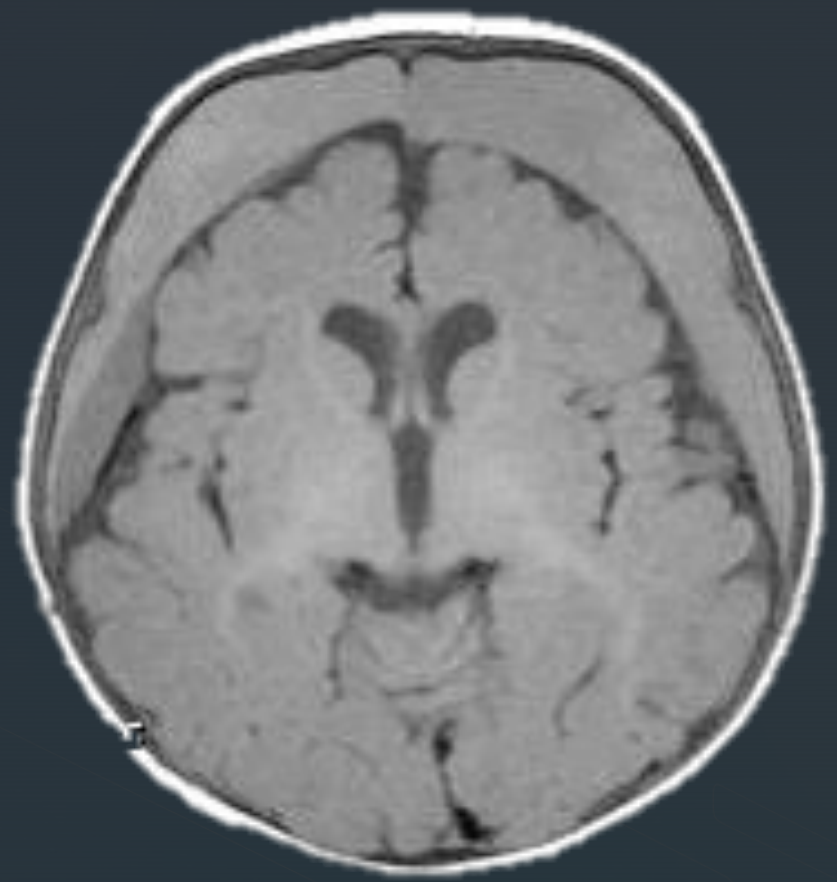


- Subdural
  - Higher energy
  - Brain Injury
  - Bridging Vein
- Epidural
  - Focal Blow
  - +/- Surgical Emergency
  - Arterial Source

Abusive Head Trauma

Overview

- Mean age < 1 year
  - ≥24% of under 2y admitted for TBI
- “Shaken baby” and “NAT” obsolete
- Risk factors
    - Young parents
    - Low socioeconomic status
    - Single parent
    - History of abuse in caretaker
    - Substance abuse in caretaker
- Risk factors for missed diagnosis
    - Intact families
    - Caucasian children



Abusive Head Trauma

Diagnostic clues

Initially no apparent history of trauma or low-height fall

Symptoms and Signs

- Mild:
  - Feeding difficulty
  - Vomiting
  - Irritability
  - Enlarging head
- Severe:
  - Seizures
  - Apnea
  - Unresponsiveness

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Abusive Head Trauma

Work-up

- ***Social Work/Child Protection Team Evaluation***
- ***Ophthalmology exam with dilation***
  - Multilayer retinal hemorrhages
- ***X-ray skeletal survey***
  - 2 view skull
  - 2 view spine
  - Chest with oblique views for posterior rib fractures
  - Extremity views—metaphyseal fractures

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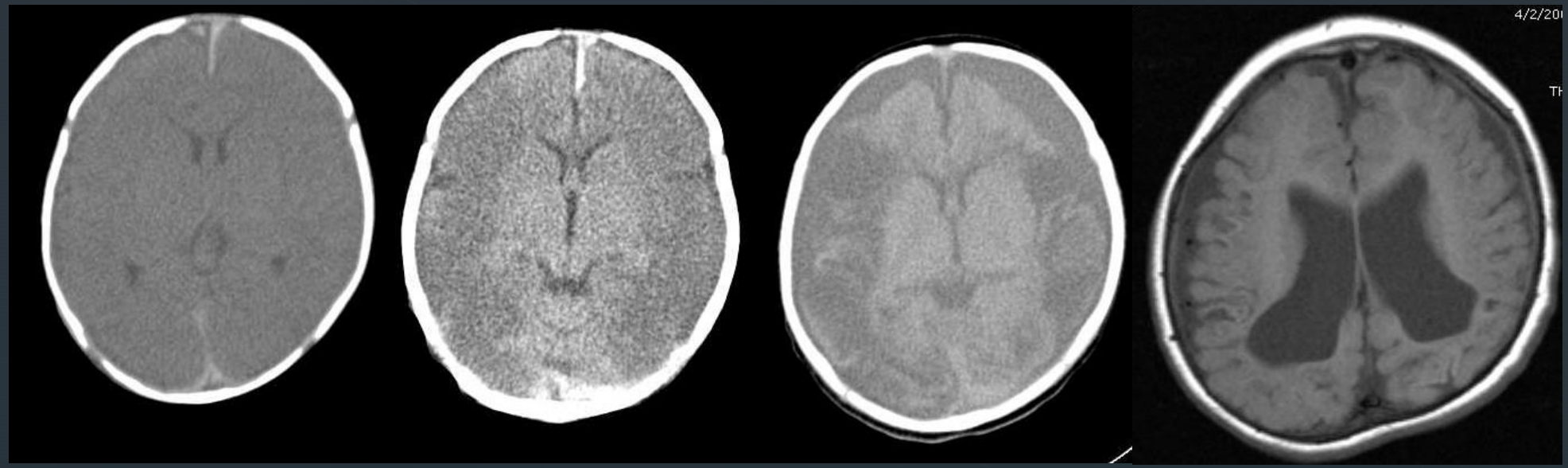
Abusive Head Trauma

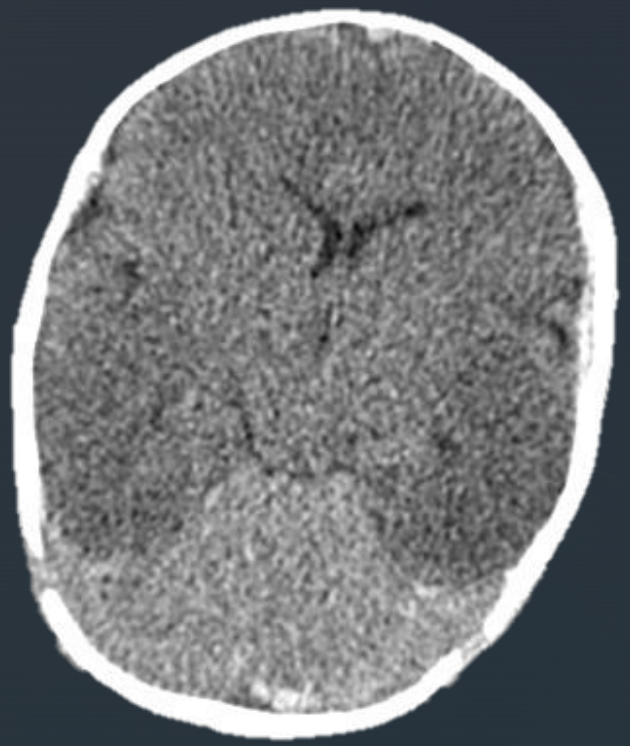
Imaging evolution

Initial Two days Two weeks Two years



Abusive Head Trauma

Medical/surgical management



- +/- Evacuation of chronic subdurals
- Monitoring for re-bleeding

- Systemic support
- Seizure Control
  - EEG to diagnose subclinical seizure

- ?? ICP management
  - ischemic injury – is damage done?

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When to monitor vs. transfer?

Monitor in ED

Clinical status: GCS >13

No neurologic issues

Compliant/consolable

Tolerating PO intake

Headache/symptoms improving

Imaging not concerning for possible expansion

Non-depressed skull fracture
Traumatic subarachnoid hemorrhage
Trace subdural hematoma (2-3 mm)
Trace epidural hematoma (2-3 mm)

Transfer to higher level of care

Clinical status: GCS <13 or declining

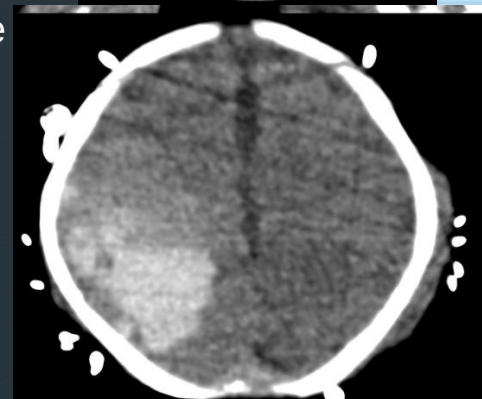
Neurological deficit

Irritable/inconsolable

Worsening headache

Imaging concerns

SDH/EDH (~>5mm)
Intraparenchymal hemorrhage
Intracerebral contusion
Intraventricular hemorrhage
Midline shift



Summary

- **Clinical assessment** is the key predictor for intervention and outcomes
- **Mild TBI** carries a lower risk for expansion or escalation of care
  - Important to identify risk factors for escalation of care
- **Optimization of TBI patients with elevated ICP** begins with simple maneuvers then advancing to medications and surgery
- **AHT** common in young children/ severe injury is likely primary and so responds poorly to treatment
- **Prevent secondary injury** in both brain and spine trauma
  - *Hypoxia/Hypotension*
- **Telemedicine** is an increasingly useful adjunct

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Thank you!

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