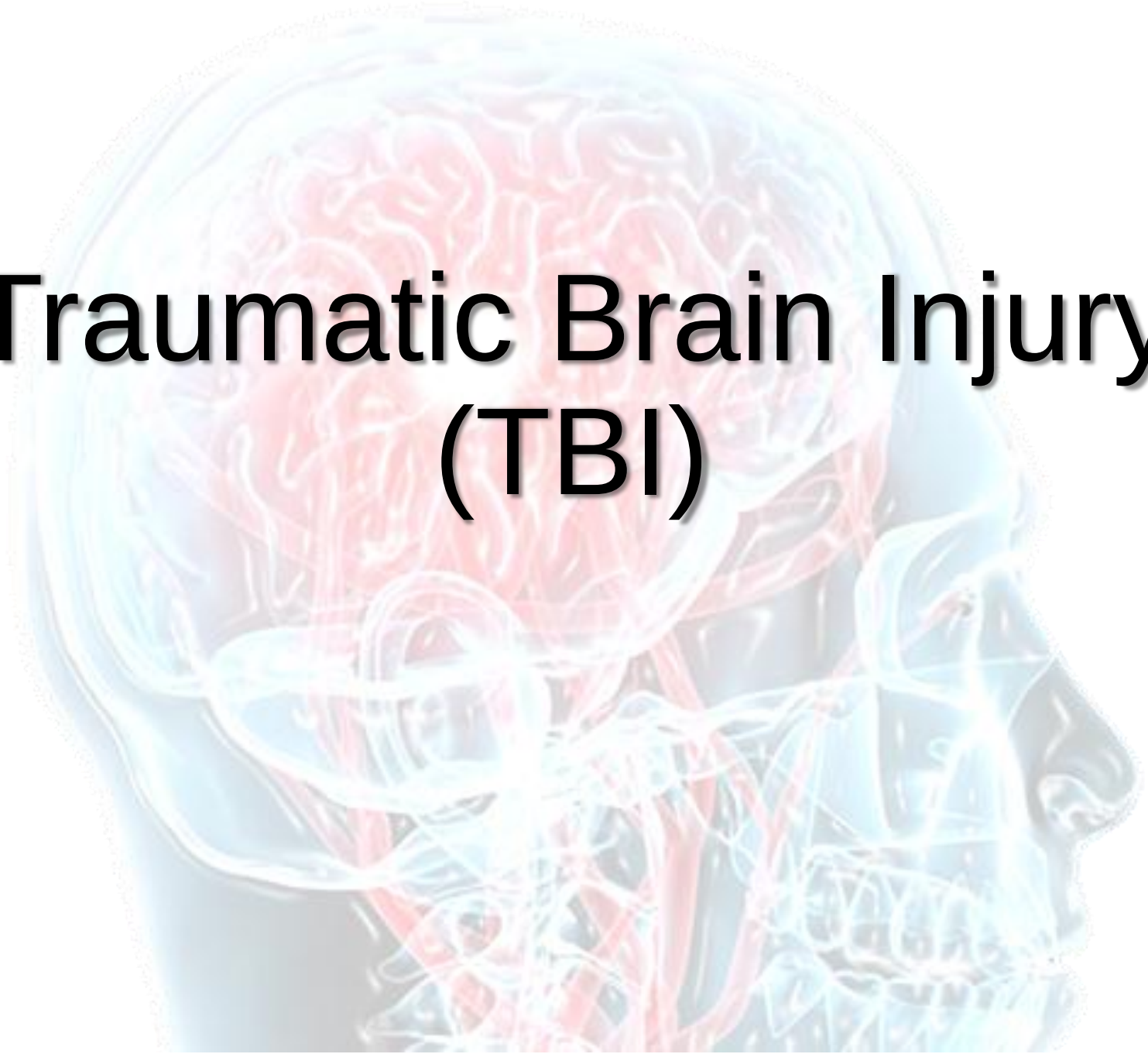
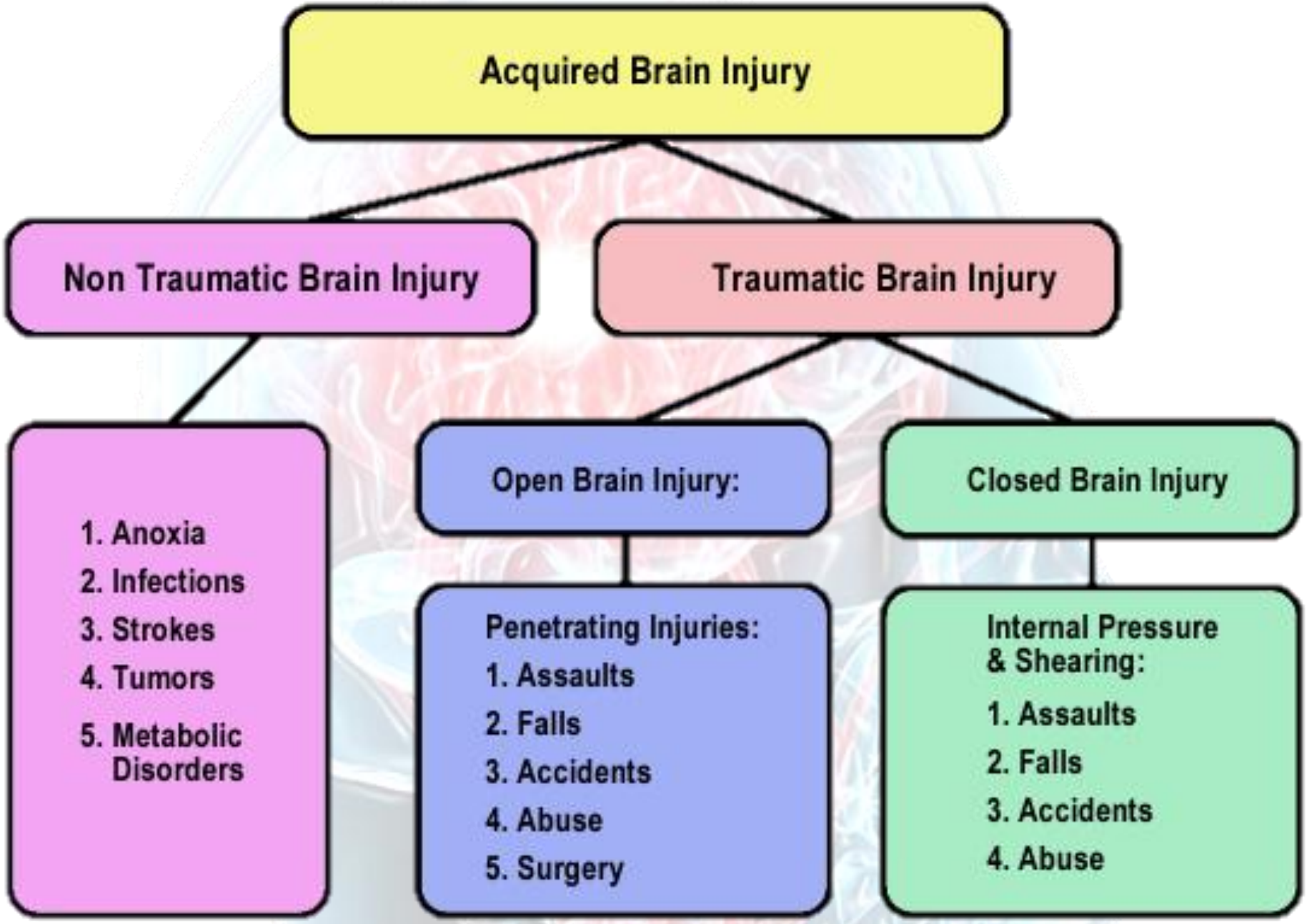
# Traumatic Brain Injury (TBI)




Acquired Brain Injury
Non Traumatic Brain Injury
Traumatic Brain Injury
1. Anoxia
2. Infections
3. Strokes
4. Tumors
5. Metabolic Disorders
Open Brain Injury:
Closed Brain Injury
Penetrating Injuries:
1. Assaults
2. Falls
3. Accidents
4. Abuse
5. Surgery
Internal Pressure & Shearing:
1. Assaults
2. Falls
3. Accidents
4. Abuse

# Epidemiology

- **Falls**
  - are the leading cause of TBI and recent data shows that the number of fall-related TBIs among children aged 0-4 years and in older adults aged 75 years or older is increasing
- Among all age groups, **Motor Vehicle Collision** and traffic-related incidents result in the largest percentage of TBI-related deaths (20-30%)

- **ED visits for TBI related injuries increased from 2006 to 2010**
  - A population-based cohort study in from 2006 to 2010
  - 138,223,016 emergency department visits were analyzed
  - traumatic brain injury diagnosis in 1.7% of visits (2,350,000)

JAMA 2014 May 14;311(18):1917

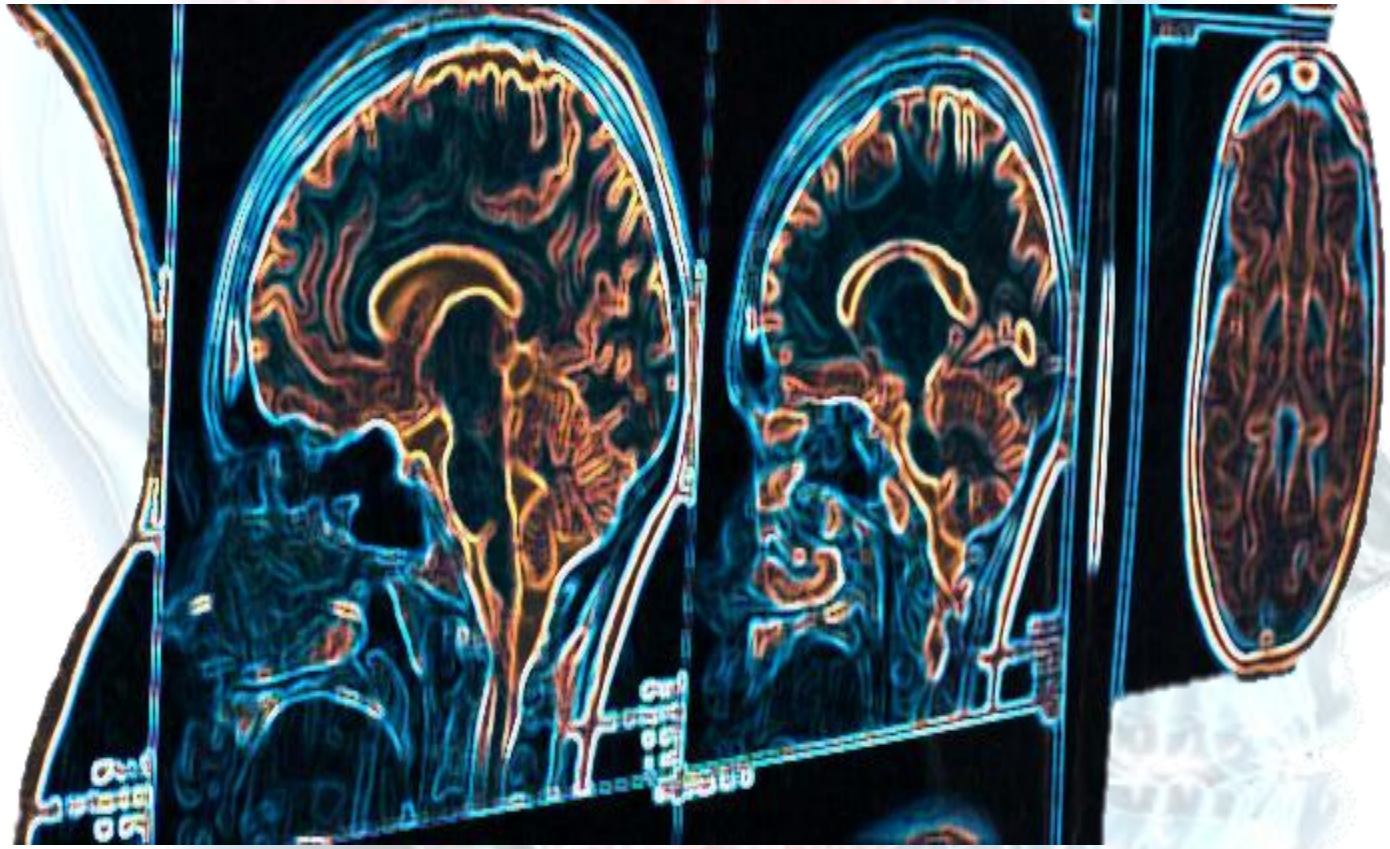
# Epidemiology

- **Pts. >75 years**
  - have the highest rates of TBI-related hospitalizations and death
- **Shaken Baby Syndrome (SBS)**
  - a form of abusive head trauma (AHT) and inflicted traumatic brain injury (ITBI), is a leading cause of child maltreatment

# Classification of TBI

- **Mild TBI (80%)**
  - GCS 13-15
- **Moderate TBI (20%)**
  - GCS 9-12
- **Sever TBI(20%)**
  - GCS <9

# Imaging Studies



# skull film x-rays

ACEP Level B
International Brain Injury Association

- not recommended for mild TBI ; skull fracture does not have sufficient sensitivity to be useful for identifying or ruling out intracranial lesion
- not recommended for mild traumatic brain injury, but are useful as part of skeletal survey in children with suspected non-accidental injury
- discontinuation of routine of obtaining skull x-rays for head injury evaluation not associated with increase in admission rate or missed intracranial injury

level 2 [mid-level] evidence)

# skull film x-rays

- 2-factor decision rule may help rule out skull fracture without radiologic evaluation in children < 2 years old presenting to emergency department with low-risk minor head trauma

**level 2 [mid-level] evidence**

**skull radiology indicated by decision rule if either:**

•parietal or occipital swelling or hematoma
•age < 2 months

children < 2 years old (median age 8 months) presenting to ED within 24 hours of head trauma

derivation cohort included 811 children

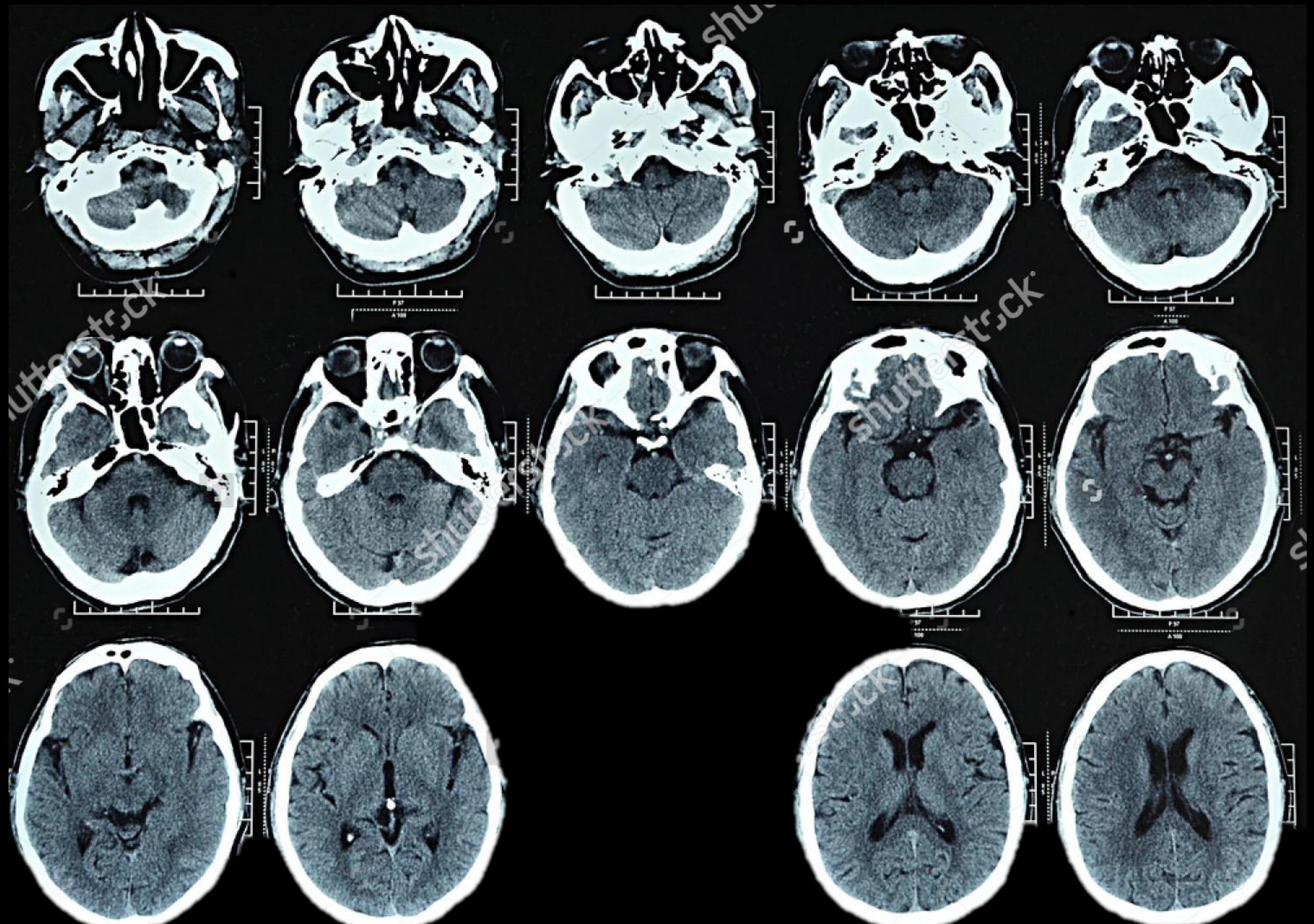
validation cohort included 856 children

**CMAJ 2015 Nov 3;187**

# skull film x-rays

- performance of skull fracture decision rule for prediction of skull fracture
  - sensitivity 94% in derivation cohort and 89% in validation cohort
  - specificity 86% in derivation cohort and 87% in validation cohort
  - positive predictive value 31% in derivation cohort and 26% in validation cohort
  - negative predictive value 100% in derivation cohort and 99% in validation cohort
  - use of skull fracture decision rule would have reduced use of radiography by 58% in validation cohort

CMAJ 2015 Nov 3;187



# New Orleans Criteria

- applies to patients who have GCS score 15, computed tomography (CT) required only for patients with any of
  - headache
  - vomiting
  - age > 60 years
  - drug or alcohol intoxication
  - short-term memory deficits (defined as persistent anterograde amnesia)
  - physical signs of trauma above clavicles
  - seizure

# Canadian CT Head Rule

(level 2 [mid-level] evidence)

- applied to patients with minor head injury who present with GCS score 13-15 after witnessed LOC, amnesia, or confusion
- **CT required only in patients with any of:**
  - GCS score < 15 at 2 hours after injury
  - suspected open or depressed skull fracture
  - any sign of basilar skull fracture (hemotympanum, "raccoon" eyes, cerebrospinal fluid [CSF] otorrhea or rhinorrhea, Battle sign)
  - 2 or more episodes of vomiting
  - age ≥ 65 years
  - amnesia for ≥ 30 minutes of events before impact
  - dangerous mechanism (pedestrian struck by motor vehicle, occupant ejected from vehicle, fall ≥ 3 feet [1 meter] or 5 stairs)

does not apply to patient without trauma, GCS score < 13, < 16 years old, obvious open skull fracture, bleeding disorder, or taking warfarin

# National Emergency X-radiography Utilization Study II (NEXUS II) Rule

- computed tomography (CT) suggested if any of
  - age > 65 years
  - skull fracture
  - scalp hematoma
  - neurologic deficit
  - abnormal alertness
  - abnormal behavior
  - coagulopathy
  - persistent vomiting

# Computed Tomography in Head Injury Patients (CHIP) Prediction Rule

- simple prediction rule based on 1 major or 2 minor risk factors

**10 major risk factors**

1. pedestrian or cyclist struck by vehicle
2. ejected from vehicle
3. vomiting
4. posttraumatic amnesia ≥ 4 hours
5. clinical signs of skull fracture
6. Glasgow Coma Scale (GCS) score < 15
7. GCS deterioration ≥ 2 points (1 hour after presentation)
8. use of anticoagulant therapy
9. posttraumatic seizure
10. age ≥ 60 years

**8 minor risk factors**

1. fall from any elevation
2. persistent anterograde amnesia
3. posttraumatic amnesia of between 2 and 4 hours
4. contusion of skull
5. neurologic deficit
6. loss of consciousness
7. GCS deterioration of 1 point (1 hour after presentation)
8. age 40-60 years

# ACEP

adults ≥ 16 years old with mild traumatic brain injury [GCS] score 14 or 15

- history of loss of consciousness or post-traumatic amnesia, noncontrast (CT) indicated only if 1 or more of
  - Headache vomiting
  - age > 60 years
  - drug or alcohol intoxication
  - short-term memory deficit
  - signs of trauma above clavicle
  - post-traumatic seizure
  - GCS score < 15
  - focal neurologic deficit
  - coagulopathy
- without loss of consciousness or post-traumatic amnesia, noncontrast head CT may be considered only if any of
  - focal neurologic deficit
  - severe headache
  - vomiting
  - age > 65 years
  - signs of basilar skull fracture
  - GCS score < 15
  - coagulopathy
  - dangerous mechanism of injury, including
  - ejection from motor vehicle
  - pedestrian struck by vehicle
  - fall from > 3 feet (1 meter) or 5 stairs

# National Institute for Health and Care Excellence (NICE)

- Recommends CT head within 1 hour if any of
  - GCS score < 13 on initial assessment in ED
  - GCS score < 15 at 2 hours after injury on assessment in ED
  - suspected open or depressed skull fracture
  - sign of basal skull fracture (hemotympanum, "panda" eyes, CSF leakage from ear or nose, Battle sign)
  - post-traumatic seizure
  - focal neurologic deficit
  - > 1 episode of vomiting
- CT head within 8 hours of head injury in adults with
  - any LOC or amnesia since injury if any of
    - amnesia for events > 30 minutes before impact (retrograde amnesia > 30 minutes)
    - age > 65 years
    - coagulopathy (history of bleeding or clotting disorder)
    - dangerous mechanism of injury (pedestrian or cyclist struck by motor vehicle, occupant ejected from motor vehicle, fall from height > 1 meter [3.28 feet] or 5 stairs)
  - use of warfarin treatment, regardless of any other indications

# International Brain Injury Association

- mild traumatic brain injury defined by American College of Rehabilitation Medicine as any of
  - loss of consciousness < 30 minutes and GCS score 13-15 after resolution of loss of consciousness
  - any memory loss of event immediately before or after accident that continues for < 24 hours
  - any altered mental status at time of accident
  - computed tomography (CT) of head not necessary in patients without headache, vomiting, age > 60 years, drug or alcohol intoxication, short-term memory deficits, physical evidence of trauma above clavicle, or seizure; based on multiple high-quality studies

# American Academy of Neurology (AAN)

- computed tomography (CT) imaging should not be used to diagnose sports-related concussion, but might be done to rule out more serious traumatic brain injury in patients with (AAN Level C)
- loss of consciousness
- posttraumatic amnesia
- persistently altered mental status (Glasgow Coma Scale < 15)
- focal neurologic deficit
- evidence of skill fracture on examination
- signs of clinical deterioration

# Eastern Association for the Surgery of Trauma (EAST)

- perform brain computed tomography (CT) scan on patients who present with suspected brain injury in acute setting if CT scan is available (EAST Level 2)
- if CT resources are limited (EAST Level 2)
- consider using standardized criteria (such as Canadian CT Head Rule or New Orleans Criteria) to determine which patients with mild traumatic brain injury receive brain CT scan
- be aware that using standardized criteria is associated with nonzero missed injury rate

# Canadian Association of Radiologists

- Canadian Association of Radiologists recommends against imaging for minor head trauma unless red flags are present
- red flags include
- Glasgow Coma Scale (GCS) < 13
- GCS < 15 at 2 hours post injury
- patient ≥ 65 years old
- obvious open skull fracture
- suspected open or depressed skull fracture
- any sign of basilar skull fracture (such as hemotympanum, raccoon eyes, Battle sign, cerebrospinal fluid [CSF] otorhinorrhea)
- retrograde amnesia to the event lasting ≥ 30 minutes after the event
- “dangerous” mechanism (such as pedestrian struck by motor vehicle, occupant ejected from motor vehicle, or fall from higher than 3 feet [0.9 meters] or down more than 5 stairs)
- coumadin use or bleeding disorder

# Comparisons of Clinical Decision Rules

- Canadian CT Head Rule and New Orleans Criteria are most studied clinical decision rules for minor head injury
  - both decision rules appear to have high sensitivity for detecting need for neurosurgical intervention and moderate-to-high sensitivity for detecting intracranial injury (level 2 [mid-level] evidence)
  - Canadian CT Head Rule may have higher specificity than New Orleans Criteria (level 2 [mid-level] evidence)
  - Canadian CT Head Rule had higher sensitivity than New Orleans Criteria in 1 of 2 direct comparison studies (level 2 [mid-level] evidence)

systematic review of 22 studies evaluating 25 clinical decision rules for detecting minor head injury requiring neurosurgical intervention or at risk of intracranial injury in adult patients

| Clinical Decision Rule | Sensitivity (Range) | Specificity (Range) | Number of Studies Analyzed |
|---|---|---|---|
| Canadian CT Head Rule high-risk criteria (5 criteria) | 99%-100% | 48%-77% | 4 |
| Canadian CT Head Rule high- and medium-risk criteria (7 criteria) | 99%-100% | 37%-48% | 3 |
| Canadian CT Head Rule high- and medium-risk adapted to cohort | 100% | 37% | 1 |
| New Orleans Criteria | 99%-100% | 4%-31% | 4 |
| New Orleans Criteria adapted to cohort | 100% | 3% | 1 |
| NCWFNS high and medium risk | 94%-99% | 3%-44% | 2 |
| NICE lenient criteria | 94%-98% | 29%-67% | 3 |
| Scandinavian lenient criteria | 94%-99% | 20%-50% | 2 |
| Miller criteria | 50%-100% | 61%-66% | 2 |

Abbreviations: CT, computed tomography; NCWFNS, Neurotraumatology Committee of World Federation of Neurosurgical Societies; NICE, National Institute for Health and Clinical Excellence.

# Comparisons of Clinical Decision Rules

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| Decision Rule | Sensitivity for Clinically Important Brain Injury | Specificity for Clinically Important Brain Injury | Sensitivity for Neurosurgical Intervention | Specificity for Neurosurgical Intervention |
|---|---|---|---|---|
| Canadian CT Head Rule | 79.2% | 41.3% | 100% | 38.3% |
| New Orleans Criteria | 91.9% | 22.4% | 100% | 20.4% |
| NEXUS-II | 88.7% | 46.5% | 95.1% | 41.4% |

Abbreviations: CT, computed tomography; NEXUS-II, National Emergency X-radiography Utilization Study II.

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# Comparisons of Clinical Decision Rules

- systematic review
  - 6 clinical decision rules appear to have similar sensitivity for detecting surgical hematomas (although possibly highest with NEXUS-II); Canadian and Scandinavian clinical decision aids may have highest specificity (level 2 [mid-level] evidence)

7,955 patients > 10 years old with mild traumatic brain injury used to evaluate 6 common clinical decision rules

# Comp n Rules

| Clinical Decision Rule | Sensitivity for Hematoma | Sensitivity for Any Lesion | Specificity for No Hematoma | Specificity for No Lesion |
|---|---|---|---|---|
| Canadian CT Head Rule (high risk) | 99% | 97% | 48% | 51% |
| Canadian (medium or high risk) | 99% | 99% | 45% | 47% |
| NCWFNS | 99% | 96% | 45% | 47% |
| New Orleans | 99% | 99% | 31% | 33% |
| NEXUS-II | 100% | 97% | 44% | 47% |
| NICE | 98% | 99% | 29% | 31% |
| Scandinavian | 99% | 96% | 50% | 53% |

Abbreviations: CT, computed tomography; NCWFNS, Neurotraumatology Committee of World Federation of Neurosurgical Societies; NEXUS-II, National Emergency X-radiography Utilization Study II; NICE, National Institute for Health and Clinical Excellence.

# Choosing Wisely-ACEP

- American College of Emergency Physicians recommends avoiding computed tomography (CT) scans of the head in emergency department patients with minor head injury who are at low risk based on validated decision rules **(Choosing Wisely 2014 Oct 27)**

# Choosing Wisely-CAEP

- CAEP recommends avoiding computed tomography (CT) head scans in adults and children who have suffered minor head injuries (unless positive for a head injury clinical decision rule) (**Choosing Wisely Canada 2015 Jun 2**)
- Canadian Association of Radiologists recommends against imaging for minor head trauma unless red flags are present
  - **red flags include**
    - Glasgow Coma Scale (GCS) < 13
    - GCS < 15 at 2 hours post injury
    - patient ≥ 65 years old
    - obvious open skull fracture
    - suspected open or depressed skull fracture
    - any sign of basilar skull fracture (such as hemotympanum, raccoon eyes, Battle sign, cerebrospinal fluid [CSF] otorhinorrhea)
    - retrograde amnesia to the event lasting ≥ 30 minutes after the event
    - "dangerous" mechanism (such as pedestrian struck by motor vehicle, occupant ejected from motor vehicle, or fall from higher than 3 feet [0.9 meters] or down more than 5 stairs)
    - coumadin use or bleeding disorder (**Choosing Wisely Canada 2014 Apr 2)**

# Choosing Wisely-Australia

- Choosing Wisely Royal Australian and New Zealand College of Radiologists recommends against requesting computed tomography (CT) head scans in patients with a head injury, unless indicated by a validated clinical decision rule (**Choosing Wisely Australia 2015 Apr 22**)
- Australian College for Emergency Medicine recommends against requesting computed tomography (CT) head scans in patients with a head injury, unless indicated by a validated clinical decision rule (**Choosing Wisely Australia 2015 Apr 22**)

# Skull ultrasound

- point-of-care ultrasonography identifies skull fracture in children (level 1 [likely reliable] evidence)
- based on diagnostic cohort study
- reference standard for skull fracture was interpretation of computed tomography (CT) scan by trained radiologist
  - 12% had skull fracture
  - for diagnosis of skull fracture, ultrasonography had
    - sensitivity 88%
    - specificity 97%
    - positive likelihood ratio 27
    - negative likelihood ratio 0.13

**Pediatrics 2013 Jun**

# Magnetic resonance imaging (MRI) for head imaging

- not indicated as primary study for clinically important brain injury in patients with head injury
- may provide additional important information related to patient's prognosis
- MRI for identification of diffuse axonal injury (specific type of traumatic brain injury caused by shearing forces leading to widespread tearing of axons and small vessels

[PLoS One 2015;10(3)

- diffusion tensor MRI may identify axonal injury in patients with blast-related traumatic brain injury

N Engl J Med 2011 Jun

# Thank You