Heads Up:

New Guidelines in Monitoring & Interventions for Mild, Moderate & Severe TBI

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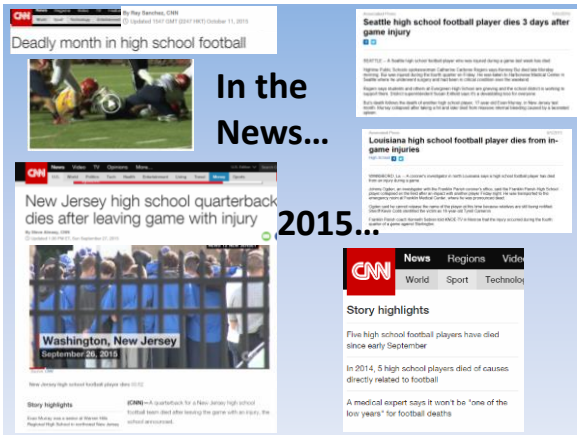
Disclosures

- Honorarium
  - Bard
- Medical Advisory Board
  - Brain Trauma Foundation
  - Malinckrodt
  - Neuroptics
- Stock Options
  - Neuroptics

Objectives

- Differentiate between minor, moderate and severe traumatic brain injury
- Prioritize interventions related to managing minor, moderate and severe TBI
- Identify strategies to reverse coagulopathy when patients on anticoagulants/antiplatelets present to the ED with bleeding in the brain following trauma

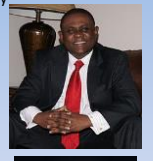


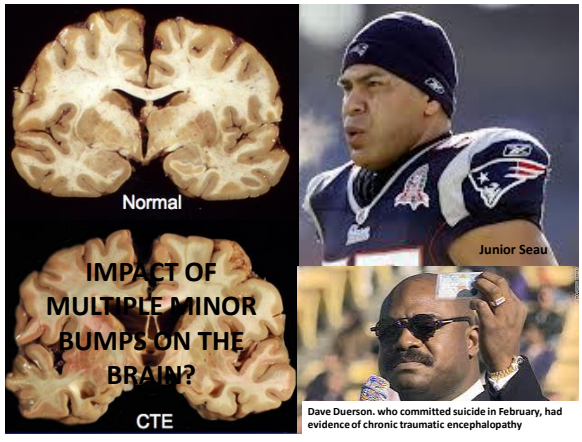
In the News…Concussion

- Pathologist Dr. Bennet Omalu uncovers the truth about brain damage in football players who suffer repeated concussions in the course of normal play…1st publication 2005 Neurosurgery


SPECIAL REPORT

CHRONIC TRAUMATIC ENCEPHALOPATHY IN A NATIONAL FOOTBALL LEAGUE PLAYER





Dave Duerson. who committed suicide in February, had evidence of chronic traumatic encephalopathy

CDC Definition of TBI

Definition of TBI

CDC defines TBI as a disruption in the normal function of the brain that can be caused by a bump, blow, or jolt to the head or a penetrating head injury (Marr and Coronado, 2004). Explosive blasts can also cause TBI, particularly among those who serve in the U.S. military. Observing one of the following clinical signs constitutes an alteration in brain function (Menon, Schwab, Wright, and Maas, 2010):

a. Any period of loss of or decreased consciousness;

b. Any loss of memory for events immediately before (retrograde amnesia) or after the injury (post-traumatic amnesia);

c. Neurologic deficits such as muscle weakness, loss of balance and coordination, disruption of vision, change in speech and language, or sensory loss;

d. Any alteration in mental state at the time of the injury such as confusion, disorientation, slowed thinking, or difficulty with concentration.

Suggested Citation: Centers for Disease Control and Prevention. (2015). *Report to Congress on Traumatic Brain Injury in the United States: Epidemiology and Rehabilitation.* National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention. Atlanta, GA.

DoD Definition of TBI

- A traumatic brain injury (TBI) is defined as a traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force and is indicated by new onset or worsening of at least one of the following clinical signs immediately following the event
  - Any period of loss of or a decreased level of consciousness
  - Any loss of memory for events immediately before or after the injury (post traumatic amnesia)
  - Any alteration in mental state at the time of the injury (e.g., confusion, disorientation, slowed thinking, alteration of consciousness/mental state)
  - Neurological deficits (e.g., weakness, loss of balance, change in vision, praxis, paresis/plegia, sensory loss, aphasia) that may or may not be transient
  - Intracranial lesion

Source: 1) VA/DoD Clinical Practice Guideline for the Management of Concussion-mild Traumatic Brain Injury February 2016 Page 5 of 53.
2) Assistant Secretary of Defense. Traumatic brain injury: Updated definition and reporting. Washington, DC: Department of Defense; 2015.
3) Centers for Disease Control Prevention; National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention. *Report to congress on traumatic brain injury in the United States: Epidemiology and rehabilitation.* Atlanta, GA: Centers for Disease Control Prevention; 2014.

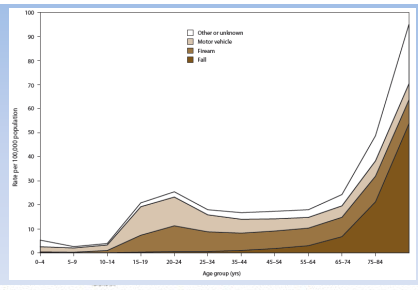
Classification of Head Injury: Presentation

(If a patient meets criteria in more than one category of severity, the higher severity level is assigned)			
Criteria	**Mild**	**Moderate**	**Severe**
Structural imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of Consciousness (LOC)	0-30 min	>30 min and <24 hours	>24 hours
Alteration of consciousness/ mental state (AOC)*	up to 24 hours	>24 hours; severity based on other criteria	
Posttraumatic amnesia (PTA)	0-1 day	>1 and <7 days	>7 days
Glasgow Coma Scale (GCS) (best available score in first 24 hours)**	13-15	9-12	<9

*Alteration of mental status must be immediately related to the trauma to the head. Typical symptoms would be looking and feeling dazed and uncertain of what is happening, confusion, and difficulty thinking clearly or responding appropriately to mental status questions, and being unable to describe events immediately before or after the trauma event.
**In April 2015, the DoD released a memorandum recommending against the use of GCS scores to diagnose TBI. See the memorandum for additional information.[3]

TBI Classification by Age Group - Mechanism

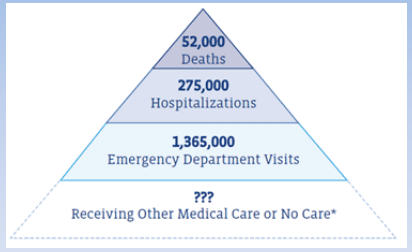
FIGURE 5. Average annual rates for traumatic brain injury deaths, by age group and external mechanism of injury --- United States, 1997--2007



Alternate Text: Figure 5 is a line graph showing the average annual rates for traumatic brain injury (TBI) deaths, by age group and external mechanism of injury, in the United States during 1997-2007. Firearm-related TBI death rates were highest among persons aged 20-24 and ≥75 years. Motor vehicle-related TBI death rates were highest among persons aged 15-24 years. Fall-related TBI death rates were highest among adults aged ≥75 years and increased significantly with age. In each age group and for each external cause, males had higher rates of TBI-related death than females.

http://www.cdc.gov/mmwr/preview/mmwrhtml/figures/s6005a1f5.gif

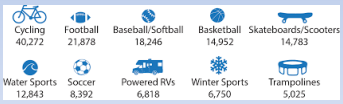
TBI Impact



National TBI Estimates. *The number of people with TBI who are not seen in an emergency department or who receive no care is unknown. Source: CDC

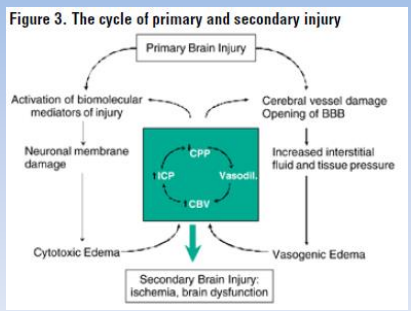
Mechanism of Injury

- Biomechanical
  - contact
  - acceleration-deceleration
  - rotational acceleration-deceleration
  - blast
- Mechanism
  - Falls
  - MVAs
  - Sports
  - Blast Induced neurotrauma
- PREVENTION IS PARAMOUNT!



What types of Brain Injury are you most concerned about as Critical Care Nurse?

Primary & Secondary Injury



Mild TBI

80-90 % of all TBI is Mild!

Mild TBI: Concussion

- Mild traumatic brain injury (mTBI) is defined as an acute brain injury resulting from mechanical energy to the head from external physical forces which result in a complex pathophysiologic process inducing biochemical changes in the brain
  - The injury produced results in a functional disturbance in brain function without typical structural findings indicative of injury (CT or MRI).
  - mTBI is composed of physical, cognitive, emotional, and sleep-related symptoms.
  - The impact on the patient may last minutes to months.

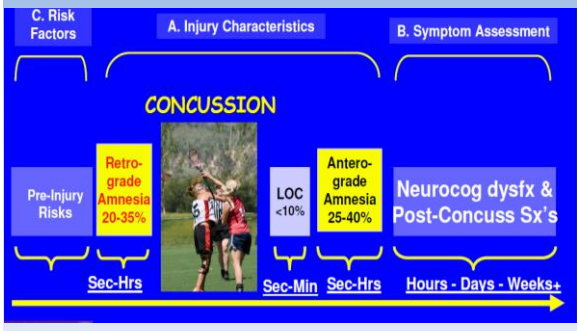
Facts and Stats

- Estimates of mild traumatic brain injury (mTBI) impact 2.5 million affected individuals annually in the United States, many of whom do not obtain immediate medical attention (CDC 2015)
- Approximately 2 million emergency department (ED) visits occur in the United States annually for TBI (CDC 2015)
  - only 56% of these are recognized at mTBI
- The incidence of clinician-confirmed TBI in U.S. soldiers returning from Iraq and Afghanistan is reported to be approximately 23%, where the majority are MTBI (Terrio et al., 2009).
- 2% of US population live with TBI caused disabilities
- Economic impact: $77 billion per year (CDC 2015, Faul et al 2010)

Suggested Citation: Centers for Disease Control and Prevention. (2015). Report to Congress on Traumatic Brain Injury in the United States: Epidemiology and Rehabilitation. National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention. Atlanta, GA.

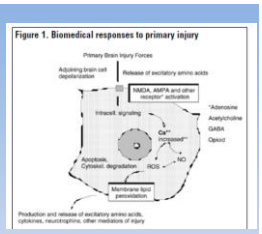
References: Christopher C. Giza, Jeffrey S. Kutcher, Stephen Ashwal, et al. *Neurology 2013;80;2250-2257; Mild TBI Guidelines AANN); &* Faul M, Xu L, Wald MM, Coronado VG. Traumatic brain injury in the United States: emergency department visits, hospitalizations, and deaths 2002–2006. Atlanta (GA): US Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2010: 1–71

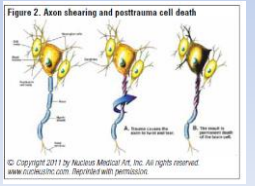
Anatomical Timeline of a Concussion Defining the Key Factors



Pathophysiology

- Primary injury:
  - Concussion is always a primary injury as is the initial neurological insult. **While the primary event cannot** be changed, steps can be taken to prevent secondary injury.





Progressive Biomechanical Changes

- Secondary injury ensues – hours to days
  - Complex neuro inflammatory changes
    - Abrupt, massive depolarization of neuronal, glial, and endothelial cells of the cerebral vessels
    - Release excitatory neuro transmitters, ionic shifts, altered glucose metabolism, and CBF and impaired axonal function
    - Excessive Ca influx-damage axonal exoskeleton creating axonal disconnection
    - Neuronal apoptosis and programmed cell death occur
  - Danger: Second impact syndrome can occur if another impact to the brain occurs in the immediate period (hours to few weeks) following the initial injury (primarily reported in children and young adults).
    - Blow results in neuro inflammatory response—massive cerebral edema and rapid rise in ICP

CLINICAL GUIDELINES PUBLISHED

Eastern Association for the Surgery of Trauma Practice Guidelines: Mild TBI

- Mild TBI defined
  - Acute alteration in brain function caused by a blunt external force and is characterized by
    - GCS 13-15
    - Loss of consciousness for 30 minutes or less
    - Duration of post traumatic amnesia < 24 hours.
  - CT brain normal

DOI: 10.1097/TA.0b013e3182701885
J Trauma Acute Care Surg
Volume 73, Number 5, Supplement 4

Eastern Association for the Surgery of Trauma Practice Guidelines: Mild TBI

- Recommendations Radiographic Study
  - Clinicians should perform brain CT scan on patients with suspected brain injury (II)
  - If CT resources limited, use set of criteria to determine which patients get a CT (II)
  - Clinicians should not routinely use MRI, PEAT or NMR in management of patients at present (III)

DOI: 10.1097/TA.0b013e3182701885
J Trauma Acute Care Surg
Volume 73, Number 5, Supplement 4

Eastern Association for the Surgery of Trauma Practice Guidelines: Mild TBI

- Recommendations
  - Patients with isolated TBI and negative CT brain
    - d/c from ED if no other injuries requiring admit (III)
  - Patients taking warfarin presenting with mild TBI should have their INR evaluated (III)
  - Anti-coagulated patients with ↑ INR and normal CT remain a significant risk for interval development of ICH and should be admitted for observations (III)
  - Patients may be advised that measurable deficits in cognition/memory usually resolve at 1 month but 20-40% of cases, post-concussive symptoms may present for 3 months or longer (III)

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Eastern Association for the Surgery of Trauma Practice Guidelines: Mild TBI

- Recommendations
  - Ability to operate motor vehicles safely may be impaired for a variable length of time in patients with MTBI. Individualize resumption of driving (III)
  - Timing return to work individualized with formal neuropsychologic testing considered (III)
  - Biochemical markers such as S100B, neuron specific enolase, and serum tau should not be routinely used in clinical management except in context of research protocol (III)

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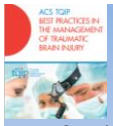
TQIP GUIDELINES
ACS



TQIP Guidelines Focus Severe TBI

- Section on Elderly Patients with TBI
  - Often present with GCS 13-15 and appear mild in nature due to brain atrophy
  - Neuro evaluation more complicated due to dementia, cognitive decline, and hearing/visual deficits
    - Determine baseline from family
  - Anti-coagulants/Anti-platelet medications exacerbate sequalae of TBI
    - Reversal is important to remember
  - Older age carries higher mortality and worse functional outcome

How do we detect mild TBI?

Evidence Based Literature:
Significant Variables associated with Mild TBI

TABLE 2. Evidence-Based Indicators for Concussion

Indicators of concussion, observed in alert[a] individuals after a force to the head, are:
Observed and documented disorientation or confusion[b] immediately after the event[13,15,28]
Impaired balance[c] within 1 day after injury[3,5]
Slower reaction time[d] within 2 days after injury[3,14,28]
Impaired verbal learning and memory[e] within 2 days after injury[6,10,14,28]

- Absolute prevalence of symptoms (50%) associated with concussion:
  - Headache, dizziness, blurred vision and nausea

Scene Assessment

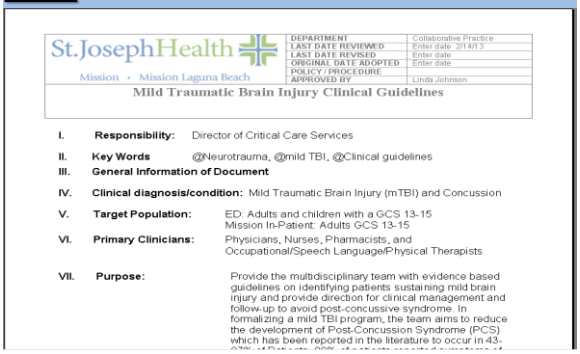
- **Sports Related**
  - Pre-season: IMPACT Testing
  - **AT event:**
    - **LOC:**
      - **Assess ABCs & Maintain Spine Precautions**
      - **Assess GCS and Pupils**
      - **Transport to ED**
    - **NO LOC**
      - **Athlete is removed from game and not allowed to return to play that day**
      - Sideline Assessment
        - » SCAT 2 or similar
        - » Balance Error Scoring System (BESS)
      - Post Game:
        - » Parent Education
        - » Cognitive Rest until symptom free
        - » Tylenol – no Advil
        - » Sleep and Quick Checks

•Follow-up
- •Medical Clearance
- •Retesting IMPACT
- •Teacher alert

Scene Assessment

- **EMS Response MVA or Fall**
  - Injury characteristics:
    - Mechanism of injury
    - History of event
  - GCS
    - 13-15 indicative of Mild TBI
  - Brief LOC < 30 minutes
  - Asses for key symptoms: headache, dizziness, nausea, blurred vision
  - Medical History
    - Older patient on anti-coagulants/anti-platelet
    - Young: ADD, ADHD, Migraine History, Learning disabilities, depression, etc
    - Recent concussion
  - Transport to ED for evaluation

Clinical Guidelines Created



St. Joseph Health
Mission • Mission Laguna Beach

DEPARTMENT	Collaborative Practice
LAST DATE REVIEWED	Enter date 3/14/13
LAST DATE REVISED	Enter date
ORIGINAL DATE ADOPTED	Enter date
POLICY / PROCEDURE	
APPROVED BY	Linda Johnson

Mild Traumatic Brain Injury Clinical Guidelines

I. **Responsibility:** Director of Critical Care Services

II. **Key Words** @Neurotrauma, @mild TBI, @Clinical guidelines

III. **General Information of Document**

IV. **Clinical diagnosis/condition:** Mild Traumatic Brain Injury (mTBI) and Concussion

V. **Target Population:** ED: Adults and children with a GCS 13-15
Mission In-Patient: Adults GCS 13-15

VI. **Primary Clinicians:** Physicians, Nurses, Pharmacists, and Occupational/Speech Language/Physical Therapists

VII. **Purpose:** Provide the multidisciplinary team with evidence based guidelines on identifying patients sustaining mild brain injury and provide direction for clinical management and follow-up to avoid post-concussive syndrome. In formalizing a mild TBI program, the team aims to reduce the development of Post-Concussion Syndrome (PCS) which has been reported in the literature to occur in 43-

Standard Work

mTBI- Concussion Guidelines
Standard of Work

Triage

- ☐ Identify patients that present with concussion symptoms
- ☐ Document the history of the event in triage note
- ☐ Complete ACE ED form
- ☐ Place concussion packet with the patient chart

Bedside Treatment

- ☐ Place patient in quiet room
- ☐ Lights dimmed or off
- ☐ Limit noise (monitor alarms, etc.)
- ☐ Minimize visitors and limit phone calls
- ☐ Place the "Sleeping Brain" sign on the door
- ☐ Neuro assessment every hour and more frequently if a decrease in LOC

Discharge

- ☐ Give verbal instruction on cognitive rest, red flags, post concussive syndrome, follow up care
- ☐ Give written brochure for adult patients
- ☐ Give blank ACE form for the patient to take to their PMD
- ☐ Give a completed copy of the ACE ED form for the patient to take to their PMD

Triage Assessment

Physical

- Headache
- Nausea
- Vomiting
- Balance problems
- Dizziness
- Visual problems
- Fatigue
- Sensitivity to light
- Sensitivity to noise
- Numbness/tingling
- Dazed
- Stunned

Triage Assessment

Cognitive

- Feeling mentally "foggy"
- Feeling slowed down
- Difficulty concentrating
- Difficulty remembering
- Forgetful of recent information and conversations
- Confused about recent events
- Answers questions slowly
- Repeats questions

Triage Assessment

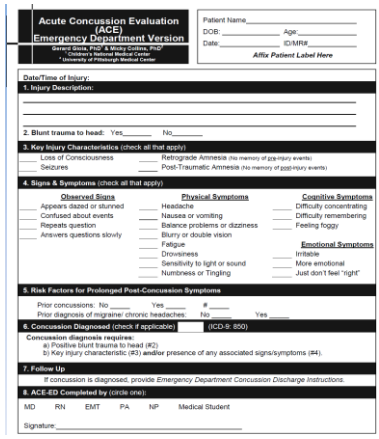
- **Emotional**
- Irritable
- Sadness
- More emotional
- Nervousness

- **Sleep**
- Drowsiness
- Sleeping more than usual
- Sleeping less than usual
- Difficulty falling asleep

Brain Fog

- "Symptoms such as migraine-type headache and dizziness or self-described "fogginess" seem to be predictive of longer recovery. Interestingly, loss of consciousness at the time of the concussion is not predictive of longer recovery[5]".

ACE Tool for ED



Acute Concussion Evaluation (ACE) Emergency Department Version

Gerard Gioia, PhD* & Mindy Collins, PhD*
* Children's National Medical Center
* University of Pittsburgh Medical Center

Patient Name:
DOB: Age:
Date: ID/MR#:
Affix Patient Label Here

Date/Time of Injury:

1. Injury Description:

2. Blunt trauma to head: Yes No

3. Key Injury Characteristics (check all that apply)

- Loss of Consciousness
- Seizures
- Retrograde Amnesia (No memory of pre-injury events)
- Post-Traumatic Amnesia (No memory of post-injury events)

4. Signs & Symptoms (check all that apply)

Observed Signs	Physical Symptoms	Cognitive Symptoms
Appears dazed or stunned	Headache	Difficulty concentrating
Confused about events	Nausea or vomiting	Difficulty remembering
Repeats question	Balance problems or dizziness	Feeling foggy
Answers questions slowly	Blurry or double vision	
	Fatigue	**Emotional Symptoms**
	Drowsiness	Irritable
	Sensitivity to light or sound	More emotional
	Numbness or Tingling	Just don't feel "right"

5. Risk Factors for Prolonged Post-Concussion Symptoms

Prior concussions: No Yes # Prior diagnosis of migraine/ chronic headaches: No Yes

6. Concussion Diagnosed (check if applicable) (ICD-9: 850)

Concussion diagnosis requires:
a) Positive blunt trauma to head (#2)
b) Key injury characteristic (#3) and/or presence of any associated signs/symptoms (#4).

7. Follow Up

If concussion is diagnosed, provide *Emergency Department Concussion Discharge Instructions*.

8. ACE-ED Completed by (circle one):

MD RN EMT PA NP Medical Student

Signature:

ACE ED Tool Provided courtesy of Gerard Gioia PhD

Diagnostics-Adults

Adult Criteria: 18 years and older

A non-contrast CT of head should be ***considered*** in mild TBI pts **with LOC or Post Traumatic Amnesia** (PTA) only if one of the following is present –

- vomiting,
- headache,
- age > 60,
- drug or alcohol intoxication,
- deficits in short term memory,
- physiologic evidence of trauma above the clavicle,
- post traumatic seizure,
- GCS < 15,
- focal neuro deficit, or coagulopathy

Diagnostics-Adults

Adult Criteria: 18 years and older

Non contrast CT head should be considered in MTBI patients **with no LOC or PTA if**:

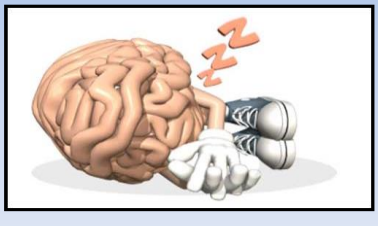
- Focal neurologic deficit present
- Vomiting
- Severe headache
- Age>65
- Signs of Basilar skull fracture
- GCS <15
- Coagulopathy
- Dangerous mechanism of injury

Monitoring the Minor TBI in ED

- Close monitoring of GCS & Symptoms
  - Admit
  - 30 minutes
- Treating headache with non-narcotics
- Treating nausea/vomiting
- Keep in Quiet Area (if possible)

Cognitive Rest

Brain at rest. DO NOT DISTURB!



Cognitive Rest-Cocooning

- Rationale:
  - The literature is in general agreement that strenuous cognitive and physical activity may increase symptoms and delay recovery
- Room lighting is to be kept dim
- Promote rest and periods of uninterrupted sleep
- Patients should not watch the TV, use a cell phone, computer, iPad or any other electronic device, including playing video games, or listening to iPods or radios
- Anything causing mental exertion should be avoided such as reading or homework, or anything that takes concentration to perform
- Limit visitors 1-2
- Patient should not make any important life decisions a this time

Education Begins

Post Concussive Syndrome

Cluster of symptoms that frequently occur after minor head injury or other causes of head acceleration-deceleration

Cognitive

- Memory
- Poor concentration
- Easily distracted
- Slowed thinking
- Sensitive to light
- Sensitive to noise
- Sleep problems
- Language
- Impaired judgment
- Decreased speed

Post Concussive Syndrome

Somatic

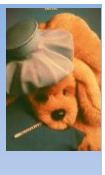
- Headache
- Dizziness
- Fatigue
- Blurred vision
- Ataxia
- Neck pain
- Smell/taste

Post Concussive Syndrome

Affective

- Depression
- Irritability
- Decreased drive
- Anxiety
- Emotional labile
- Impatient
- Poor frustration

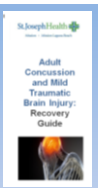
Post Concussive Syndrome: Impact

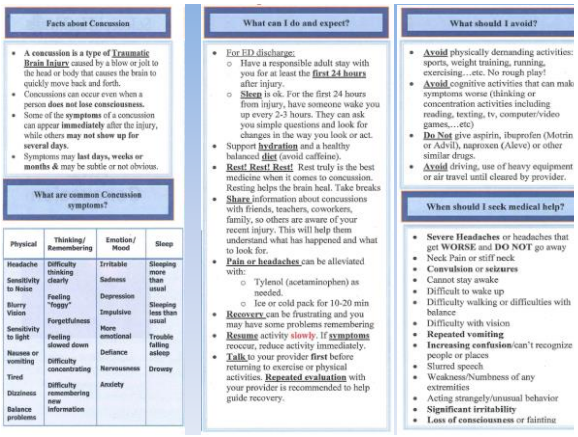


- Post concussive symptoms affect
  - >58% of patients 1 month after the injury
  - 32% of patients at 6 months
  - 15% at 1 year
- Provides long term impact of PCS
  - 6% experience depression at 3 months
  - 15-20%reported at least 1 behavioral problem
  - Employment:
    - miss an average of 47 days of work
    - Unable to work
      - 56% report unable to work at 2 weeks
      - 27% unable to work at 6 weeks.
      - ~ 20 % of patients are unemployed at 1 year
  - 9-33% had moderate to severe disability at 1 year

Disposition Home

- D/C Home with specific instructions
  - Facts about concussion
  - When should I return to the ER?
  - What can I do and Expect?
    - Need 2-4 more hours sleep per night after concussion
    - Continue cognitive rest until symptom free
  - What to avoid until symptom free
    - Alcohol
    - Cognitive, Physical and Psychological Stressors
  - Returning to work or school
    - MD follow-up
  - How can I prevent further concussion?
  - What is Post concussion syndrome?





Facts about Concussion

- A concussion is a type of Traumatic Brain Injury caused by a blow or jolt to the head or body that causes the brain to quickly move back and forth.
- Concussions can occur even when a person does not lose consciousness.
- Some of the symptoms of a concussion can appear immediately after the injury, while others may not show up for several days.
- Symptoms may last days, weeks or months & may be subtle or not obvious.

What are common Concussion symptoms?

Physical	Thinking/ Remembering	Emotion/ Mood	Sleep
Headache	Difficulty thinking clearly	Irritable	Sleeping more than usual
Sensitivity to Noise	Feeling "foggy"	Sadness	Sleeping less than usual
Blurry Vision	Forgetfulness	Depression	Trouble falling asleep
Sensitivity to light	Feeling slowed down	Impulsive	Drowsy
Nausea or vomiting	Difficulty concentrating	More emotional	
Tired	Difficulty remembering new information	Defiance	
Dizziness		Nervousness	
Balance problems		Anxiety	

What can I do and expect?

- For ED discharge:
  - Have a responsible adult stay with you for at least the first 24 hours after injury.
  - Sleep is ok. For the first 24 hours from injury, have someone wake you up every 2-3 hours. They can ask you simple questions and look for changes in the way you look or act.
- Support hydration and a healthy balanced diet (avoid caffeine).
- Rest! Rest! Rest! Rest truly is the best medicine when it comes to concussion. Resting helps the brain heal. Take breaks
- Share information about concussions with friends, teachers, coworkers, family, so others are aware of your recent injury. This will help them understand what has happened and what to look for.
- Pain or headaches can be alleviated with:
  - Tylenol (acetaminophen) as needed.
  - Ice or cold pack for 10-20 min
- Recovery can be frustrating and you may have some problems remembering
- Resume activity slowly. If symptoms reoccur, reduce activity immediately.
- Talk to your provider first before returning to exercise or physical activities. Repeated evaluation with your provider is recommended to help guide recovery.

What should I avoid?

- Avoid physically demanding activities: sports, weight training, running, exercising…etc. No rough play!
- Avoid cognitive activities that can make symptoms worse (thinking or concentration activities including reading, texting, tv, computer/video games…etc)
- Do Not give aspirin, ibuprofen (Motrin or Advil), naproxen (Aleve) or other similar drugs.
- Avoid driving, use of heavy equipment or air travel until cleared by provider.

When should I seek medical help?

- Severe Headaches or headaches that get WORSE and DO NOT go away
- Neck Pain or stiff neck
- Convulsion or seizures
- Cannot stay awake
- Difficult to wake up
- Difficulty walking or difficulties with balance
- Difficulty with vision
- Repeated vomiting
- Increasing confusion/can't recognize people or places
- Slurred speech
- Weakness/Numbness of any extremities
- Acting strangely/unusual behavior
- Significant irritability
- Loss of consciousness or fainting

Returning to school

School: Returning to school should be based upon careful attention to your child's symptoms. Your child may need ***temporary accommodations*** to enable them to be successful and symptom free

School personnel should watch for:

- Increased problems paying attention
- Increased problems remembering or learning new information
- Longer time needed to complete tasks or assignments
- Greater irritability, less able to cope with stress.

ED Discharge Instructions Children

Caring for your Child after a Concussion

RETURNING TO SCHOOL

Returning to school should be based upon your child's symptoms. You may need to work with teachers at school to make a plan specific for your child's return to school. This will help them be successful and symptom free.

School personnel should watch for:
• Increased problems paying attention.
• Increased problems remembering or learning new information.
• Longer time needed to complete tasks or assignments.
• Greater irritability, less able to cope with stress.

HOW CAN I PREVENT FURTHER CONCUSSIONS?

• Wear a seat belt.
• Wear a helmet that fits properly
when biking, skateboarding, sledding,
batting, skiing, or other contact sports.
• Use the right protective equipment
and follow safety rules.
• Prevent falls at home by using safety
gates at the top and bottom of stairs
for younger children.
• Remove trip hazards
• Improve lighting
• Place non-slip mats in the bathtubs
and secure loose rugs

American Guidelines Return to Play

- Return to play guidelines: Concussion symptoms must be resolved before returning to exercise
- Progressive gradual stepwise process
- Return to practice/play includes medical clearance from a licensed healthcare provider

American Medical Society for Sports Medicine Position Statement: Concussion in Sport

Kimberly G. Harmon, MD,* Jonathan Drezner, MD,† Matthew Gammons, MD,‡ Kevin Guskiewicz, ATC, PhD,§ Mark Halstead, MD,‖ Stan Herring, MD,¶ Jeff Kutcher, MD,** Andrea Pana, MD,†† Morgan Putukian, MD,‡‡ and William Roberts, MD§§

Clin J Sport Med • Volume 23, Number 1, January 2013

TABLE 5. Graduated Return-to-Play Protocol

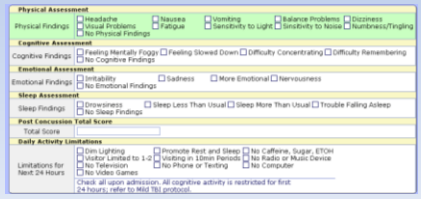
Rehabilitation Stage	Objective of Stage
No activity	Recovery
Light aerobic exercise	Increase heart rate
Sport specific exercise	Add movement
Non-contact training drills	Exercise, coordination, and cognitive load
Full-contact practice	Restore athlete's confidence; coaching staff assesses functional skills
Return to play	

Patient Admitted to Floor

- Frequent neurologic checks
  - performed at least every 4 hours and prn for the first 24 hours
  - Changes in the patient's level of consciousness, worsening of GCS, pupil changes or worsening neurological symptoms should be reported to the physician immediately
- Care priorities
  - intravenous fluids with Normal Saline
  - acetaminophen for headache avoiding non-steroidal anti-inflammatory agents
  - medications for nausea and/or vomiting

Patient Admitted to Floor

- Assess pt for any physical, cognitive, emotional and sleep pattern symptoms to establish a baseline assessment for concussion symptoms using the "Post-Concussion Nursing Assessment" checklist
  - Complete daily



Cognitive Rest "Cocooning"

- Once symptoms clear, and the patient is not on any medications that would mask post concussive symptoms, the patient will gradually be able to add more cognitive activity.
  - least demanding cognitive activities will be attempted first (i.e. being read to, listening to music, talking on the phone, watching some T.V. for short periods.)
  - nurse will specify what the limitations are for each day and these will be in effect for the next 24 hours until the next assessment
- If at any time any of the symptoms return the patient will be restricted to the cognitive rest level of the last day when the symptoms were not present

Evaluation and Disposition

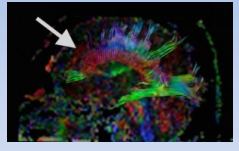
- Prior to discharge, if appropriate, Speech Therapy will be consulted and shall assist with recommendations on any outpatient treatment
- Provide a copies
  - "Concussion Assessment Tool" from in the ED on initial admit
  - Mild Traumatic Brain Injury (MTBI) Discharge Instructions
  - Blank ACE physician office assessment form

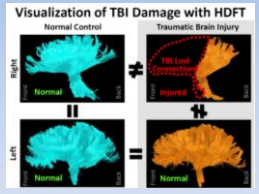
Concussions Add Up

An athlete who has a history of 1 or more concussions is at greater risk for being diagnosed with another concussion. An alternative hypothesis is that residual concussion symptoms may slow reaction times or cognitive processing, putting injured athletes at risk for an unanticipated hit.

The Hidden Truth: Emerging Technology

Diffusion tensor imaging of frontal lobe after a mild TBI. Axonal tracts in the frontal lobe are missing here.





Laboratory Analysis

Blood Biomarkers for Brain Injury in Concussed Professional Ice Hockey Players

RESULTS Concussed players had increased levels of the axonal injury biomarker total tau (median, 10.0 pg/mL; range, 2.0-102 pg/mL) compared with preseason values (median, 4.5 pg/mL; range, 0.06-22.7 pg/mL) ($P < .001$). The levels of the astroglial injury biomarker S-100 calcium-binding protein B were also increased in players with sports-related concussion

Near Future: Biomarkers

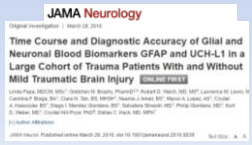
- Issue: Diagnosis of TBI in acute setting major obstacle
  - GCS clinical tool
    - Does not help with pathology
  - CT detects bleeding
    - Does not help with mild TBI
- Exploring Brain Biomarkers in TBI
  - S100B, GFAP (Flial fibriallary acidic protein), and Neuron specific endolase

Workshop Materials

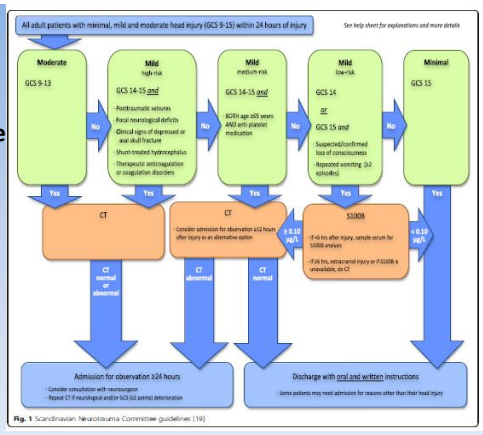
Discussion Paper:

"Advancing the Development of Biomarkers in Traumatic Brain Injury"

Released in preparation for public workshop held at FDA March 3 2016



Near Future



Minor TBI

Validation of the Scandinavian guidelines for initial management of minimal, mild and moderate traumatic brain injury in adults

- Validation of Scandinavian guidelines

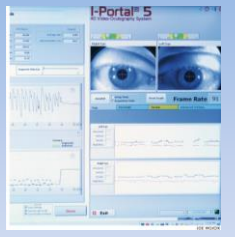
Methods: We performed a nested cohort study of adults with mild TBI presenting to six emergency departments in New York and Pennsylvania within 6 h of injury. Patients were managed according to existing guidelines for CT selection. All patients underwent head CT scanning and serum S100B measurement, as well as prospective collection of clinical variables, as a requirement of the parent study. Using the SNC guidelines, S100B values and clinical variables were applied to these subjects, classifying each into one of five pre-defined severity categories, as well as predicting the need for head CT scanning to identify IH. This classification was then compared to actual head CT results to determine guideline sensitivity and specificity.

Results: In total, 662 adults (mean age 42 years, range 18–96; 258 females, 549 Caucasians) were available for analysis; 36 (5 %) had IH on head CT scan. The SNC guidelines had a sensitivity of 97 % (95 % CI, 84–100 %) and a specificity of 34 % (95 % CI, 30–37 %) for the detection of IH on head CT. Application of the SNC guidelines would have resulted in a CT reduction of 32 % (211/662 patients). One patient with low-risk mild TBI and a S100B level under 0.10 µg/L had a traumatic CT abnormality and would have been discharged with strict adherence to the guidelines. However, this patient did not need any intervention for the injury and had a good outcome.

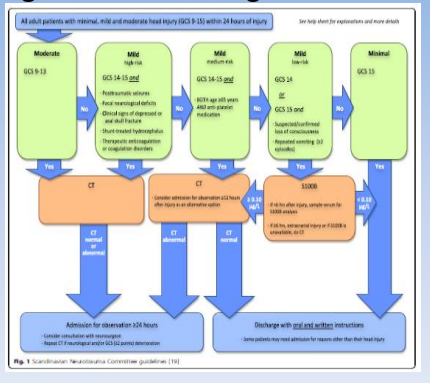
Conclusion: Using the SNC guideline could save approximately one third of CT scans in a pre-selected cohort of mild TBI patients with little or no impact on patient outcome.

Near Future: Technology

- Neuro Kinetics Inc
  - Developing monitor I-Portal 5 Portable Assessment System
  - Used to detect mild TBI
  - Displays eye tracking as the subject is looking at a test stimuli



Algorithm on Management of Mild



Moderate TBI

- Clinical Presentation
  - No USA consensus guidelines exist
  - Scandinavian Guidelines developed from consensus review of the literature

Lindén et al. BMC Medicine 2011, 9:50
http://www.biomedcentral.com/1741-7015/9/50

Scandinavian guidelines for initial management of minimal, mild and moderate head injuries in adults: an evidence and consensus-based update

Johan Undén[1*], Tor Ingebrigtsen[2] and Bertil Romner[3], for the Scandinavian Neurotrauma Committee (SNC)

Moderate TBI

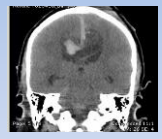
- No universally accepted definition
  - GCS 9-12
  - Duration of LOC 31-59 min
  - PTA 1-24 hours

GCS 9-12: Types of Injuries Bruises and Bleeds

Subarachnoid Hemorrhage rt Trauma

Small Epidural Hematoma

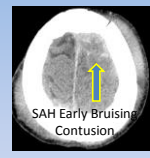
Small Intraventricular Bleed from fall

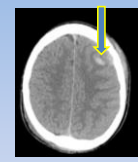


Subdural Hematoma
GCS 12
Age 72
Older Patients have more room to expand!

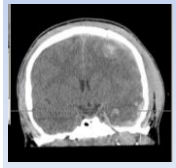
GCS 9-12: Types of Injuries Bruises and Bleeds

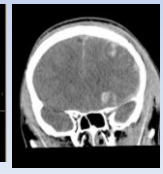
GCS on admit: 12
CT-6/11 2056





Early Contusion





Intubated after admit to SICU: GCS 7 at 2200

Management of Moderate TBI

- Scandinavian guidelines:
  - Patients with GCS ≤ 13, clinical signs of depressed or basal skull fracture, anti-coagulation disorder, post-traumatic seizure or focal neuro deficit should have
    - CT scan
    - Admit to hospital for observation
- Special consideration
  - Repeat CT in 4-6 hours in these patients and repeat stat if patients GCS changes by 2 or more points
  - Close neurologic monitoring needed in ED on these patients due to deterioration potential!!!

Management of Moderate TBI

- If patient on Anti-coagulation/anti-platelet medications and have a CT evidence of bleeding
  - Note the type of medication
  - Stop drug
  - Reversal strategies – see next page

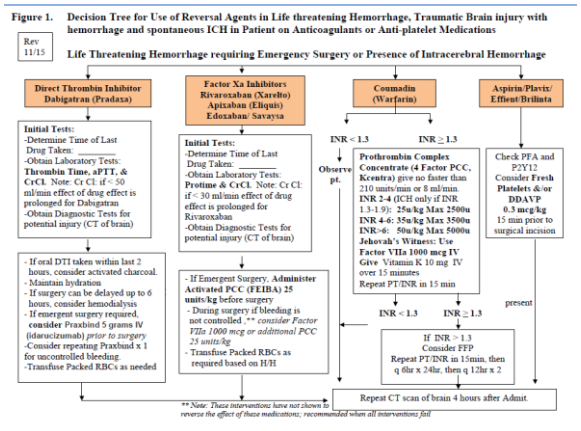


Figure 1. Decision Tree for Use of Reversal Agents in Life threatening Hemorrhage, Traumatic Brain injury with hemorrhage and spontaneous ICH in Patient on Anticoagulants or Anti-platelet Medications

Rev 11/15

Life Threatening Hemorrhage requiring Emergency Surgery or Presence of Intracerebral Hemorrhage

Direct Thrombin Inhibitor Dabigatran (Pradaxa)

Initial Tests:
-Determine Time of Last Drug Taken: _____
-Obtain Laboratory Tests: **Thrombin Time, aPTT, & CrCl.** Note: Cr Cl: if < 50 ml/min effect of drug effect is prolonged for Dabigatran
-Obtain Diagnostic Tests for potential injury (CT of brain)

- If oral DTI taken within last 2 hours, consider activated charcoal.
- Maintain hydration
- If surgery can be delayed up to 6 hours, consider hemodialysis
- If emergent surgery required, consider Praxbind 5 grams IV (idarucizumab) *prior to surgery*
-Consider repeating Praxbind x 1 for uncontrolled bleeding.
-Transfuse Packed RBCs as needed

Factor Xa Inhibitors Rivaroxaban (Xarelto) Apixaban (Eliquis) Edoxaban/ Savaysa

Initial Tests:
-Determine Time of Last Drug Taken: _____
-Obtain Laboratory Tests: **Protime & CrCl.** Note: Cr Cl: if < 30 ml/min effect of drug effect is prolonged for Rivaroxaban
-Obtain Diagnostic Tests for potential injury (CT of brain)

- If Emergent Surgery, **Administer Activated PCC (FEIBA) 25 units/kg** before surgery
- During surgery if bleeding is not controlled ,** *consider Factor VIIa 1000 mcg or additional PCC 25 units/kg*
- Transfuse Packed RBCs as required based on H/H

Coumadin (Warfarin)

INR < 1.3 INR ≥ 1.3

Observe pt.

Prothrombin Complex Concentrate (4 Factor PCC, Kcentra) give no faster than 210 units/min or 8 ml/min.
INR 2-4 (ICH only if INR 1.3-1.9): **25u/kg Max 2500u**
INR 4-6: 35u/kg Max 3500u
INR>6: 50u/kg Max 5000u
Jehovah's Witness: Use Factor VIIa 1000 mcg IV
Give Vitamin K 10 mg IV over 15 minutes
Repeat PT/INR in 15 min

INR < 1.3 INR ≥ 1.3

If INR > 1.3
Consider FFP
Repeat PT/INR in 15min, then q 6hr x 24hr, then q 12hr x 2

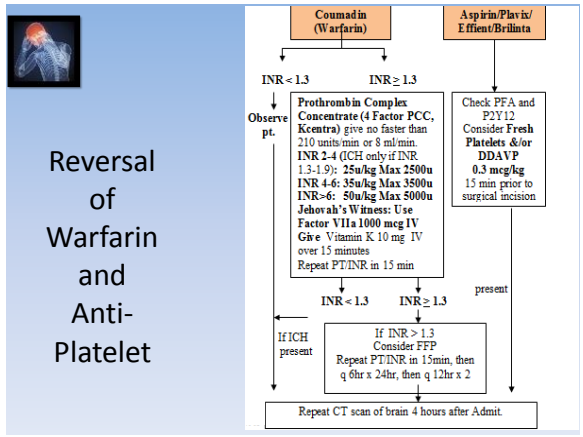
Aspirin/Plavix/ Effient/Brilinta

Check PFA and P2Y12
Consider **Fresh Platelets &/or DDAVP 0.3 mcg/kg**
15 min prior to surgical incision

present

Repeat CT scan of brain 4 hours after Admit.

** *Note: These interventions have not shown to reverse the effect of these medications; recommended when all interventions fail*



Reversal of Warfarin and Anti-Platelet

Coumadin (Warfarin)

INR < 1.3 INR ≥ 1.3

Observe pt.

Prothrombin Complex Concentrate (4 Factor PCC, Kcentra) give no faster than 210 units/min or 8 ml/min.
INR 2-4 (ICH only if INR 1.3-1.9): **25u/kg Max 2500u**
INR 4-6: 35u/kg Max 3500u
INR>6: 50u/kg Max 5000u
Jehovah's Witness: Use Factor VIIa 1000 mcg IV
Give Vitamin K 10 mg IV over 15 minutes
Repeat PT/INR in 15 min

INR < 1.3 INR ≥ 1.3

If ICH present

If INR > 1.3
Consider FFP
Repeat PT/INR in 15min, then q 6hr x 24hr, then q 12hr x 2

Aspirin/Plavix/ Effient/Brilinta

Check PFA and P2Y12
Consider **Fresh Platelets &/or DDAVP 0.3 mcg/kg**
15 min prior to surgical incision

present

Repeat CT scan of brain 4 hours after Admit.

Reversal of Warfarin

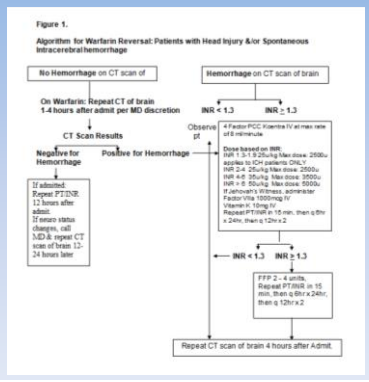


Figure 1.

Algorithm for Warfarin Reversal: Patients with Head Injury &/or Spontaneous Intracerebral hemorrhage

No Hemorrhage on CT scan of

Hemorrhage on CT scan of brain

On Warfarin: Repeat CT of brain 1-4 hours after admit per MD discretion

INR < 1.3 INR ≥ 1.3

Observe pt

4 Factor PCC Kcentra IV at max rate of 8 ml/minute

Dose based on INR:
INR 1.3-1.9:25u/kg Max dose: 2500u
applies to ICH patients ONLY
INR 2-4: 25u/kg Max dose: 2500u
INR 4-6: 35u/kg Max dose: 3500u
INR > 6: 50u/kg Max dose: 5000u
If Jehovah's Witness, administer Factor VIIa 1000mcg IV
Vitamin K 10mg IV
Repeat PT/INR in 15 min, then q 6hr x 24hr, then q 12hr x 2

CT Scan Results

Negative for Hemorrhage

If admitted: Repeat PT/INR 12 hours after admit.
If neuro status changes, call MD & repeat CT scan of brain 12-24 hours later

Positive for Hemorrhage

INR < 1.3 INR ≥ 1.3

FFP 2 - 4 units. Repeat PT/INR in 15 min, then q 6hr x 24hr, then q 12hr x 2

Repeat CT scan of brain 4 hours after Admit.

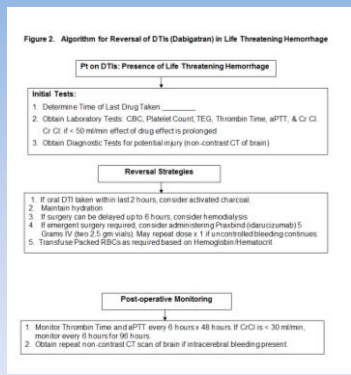


Figure 2. Algorithm for Reversal of DTIs (Dabigatran) in Life Threatening Hemorrhage

Pt on DTIs: Presence of Life Threatening Hemorrhage

Initial Tests:
1. Determine Time of Last Drug Taken: _____
2. Obtain Laboratory Tests: CBC, Platelet Count, TEG, Thrombin Time, aPTT, & Cr Cl. Cr Cl: if < 50 ml/min effect of drug effect is prolonged
3. Obtain Diagnostic Tests for potential injury (non-contrast CT of brain)

Reversal Strategies

1. If oral DTI taken within last 2 hours, consider activated charcoal.
2. Maintain hydration
3. If surgery can be delayed up to 6 hours, consider hemodialysis.
4. If emergent surgery required, consider administering Praxbind (idarucizumab) 5 Grams IV (two 2.5 gm vials). May repeat dose x 1 if uncontrolled bleeding continues.
5. Transfuse Packed RBCs as required based on Hemoglobin/Hematocrit

Post-operative Monitoring

1. Monitor Thrombin Time and aPTT every 6 hours x 48 hours. If CrCl is < 30 ml/min, monitor every 6 hours for 96 hours.
2. Obtain repeat non-contrast CT scan of brain if intracerebral bleeding present.

MH Reversal Algorithm

DTIs
i.e.
Dabigatran

Pt on Factor Xa Inhibitors: Presence of Life Threatening Hemorrhage

Initial Tests:
1. Determine Time of Last Drug Taken: _____
2. Obtain Laboratory Tests: CBC, Platelet Count, Protime & CrCl. Cr Cl: if < 50 ml/min effect of drug effect is prolonged
3. Obtain Diagnostic Tests for potential injury (non contrast CT of brain)

Reversal Strategies

1. If emergent surgery required, consider administering -Activated PCC (4 Factor II, VIIa, IX, and X) 25-50 Units/kg prior to surgery. May give 25 units/kg prior to surgery and repeat with 25 units/kg during surgery -During surgery if bleeding is not controlled, consider giving Factor VIIa 1000 mcg**
2. Transfuse Packed RBCs as required based on Hemoglobin/Hematocrit

Post operative Monitoring

1. Monitor PT every 6 hours x 48 hours. If CrCl is < 30 ml/min, monitor every 6 hours for 96 hours.
2. Obtain repeat non-contrast CT scan of brain if intracerebral bleeding present.

** ***Note***: *These interventions have not shown to reverse the effect of these medications; recommended when al interventions fail*

MH Reversal Algorithm Factor Xa Inhibitors
i.e.
Rivaroxaban and Apixaban

Nursing Priorities

- Placement
  - ICU vs Floor Neuro Unit
    - ICU: GCS 9-12 or Any evidence of bleeding on CT & patient is on AC/Anti-platelet meds even if GCS 13-15
    - Floor Neuro Unit: GCS 13-15 with negative CT or minimal SAH
  - Priorities
    - Monitor Neuro checks q 1-2 hours x 24 hours
    - Keep pt in quiet room (cognitive rest)
    - Speech language evaluation
    - Fall Risk

Case study

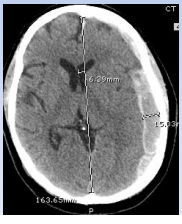
A patient who falls and bonks his head on Pradaxa, Plavix, and ASA

Case and Event

- 72 year old male with history of atrial fibrillation falls and hits his head with LOC
  - Medications: Pradaxa, Plavix and aspirin
    - Pradaxa taken 14 hours prior
  - Medical History
    - Cardiac Stents
    - Chronic Atrial fibrillation with failed ablation tx
    - High cholesterol, CAD, hypertension
    - Alcohol use
  - CT scan at another hospital reveals a large SDH

Neuro Evaluation

- Initially: Awake and oriented x 2 in ED (GCS 14)
- Speech clear
- Moving all 4 extremities 5/5
- Lab
  - PT 16.7
  - INR 1.4
  - aPTT 40
  - PFA epi >300
  - PFA adp 70 (normal)
    - Indicative of ASA effect
- Deteriorates LOC within 2 hours of arrival in ED to GCS 9



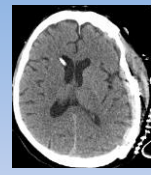
Coagulation Reversal

- PCC/Factor VII 2 mg
- FFP 2 units
- DDAVP 0.3 mcg/kg IV
- Platelets 2 super packs

OR

- Subdural hematoma removed
- ICP placed
  - Opening pressure 25
- Able to control bleeding in field
- To ICU post op

Hospital Stay



- ICU Care x 14 days
  - ICP well controlled
  - Intubated x 12 days (detox issues)
  - ASA restarted Day 5 (rectal)/Day 13 oral
- PCSU x 1 day
- ARU x 14 days
- Back to work 8 weeks later

Severe TBI
GCS 3-8

Severe TBI

- Sum score 3 to 8 &/or motor score ≤ 5
- Brain injury association
  - Prolonged unconscious state or coma lasting days, weeks or months
- CT criteria

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Table 12-6. Marshall CT Classification of TBI

Category	Definition
Diffuse injury I (no visible pathology)	No visible intracranial pathology seen on CT scan
Diffuse injury II	Cisterns are present with midline shift < 5 mm, and/or lesion densities present No high- or mixed-density lesion > 25 ml; may include bone fragments and foreign bodies
Diffuse injury III	Cisterns compressed or absent with midline shift 0–5 mm No high- or mixed-density lesion > 25 ml
Evacuated mass lesion	Any lesion surgically evacuated
Nonevacuated mass	High- or mixed-density lesion > 25 ml not surgically evacuated

Note. CT = computed tomography. Adapted from "Traumatic brain injury: Assessment, resuscitation and early management," by I. Moppett, 2007, British Journal of Anaesthesia, *99(1), pp. 18–31.*

Managing Severe TBI

- 2015 ACS TQIP Guidelines

Table 2. Goals of Treatment

Pulse Oximetry ≥ 95%	ICP 20 - 25 mmHg	Serum sodium 135-145
PaO_2 ≥ 100 mmHg	$PbtO_2$ ≥ 15 mmHg	INR ≤ 1.4
$PaCO_2$ 35-45 mmHg	CPP ≥ 60 mmHg*	Platelets ≥ 75 x 10^3 / mm^3
SBP ≥ 100 mmHg	Temperature 36.0-38°C	Hemoglobin ≥ 7 g/dl
PH 7.35-7.45	Glucose 80-180 mg/dL	

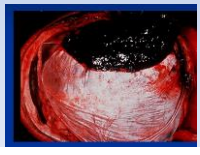
These clinical parameters should be maintained as part of goal-directed TBI treatment. Some of these goals are more relevant for patients in the intensive care unit (ICU) setting (e.g., CPP, ICP, PbtO2) while others are applicable to all TBI patients. Adequate oxygenation and normocapnia should be maintained. Patients with significant pulmonary issues (e.g. Acute Respiratory Distress Syndrome) may require lung-specific parameters. Systolic blood pressure (SBP) and mean arterial pressure should be monitored closely to avoid hypotension. The goal for temperature management is normothermia. Core body temperature should be kept <38°C.

2016 BTF Guidelines (in press)

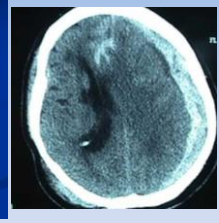
- Ventilation Therapies IIB and III
- Hyperosmolar Therapy III
- CSF Drainage III
- Anesthetics, Analgesics, and Sedatives IIB
- Steroids I
- Nutrition IIA and III
- Infection Prophylaxis IIA and III
- DVT Prophylaxis III
- Seizure Prophylaxis IIA
- Intracranial Pressure Monitoring II and III
- Cerebral Perfusion Pressure Monitoring IIB
- Advanced Cerebral Monitoring III
- Thresholds: BP, ICP, CPP and Advanced Cerebral Monitoring III
- Decompressive Craniectomy IIA
- Prophylactic Hypothermia IIB

Guidelines for the Management of Severe Traumatic Brain Injury (4th Edition)

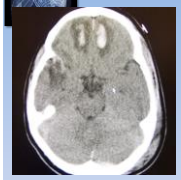
Primary Injury: Epidural Hematoma

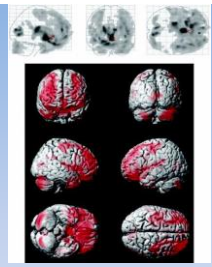


Primary Injury: Subdural Hematoma



Cerebral Contusions






- Frequently frontal or temporal regions
- Vasogenic edema and central necrosis
- Diagnosis: CT and Exam

Location, Location, Location…

- Bleeds in the posterior part of the brain are particularly dangerous and considered neurosurgical emergencies!

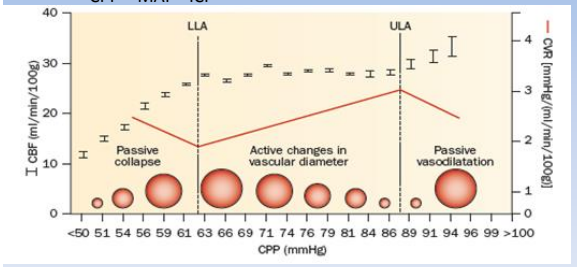


Secondary Brain Injury

- Secondary Head Injury
  - Extracranial causes
    - Hypotension
    - Hypocapnia and Hypercapnia
    - Hypoxia
    - Anemia
    - Acidosis
    - Hyperglycemia
    - Hyperthermia

Cerebral Blood Flow

- CBF = CPP / CVR
  - CPP = MAP - ICP



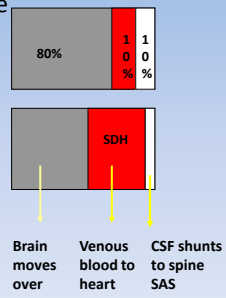
Cerebral Blood Flow

Autoregulation

- Vasomotor control
  - Intact: Increase in CPP causes vasoconstriction and decrease in ICP
  - Vasomotor reactivity failure: Increase in CPP causes vasodilation and inc ICP
- Flow metabolism
  - ↑ metabolism ↑ CBF
- Metabolic substances
  - PaO2
  - PaCO2
  - pH i.e., acidosis = vasodilatation

Physiologic Changes: Intracranial Pressure

- Theories on Brain Compartment
  - 80% brain
  - 10% blood
  - 10% CSF
- If one increases the other two decrease
- Compensatory mechanisms



Symptoms of Increased ICP: Adults

- Early
  - Altered level of consciousness, restless, agitated, headache, nausea, and contralateral motor weakness
  - cranial nerves III and VI
- Late
  - Coma, vomiting, contralateral hemiplegia, and posturing
  - Alteration in Vital Signs
  - Impaired brainstem reflexes
    - Pupils, dysconjugate gaze

Intracranial Pressure

Normal range

0-15 mm Hg

Abnormal ranges **> 20 mm Hg**

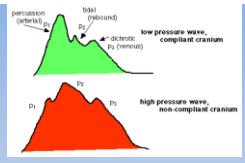
Cerebral Perfusion Pressure

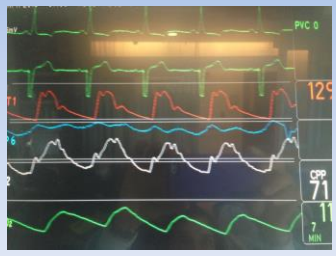
MAP – ICP = CPP

Optimal CPP in TBI

2016: 60-70 mm Hg

Intracranial Pressure





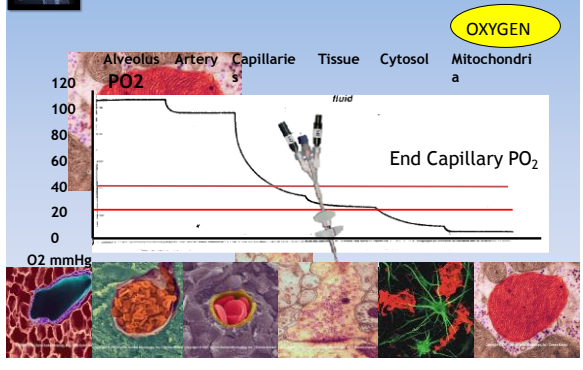
Oxygen

Retrograde jugular venous catheter	Oxygen saturation of blood from the jugular bulb: indirect measurement of global brain supply and utilisation of oxygen (Fick Principle)	Simple global measure. Trends in association with therapeutic measures can be monitored	Can give erroneous information in the presence of intracerebral shunt or infarction. Insensitive to regional ischaemia. Requires multiple blood sampling
Intraparenchymal Clarke electrode (Licox®)	Cerebral partial pressure of oxygen: detection of cerebral ischaemia, brain temperature. Often used in conjunction with ICP monitoring	Can be used as a global measure or regional when placed in vulnerable tissue. Monitors the effect of therapeutic measures. Some evidence to support use	Measurement at single focus. May fail to detect regional ischaemia when used as a global measure
Near-infra red spectroscopy	Changes in cerebral oxygen content. Redox state of cytochrome c oxidase	Detection of cerebral ischaemia, vasospasm and response to therapy. Non-invasive	Artefact-prone. Primarily research tool. Unreliable in presence of scalp or intracranial haematoma

Systemic and Brain Oxygenation: Why?

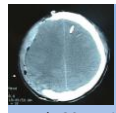
- Maintenance of adequate oxygenation is 1^{o} objective of critical care
  - Assessment of tissue oxygenation essential
- Hypoxia
  - Reduction of tissue oxygenation to levels insufficient to maintain cellular function and metabolism
  - May be a result of ischemia due to macro-vascular/microvascular, anemia, & hypoxemia
  - Cytopathic hypoxia: failure of cell to extract O2
  - Aggravates secondary brain damage
  - Monitor and Treatment paramount

Oxygen flux from air to neuron



Oxygen Dynamics: Brain Tissue Oxygen Monitoring

- PbtO2 (LICOX Brand)
  - Closed polarographic Clarke-cell technology (e.g. LICOX, Integra NeuroScience Inc., Plainsboro, NJ) allows for oxygen diffusion through an electrolyte chamber which generates an electrical current that is measured. The greater the oxygen partial pressure, the more oxygen diffuses through the membrane.
    - This oxygen-consuming process is temperature dependent and requires constant calibration with patient temperature. Some catheter models continuously monitor brain temperature.
- Quenching technology (e.g. Neurovent, Raumedic Inc., Leesburg, VA)
  - applies an optical principle with molecular oxygen directly quenching the light emitted by a luminescing agent in the tip of the probe.
    - This process does not consume oxygen and does not affect the measured oxygen level.



Oxygen: Recommendations

Brain Oxygen Monitoring (PbtO2/SjvO2)

- PbtO2 monitoring: measures partial pressure of oxygen in the brain interstitial space
  - Safe and accurate (8)
  - Two major types of PbtO2 monitors
    - Differences in absolute values (Normal 25-35 mm Hg)
    - Values <20 mm Hg considered abnormal reflecting cerebral ischemia and energy dysfunction
    - Probe location influences PbtO2
  - Helps guide treatment rt CPP, CO2, ICP, TX modalities (osmotherapy, hypothermia, barbiturates, decompressive craniectomy), Anemia rt transfusion endpoints, sedation and ventilatory management
  - Outcomes: reduced PbtO2 associated with poorer outcomes (24 studies)
    - TBI: reduced PbtO2 associated with mortality
    - Physiologic response to therapy to correct PbtO2 is associated with better outcomes in TBI and SAH

Normothermia: Keep it Normal!

Post cardiac arrest
▪ Once patient returns to 37°C following hypothermia treatment ▪ 72 hours in duration

Neurological injury (targeted duration: # days)	
Traumatic brain injury	7
Ischemic stroke	7
Intracerebral hemorrhage	7
Subarachnoid hemorrhage	≤ 14
Spinal cord Injury	7

Normothermia Implementation

- Acetaminophen IV or per rectum
- Cool room, wet towels, or ice bags
  - (increased workload of nurse)
- Iced saline 20 mL/kg bolus over 30 min x 1
- Surface external adhesive pads
- Surface blanket devices
- Intravascular devices

1. Subjective: BSAS

Type of Shivering

0: No shivering	No shivering is detected on palpation of the masseter, pectoralis, deltoids, or quadriceps muscles
1: Mild	Shivering localized to neck and/or chest
2: Moderate	Shivering involving arms and neck and/or chest
3: Severe	Intermittent generalized shivering involving all 4 extremities

Badjatia N, et al. *Stroke*. 2008;39:3242-3247.

2. Objective: BIS Shivering Assessment: Pre-intervention

Patient sedation with midazolam and fentanyl. Hypothermia at 33°C

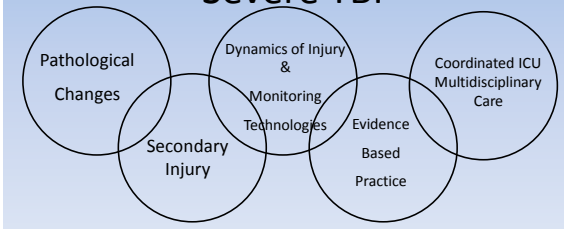
BIS =75

EMG = Max BSAS = 0

2. Objective Shivering Assessment: Post-intervention

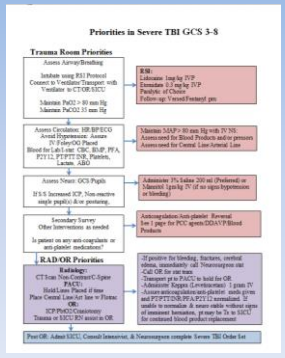
Patient bolused with norcuron
BIS = 33
EMG = 0
BSAS = 0

Critical Care Management of Severe TBI



Admission to the ED Trauma Room

- Standardize Team interventions to assure the brain is prioritized!



Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess A-B-C: Oxygenation and Ventilation

Airway: Secured with RSI

Breathing: Connect to Ventilator

Avoid hyperventilation

Use Capnography to monitor ET CO2 (35)

RSI:
Lidocaine 1mg/kg IVP
Etomidate 0.3 mg/kg IVP
Paralytic of Choice
Follow-up: Versed/Fentanyl prn

Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess A-B-C: Oxygenation and Ventilation

Assess Circulation: Assess Pulse, ECG and BP

IV fluids to maintain adequate MAP

Place Foley & OG
Maintain MAP > 80 mm Hg with IV NS:
Assess need for Blood Products and/or Vasopressors
Assess need for Central Line/Arterial Line

Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess Neuro: GCS/Pupils

If S/S Increased ICP
Non-reactive single pupil(s) &/or Posturing

Administer 3% Saline 200 ml (Preferred) or
Mannitol 1gm/kg IV (if no signs hypotension or bleeding)

Severe Brain Injury Algorithm

Secondary Survey
Other Interventions as needed

Is patient on any anti-coagulants or anti-platelet medications?

→ Anticoagulation/Anti-platelet Reversal

PCC agents
Platelets/FFP
DDAVP

Radiology:
CT Scan Non-Contrast/C-Spine
Positive for Bleeding?
PACU:
Hold/Lines Placed if time
Place Central Line/Art line with Flotrac
OR:
Monitors (ICP/PbtO2)/Craniotomy
ED Trauma or SICU RN assist in OR

Severe TBI Patient: GCS 3-8 CT+ Injury

ICU Care: Primary Interventions

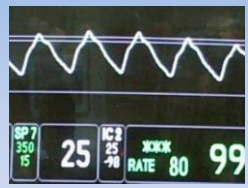
Admit to ICU

A & B: Oxygenation/Ventilation Optimization

Circulation:
Maintain CPP >60 mm Hg as initial target
Autoregulation Testing: Intact – may need CPP up to 80 mm Hg

ICP Management:
Draining CSF and Providing Sedation/Analgesia

Teamwork
Primary Intervention:
Intracranial Pressure
CSF Drainage



- Normal range
  - **0-15 mm Hg**
- Abnormal ranges
  - **> 20 mm Hg**
- **Compliance waveform analysis**

Teamwork
Primary Intervention:
Optimal Sedation /Analgesia

- Analgesia
  - Fentanyl
- Sedation
  - Propofol
  - Benzodiazepines
  - Precedex

Teamwork
Secondary/Tertiary Interventions

- Secondary Interventions
  - HTS
  - Mannitol
- Tertiary Interventions
  - Pentobarb coma
  - Decompressive hemicraniectomy
  - Mild Hypothermia

CASE DF

Pre-Hospital

- 75 year old male riding bike with helmet on down hill went over the handlebars
  - VS: BP 166/62 HR 44 R 18 O2 sat 82% on O2
  - Awake at seen: GCS 3-5-1 – deteriorating…
  - Laceration over left eye / blood coming from ears

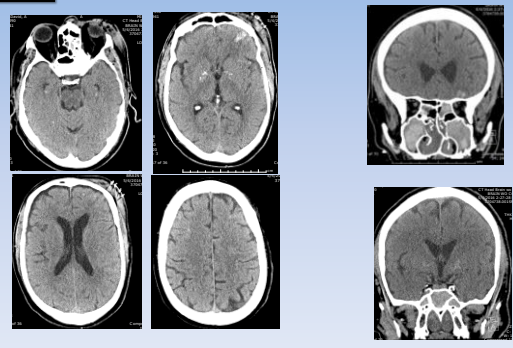
Trauma Room 1143- Tier 1 Red

- BP 80/40 HR 50s RR 18
- Intubated emergently in trauma room
- Neuro
  - GCS 1-1-1
  - Right eye 3 mm Left eye 4 mm
- Crepitus over left chest with suspicion of tension pneumo right
  - Needle thorocostomies
  - Bilateral chest tubes
  - O2 saturation improves to 100% BP 120/60
- Heart rate drops to 30s…Patient arrests (Vfib) 10 minutes after arrival
  - CPR x 6 minutes
  - Defibrillation
  - Epinephrine
  - Thorocotomy performed - Opened chest
  - Blood products given
  - To OR

IntraOp

- Left sided Thoracotomy – cross clamped aorta
  - Obvious cardiac contusion
  - Multiple lung contusions
- Abdomen opened
  - Grade 1 splenic injury
  - Mesenteric hematoma
- Flail chest noted with bilateral hemothoraces
- Massive Transfusion
  - 6 Packed RBCs, 4 FFP, and Superpack Platelets
- Abdomen left open with wound vac placed
- To CT…

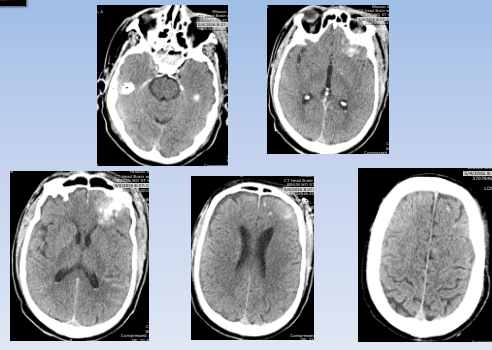
CT Non Contrast 224pm



Admit SICU 300pm

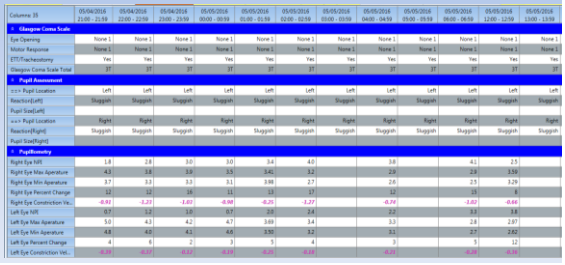
- Decision to induce hypothermia at 36 degrees C x 24 hours due to V Fib arrest
  - Concerns about bleeding
  - Neurosurgeon decides to hold ICP placement this evening
  - Pads placed strategically with open belly
  - Pacing wires present
  - Bilateral chest tubes to suction
- VS stable
  - MAP 80-90 HR 56 Ventilated at 10 breaths/minute
- Neuro
  - GCS 1-1-1
  - Pupillometer
    - Right pupil: NPI 1 CV 0.52 mm/sec
    - Left pupil: NPI 0.5 CV 0.09 mm/sec

Repeat CT 827pm



Pupillometer Trends 1st 12 hours

- Pupils are barely responsive
  - Left pupil is concerning….



SICU 5/4 Night Shift

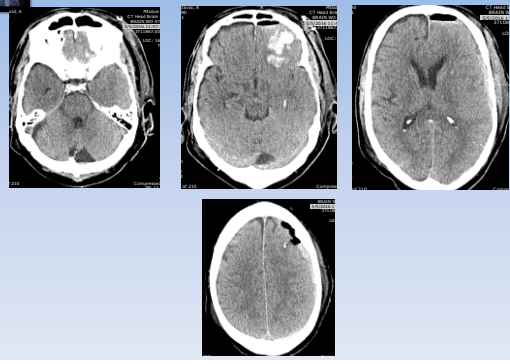
- Pupillometer 1800
  - R Eye NPI 0.8 CV 0.60 mm/sec
  - L Eye NPI 0.6 CV 0.14 mm/sec
- VS
  - BP decreases to 92/53 at 1830…HR 56
    - SVV 12%
  - What is the right BP post arrest…post TBI?
  - What is the end point of resuscitation?
  - Given Fluids to decrease SVV and improve MAP
  - Improvement in BP after Fluid Bolus
    - SVV 8%
  - BP decreases again between 0400-0800
- Conversation occurs between Neurosurgeon and Neuro CNS

SICU Day 1

- Temperature maintained at 36 degrees x 24 hours then rewarmed to 37 degrees

- Patient taken to OR for closure of abdomen and ICP/PbtO2 placement a 0800

CT Post ICP Placement 5/5 1147pm

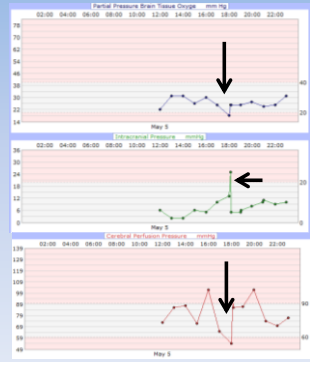


SICU Day 2 Post OP

- Guiding MAP according to PbtO2

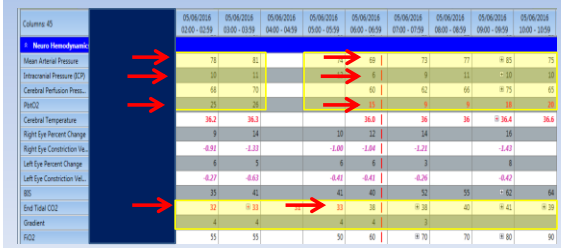
Columns: 45	05/05/2016 13:00 - 13:59	05/05/2016 14:00 - 14:59	05/05/2016 15:00 - 15:59	05/05/2016 16:00 - 16:59	05/05/2016 17:00 - 17:59	05/05/2016 18:00 - 18:59	05/05/2016 19:00 - 19:59	05/05/2016 20:00 - 20:59	05/05/2016 21:00 - 21:59	05/05/2016 22:00 - 22:59	05/05/2016 23:00 - 23:59
Blood Pressure Mean	88	96	78	107	75	55	92	110	85	79	87
Blood Pressure Source	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff
Neuro Hemodynamics											
Mean Arterial Pressure	88	90	78	107	75	91	92	110	85	79	87
Intracranial Pressure (ICP)	2	2	6	5	10	5	5	8	11	9	10
Cerebral Perfusion Press...	86	88	72	102	65	55	87	102	74	70	77
PbtO2	31	31	26	30	25	18	25	27	24	25	31
Cerebral Temperature	34.3	34.6	35.4	35.7	35.7	35.9	36.5	35.6	36.3	36.5	35.7
Right Eye Percent Change		10	9	13	7	9	8	15	17	15	
Right Eye Constriction Ve...		-0.87	-0.92	-1.21	-0.89	-0.92	-1.05	-1.62	-0.90	-1.36	
Left Eye Percent Change		6	10	8	9	6	2	10	9	10	
Left Eye Constriction Vel...		-0.62	-0.52	-0.37	-0.85	-0.24	-0.12	-0.34	-0.18	-0.27	
RR	47	37	43	49	60	30	34	29	31	44	34
End Tidal CO2	36	36	36	40	38	38	36	33	34	33	32
Gradient	2	2	1	1	1	1	1	1	4	4	4
FiCO2	60	55	55	55	55	55	55	55	55	55	55

ICP/PbtO2 monitor placed RT concerns about Brain Hemodynamics

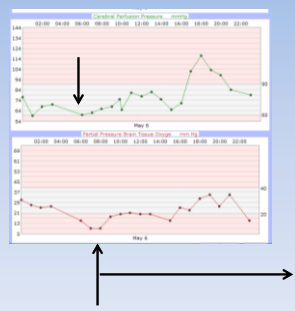


SICU Day 2 Post OP

- Guiding MAP according to PbtO2 – what is causing the drops? Hgb 6.9 – Tx with 2 u Packed RBCs 9-11am



Brain Perfusion



ICP 3-15 mm Hg

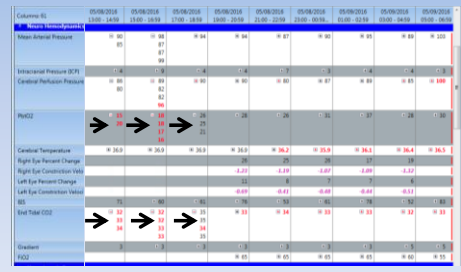
It is NOT a intracranial pressure problem!

ECG rhythm changes…brady- tachy- pauses… Pacer wire accessed

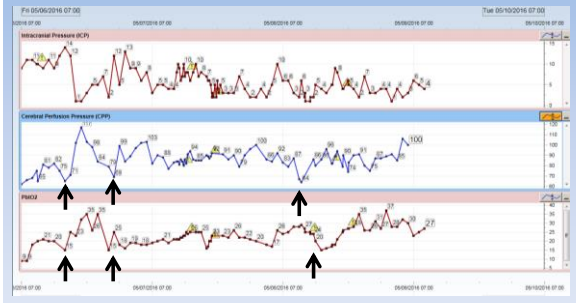
Brain Perfusion is Heavily Dependent on Blood Pressure

Columns: 45	05/06/2016 11:00 - 11:59	05/06/2016 12:00 - 12:59	05/06/2016 13:00 - 13:59	05/06/2016 14:00 - 14:59	05/06/2016 15:00 - 15:59	05/06/2016 16:00 - 16:59	05/06/2016 17:00 - 17:59	05/06/2016 18:00 - 18:59	05/06/2016 19:00 - 19:59	05/06/2016 20:00 - 20:59	05/06/2016 21:00 - 21:59
Blood Pressure Mean	90	89	91	87	79	83	103	118	106	103	89
Blood Pressure Source	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff	Automatic Cuff
Neuro Hemodynamics											
Mean Arterial Pressure	90	89	91	87	79	83	103	118	106	103	89
Intracranial Pressure (ICP)	9	11	9	12	14	12	1	1	3	5	5
Cerebral Perfusion Press...	81	78	82	75	65	71	102	117	103	98	84
PbtO2	21	20	20		15	25	23	32	35	28	35
Cerebral Temperature	36.8	36.7	36.7		36.5	36.5	36.1	36.2	36.2	36.3	36.3
Right Eye Percent Change		18				17	19		19	12	22
Right Eye Constriction Ve...		-1.47				-1.42	-1.35		-1.39	-1.04	-1.40
Left Eye Percent Change		7				7	10		8	6	10
Left Eye Constriction Vel...		-0.24				-0.46	-0.38		-0.38	-0.43	-0.52
BIS	64	66	68	74	69	64	43	41	40	46	45
End Tidal CO2	41	41	37	43	43		30		29	32	28
Gradient			4	4	4		4			4	4
FiO2	75	75	75	80	75	75	65	65	65	65	65

Brain Perfusion Dependent on Other…PaCO2

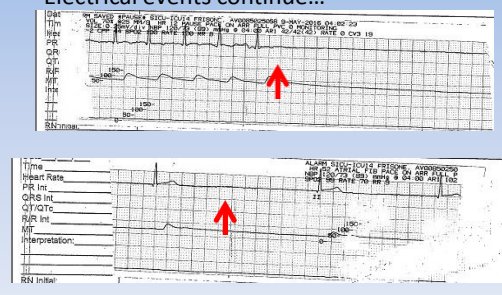


Brain Perfusion –What's the Target?

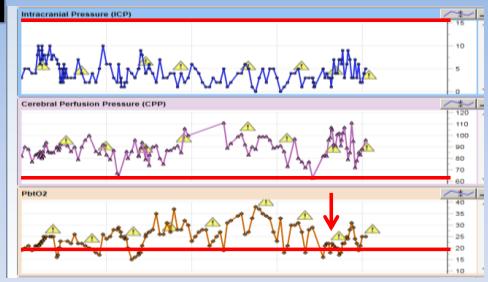


Sudden Event

- Electrical events continue…



Days 5-10



Progress in ICU

- Day 6
  - Attempted to wean sedation/analgesia
  - ICP increased to 30s
  - Decision to keep sedated x 24 hours
- Day 7-10
  - ICP/PbtO2 removed on Day 7
  - Fluid overload issues
    - Lasix daily
  - Weaning sedation
    - Precedex drip
    - Follows commands
  - Extubated on Day 9
- Day 14
  - PE
  - Started on Heparin Drip
- Day 15
  - Up in chair
  - Back in bed…patient has coffee ground emesis with aspiration
  - Arrest 1-3 minutes PEA
    - CPR with epinephrine and Reintubated

Progress in ICU

- Day 15 – Stop Heparin
- Days 16-21
  - Bronched daily x 3
- Weaning sedation on Day 19
- Day 23
  - Extubated again
  - Failed swallow evaluation
- Day 28
  - PEG placed
- Day 30
  - Transferred to ARU
  - Discharged home on Day 14 (Day 44)

Outcome

- Supervised level for bed mobility and min/contact guard assist for transfers.
- Ambulating 160 feet with only supervision.
- ADL skills have improved to supervised/contact guard assist.
- Cognitively, the patient has improved to moderate assist with memory and min assist for problem solving tasks.
- The patient's family has received training from the therapy team.
- Returned to Physician followup at 90 days
  - Independent
  - Wants to know when he can ride a bike again!

Summary and Questions