Management of severe TBI (1.2.3.1)

Learning Objectives

Upon the completion of this program participants will be able to:

- Distinguish primary and secondary brain injury
- Describe the influence of hypoxia, hypovolemia, and inadvertent hyperventilation on TBI outcomes
- Discuss the controversy surrounding prehospital ETI for TBI and importance of proper post-ETI prevention of hyperventilation
- Describe the age-appropriate, guideline-based approach to preventing and treating secondary injury
Introduction

- TBI is a massive public health issue
  - 1.4 million (old text) TBI seen in EDs (1.7-current text)
  - 53,000 die (1/3 of all trauma-related deaths)
  - Result primarily from falls (35%), MVC (17%) Direct blows to head (16%) (CAUSES)
  - 1/3 of cases are in children age 0-14
  - Male preponderance
  - Children (<18yo) and Elderly (>75yo) more likely to come to ED and more likely to die
  - Death: Firearms leading cause of death 40% (68% self-inflicted) MVC 34%, Falls 10% (MORTALITY ASSOCIATION)

Important Term

- Cerebral Perfusion Pressure: MAP-ICP
  - EMS SBP is surrogate for MAP

Key Concepts: Primary and Secondary Injury

- **Primary** Brain Injury
  - Damage that occurs at the moment of impact
  - Bleeding, contusion, cell death
  - Essentially irreversible → No known treatments
- **Secondary** Brain Injury
  - Occurs after initial trauma
  - Results from **cellular hypoxia** caused by:
    - Systemic hypoxia...or...
    - Poor CNS blood flow resulting from:
      - Low systemic BP (usually from blood loss)
      - High ICP (hematomas, edema)
  - All EMS management of TBI is aimed at preventing **secondary injury**
Major Causes of Secondary Injury

- **Brain Killers in TBI: The three “H-Bombs”:**
  - **Hypoxia**
    - Very common in severe TBI (>50% in some EMS studies)
    - A single sat <90% at least doubles mortality
  - **Hypotension**
    - A single SBP <90 in adults and children 10 and older at least doubles mortality
  - **Hyperventilation (actively ventilated patients)**
    - Even mild hyperventilation at least doubles mortality
    - One study revealed 6-fold increase in risk of death

Secondary Injury

- **Hypoxemia:** very common in TBI: Adequate oxygenation is critical priority
  - Even one episode of Sp02<90% can lead to 150% increase in mortality as well as increased morbidity
  - Supplemental O2 to all TBI patient
- **Hypotension**
  - Even one episode of SBP<90 can lead to 150% increase in mortality
  - IV crystalloids to maintain SBP>90 (adults and age specific)
- **Spalte also cites hyperventilation as increased risk of 2x mortality with “mild” hyperventilation**

EMS Evaluation of Severe TBI

- **Primary Assessment**
  - Same priorities and sequence as any major trauma
  - AVPU/GCS
- **Secondary Assessment**
  - Done en route
  - Multiple careful neuro exams
  - GCS stressed: decrease in 2 points: possible herniation
  - 9% of pts in Trauma Data Bank had this change and higher mortality
Alert-Awake but not necessarily oriented. Verbal-Responds to voice or verbal stimuli. Pain-Responds to painful stimuli. Unresponsive-Doesn’t respond at all. GCS is criticized for interrater variability but is widely used. Simplified Motor Score (SMS) can be as predictive in outcome as GCS. Current Brain Trauma Foundation guidelines favor GCS for EMS. SMS: Score 2=obeys commands 1= localizes pain 0= none or withdraws.

GCS and TBI Severity

- Mild 14-15
- Moderate 9-13
- Severe 3-8

EMS Role for TBI

- Rapid transport to APPROPRIATE facility
- Avoid secondary injury
Management of Severe TBI

- The **Essence** of the TBI Guidelines:
  - Prevent and aggressively correct the “Three H-Bombs”:
    - Hypoxia
    - Hypotension
    - Hyperventilation
  - When giving positive pressure ventilation

Management of Severe TBI

- Oxygenation and Airway Management
  - High-flow O2/NRB in all potential significant TBI
    - Pre-oxygenation important in all who might unexpectedly crash
    - One episode of hypoxemia increases morbidity and 150% increase in mortality
  - Classic teaching (supported by text)—Intubate for:
    - Inability to protect airway
    - Absence of gag reflex
    - GCS <9
  - Huge controversy in the literature (highlighted in the text)
    - If can be ventilated with BVM should patient be intubated?
    - RSI particularly controversial
    - Future research specifically called for

Management of Severe TBI

- Ventilation
  - *Initial* rates (BVM or intubated):
    - Adults and adolescents (age >14): 10 breaths/min
    - Children (age 2-14): 20 bpm
    - Infants (birth-24 mos): 25 bpm
  - Text & Guidelines: Do not use “therapeutic hyperventilation”
  - Manual and mechanical ventilation should be meticulously controlled using ETCO2 monitoring
    - ETCO2 Target: ≥36 mmHg
      - Range inferred in text (“mild hyperventilation” defined as 30-35)
      - Guidelines: Vary, but all suggest range of 36-45 with general target of 40
Management of Severe TBI

• **Prehospital Intubation**
  - Los Angeles peds study on BVM vs ETT management showed no change in neuro outcomes
  - San Diego studies show consistently poor outcomes
    • attributed in some part to hyperventilation
    • paramedic inexperience also contributed (0.5 intubations/yr)
  - Australia study showed limiting intubation to highly trained providers and end-tidal CO2 resulted in 97% successful intubation rate
    • GCS at 6 months same
    • No difference in mortality
    • Improved Neurological outcome at 6 months

Management of Severe TBI

• **Death by Hyperventilation:**
  - Inadvertent hyperventilation during manual ventilation:
    • Is incredibly common (typical rates in EMS: 24-40 bpm)
    • Is associated with markedly increased mortality
    • Must be meticulously prevented using ventilation adjuncts
  - Improper post-ETI ventilation may be a big part of the associated poor outcomes (stated in text)
    • “Intubation/Hyperventilation Paradox”: ETI makes ventilation easier to manage...but...makes inadvertent hyperventilation much more likely
  - 2008 Cochrane Review states no evidence to support intubation in an urban ground EMS program
  - Brain Trauma Foundation – monitor preintubation BP, O2 sat and end-title CO2 and consideration of time/distance

Management of Severe TBI

• **CPP = MAP - ICP**

• **Single episode of hypotension**
  - Increased morbidity
  - 150% increase in mortality

• **Prevention and management of hypotension**
  - Aggressive fluid resuscitation for hypotension (or for SBP decreasing and getting near age-appropriate threshold):
  - Specific IVF volume parameters not given in text
  - Maintain SBP >/= 90 mmHg
Management of Severe TBI

• **Hypotension** in TBI (table in text):
  - Neonates (0-28 days) <60 mmHg
  - Children (0-9 years) <70 + (2 x Age)
  - Children ≥10 yrs and adults: <90 mmHg

• "Rules of Thumb" for defining hypotension:
  - Newborn: <60 mmHg
  - Infants: <70 mmHg
  - 5 y/o: <80 mmHg
  - 10 y/o: <90 (same as adults)

Management of Severe TBI

• Prevention and management of hypotension
  - Fluids (text):
    - Isotonic crystalloids: Recommended for Adults and Peds
    - Hypertonic Saline: Not recommended (discussed equivocal literature)
    - Albumin: “...has been shown to worsen outcome in TBI.”
  - From Guidelines (explicit or inferred):
    - Adults and Older Children (>14):
      - Start with 1 liter crystalloid bolus and continue to keep SBP >90
    - Children:
      - Start with 20cc/kg crystalloid bolus and continue to keep SBP above threshold

Management of Severe TBI

• Transport: (text)
  - "Patients with moderate or severe TBI should be transported directly to a trauma center, ideally one that is fully equipped and staff to deal with acute neurosurgical emergencies."
  - When the patient is taken to the appropriate trauma center survival from TBI improves.
  - GCS as a destination tool
    - 13 or less: to the trauma center – neurosurgery coverage
    - 14-15: may follow other system protocols for destination
  - Elderly patient (>70 yo)
    - Higher morbidity and mortality – should go direct to the trauma center
  - Air medical transport considerations based on out-of-hospital time estimations
Management of Severe TBI

- Hyperventilation for herniation*
  - Temporizing measure
  - End title CO2 goal of 30-35 mmHg
- Mannitol for herniation
  - There is currently insufficient evidence to recommend use in the prehospital setting
- Hypertonic Saline
  - EMS RCT: no survival benefit or outcome benefit at 6 mo

*extremely controversial: this is from 2 vol text

Hyperventilation: Direct from the 2 volume Textbook

- “Currently, mild hyperventilation is indicated for brief periods to treat suspected cerebral herniation”. Signs:
  - Dilated and unreactive pupils, asymmetric pupils
  - Motor exam with extensor posturing or no response
  - Decrease in GCS by 2 points or more.
- Hyperventilation goals should be end-tidal of 30-35

* Extremely controversial: vasoconstriction in remaining good tissue, herniation not reversed. If presented as a test question in terms of temporizing measures may need to pick as best answer.
Management of Severe TBI

• Steroids
  – Increase risk of death
  – Not indicated or recommended

• Anti-epileptics
  – Post head injury seizure risk higher in children
  – No benefit to prophylactic anti-epileptics in adults or children

• Hypothermia
  – Mixed results
  – No conclusive evidence of benefit

Management of Severe TBI

Other Considerations

• Blood alcohol over 80 mg/dl has linear effect on GCS
• ASA, clopidogrel, warfarin, dabigatran increase intracranial hemorrhage risk
• Impaled objects need to be left in place during transport
• Firearm injury 40% or TBI deaths (68% self-inflicted)

Management of Severe TBI

Poor Prognostic Indicators on Arrival

• GCS 3-5
• Hypotension
• Bilateral hemisphere involvement
• Bilaterally non-reactive pupils
Management of Severe TBI

**Prevention Measures**

- **Pediatric**
  - Window guards
  - Safety gates at stairs
  - Car seats and safety belts

- **Elderly**
  - Removing loose rubs and obstacles
  - Exercise programs

- **All ages**
  - Firearms in the home locked and unloaded
  - Helmets for bike riding, motorcycles, horse riding, snow sports, baseball, and contact sports
  - Seatbelts

**Take-Home Points**

- Preventing secondary injury is everything:
  - Aggressively prevent and correct the 3 H-Bombs
- ETI/RSI is recommended in text, but acknowledged as controversial and potentially harmful
- Proper ventilation and ETCO₂ monitoring is emphasized
Management of concussion (1.2.3.2)

Learning Objectives:
1) Define concussion and describe the importance of appropriate prehospital management
2) List the signs/symptoms for concussion
3) Discuss the related treatment guidelines for concussion
4) Describe the role of prehospital providers and sideline sports healthcare providers in identifying and treating patients with concussion

Introduction

Textbook definition: TBI with GCS 14-15

American Academy of Neurology Definition: "A trauma-induced alteration in mental status that may or may not include a loss of consciousness." Concussion = Mild TBI (MTBI)

- Incidence:
  - ~ 75% of all reported TBI are concussion
  - Males > Females

- Concussion is usually not life-threatening but can have serious long term effects
- Duration of symptoms is highly variable but typically lasts 7-10 days, however may be months or even longer. Recovery time may be longer for children and adolescents.
- Appropriate prehospital identification of concussion can help achieve optimal recovery and reduce morbidity

Concussion

Pathophysiology:
- Abrupt neuronal depolarization/release of excitatory neurotransmitters
- Impaired axonal transmission
- Altered cerebral blood flow

Classic Symptoms:
- Vacant stare
- Delayed verbal or motor responses
- Confusion and inability to focus
- Disorientation
- Slurred/ incoherent speech
- Incoordination
- Memory deficits
- Any period of loss of consciousness (occurs in < 10%)

* Concussion grading is being abandoned by experts

Concussion
Concussion Evaluation and Management

1) Initial assessment and treatment of concussion is the same as for general trauma patients – addressing ABCs

2) C-Spine immobilization as appropriate (see C-spine immobilization section)

3) High degree of suspicion for more serious TBI and other injuries (especially with prolonged LOC and intoxication)

Transport to nearest ED if any of the following:
- Altered LOC/focal neuro exam
- Seizure
- More than a brief LOC
- Severe headache and/or vomiting
- Management – If transported use high-flow O2 if LOC

Medical Oversight

1) Assure that prehospital providers have adequate concussion training

2) Standardized prehospital concussion evaluation and transport guidelines

TBI and EMS Prevention & Public Health

- EMS is in a unique position to identify potential hazards and remove hazards or relay information to appropriate authorities (e.g., window guards, throw rugs, ETOH and driving, appropriate protective equipment)
Concussion

Take-Home Points
1) Appropriate prehospital identification of concussion can help achieve optimal recovery and reduce morbidity
2) Providers need a high degree of suspicion for more serious TBI
3) Transport to ED for specific criteria with high-flow O2 and C-spine immobilization if indicated
4) Recommend to non-transported patients that they should not return to high risk activities (i.e., sports, high speed activities like bicycle riding) until cleared by a qualified healthcare provider

Sideline Management for Team Medics/Physicians (1.2.3.3)

Learning Objectives:
1) Describe the importance of recognition of sports concussion
2) Discuss the treatment Guidelines for sports concussion
3) Describe the role of sideline sports healthcare providers in identifying and evaluating athletes with concussion

Introduction
1) Sport-related concussions are common in youth and high school sports (some estimates 4-5 million/yr)
2) EMS providers and team physicians often provide on-scene medical care during sporting events
3) Appropriate sideline identification and evaluation of sports-related concussion can prevent long term morbidity
4) There is a strong tendency towards returning to sports too quickly, which is associated with worse outcomes and rarely even death
Sideline Management for Team Medics/Physicians (1.2.3.3)

Treatment Guidelines:
1) Goal is to assure no more serious injury and prevent re-injury (concussion takes weeks to heal)
2) Athletes who are suspected of having a concussion should be removed from play immediately, not to return to play the same day (even if asymptomatic)
3) Athletes with concussion should rest, both physically and cognitively until symptoms resolve both at rest and with exertion
4) Clearance to play should be performed at a later date by a qualified health care physician
5) Transport to ED per recommendations in section 1.2.3.2.

Sports Concussion Take-Home Points
1) Athletes with AMS and/or focal neuro exam should be transported with high flow O2 & C-spine immobilization
2) All athletes who have had a concussion must see a qualified physician and have a neurologic examination before they are allowed to return to play
3) No return to play that day...No exceptions!!!
4) When in doubt transport to ED

Controlled hyperventilation for management of impending brain herniation in TBI (1.4.2.3.10)
Learning Objectives

Upon the completion of this program participants will be able to:
• Describe the signs of impending uncal herniation
• State the initial age-related rates for mild "therapeutic" hyperventilation and the target ETCO$_2$ range
• Discuss the lack of evidence supporting therapeutic hyperventilation and the risks of teaching its use to EMS providers

Introduction

• There is no evidence that “therapeutic hyperventilation” improves patient outcomes in any setting
• The recommendation for “therapeutic hyperventilation” is based solely upon historical and theoretical grounds
• The cerebral vasoconstriction that leads to the intended decrease in ICP may cause worsening ischemia that negates any potential benefit

Identification of Impending Herniation

• Signs: (Table in text)
  – GCS <9 and decrease of GCS >2 points
  – Anisocoria (“blown” or unequal pupils)
  – Dilated, non-reactive pupil(s)
  – Motor signs: Extensor posturing or no response
  
  – Note:
  • Blown pupil-Unilateral pupillary dilation with decreased reactivity is LATE sign signifies uncal herniation with compression of ipsilateral 3rd cranial nerve.
Management of Impending Herniation

- From both the Text and the Guidelines:
  - Only treat clear signs of impending herniation
  - Only treat with mild “therapeutic” hyperventilation
    - ETCO₂ target range 30-35 mmHg
  - Initial rates to achieve intended ETCO₂ range: (table/text)
    - Adult and adolescents (age ≥15 yrs): 20 breaths/min
    - Child (2-14 yrs): 25 breaths/min
    - Infant (0-24 mos) 30 breaths/min

Potential Test Questions

- Signs of impending herniation
- “Mild hyperventilation
  - Age-specific initial rates
  - ETCO₂ range
  - Problem of decreased ICP at expense of cerebral blood flow

Take-Home Points

- Teaching point inferred from text: The literature has shown that the typical, inadvertently fast ventilation rates for non-herniating adults (usually >30 bpm) are higher than those recommended for herniating infants
- Beware: Teaching hyperventilation in impending herniation may unintentionally translate to “the worse the TBI...the faster we should ventilate.”
  - If this occurs, many patients without herniation will be harmed by the intentional, inappropriate hyperventilation
Summary

- Understand primary vs secondary brain injury
- Know magnitude of problem and that EMS's primary goal is rapid transport to appropriate facility
- Hypoxemia, hypotension (very likely hypo and hypercapnia) are killers and EMS must avoid
- Intubation is controversial but airway management is not.
- Concussion and sports injury briefly covered in text and bears review