EXPLOSIVE BLAST
TRAUMATIC
BRAIN INJURY

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• Traumatic brain injury remains a leading cause of death and disability
• Historically, head injury accounts for 15-20% of battle related casualties
  – Over 50% of patients who died of wounds (DOW)
• Today, estimates of head injury is about 15%
  – but mild TBI estimated up to 40% of all soldiers

Navy-Marine Combat Casualty Registry (2005)
Joint Theater Trauma Registry, Nov 2007
• 25-40% OIF soldiers may have suffered closed head injury
• Many (how many?) may have suffered more than one such injury
• Many (how many?) may have persistent subtle neurological symptoms (> 6 months)
  – Estimates of 20-40% of exposed patients
  – Recent data suggest it is about 5% for mild injury
Pt suffered blast TBI from about 8 feet away

- Wearing helmet/armor
- No LOC but confusion/amnesia for at least 15min (Grade 2 concussion)
- CT: normal
- Persistent neuro cognitive deficits on Day #2 (transfer)
  - Frontal lobe based tasks (digit span, word list generation)
  - Normal by Day 7, returned to duty
Moderate TBI
(low velocity shrapnel)

- Pt exposed to mortar explosion and struck by frag

Day #14, fully recovered
Pt suffered TBI from hanging IED

- Pt underwent extensive surgery including hemicraniectomy
- 10-day ICU care, complicated course
- Recovered to awake, following commands, extubated --- tx to civilian rehab
Blast TBI with Hemorrhagic Shock

- Pt injured in IED blast
- A/E to CSH but cardiac arrest during landing
- Resuscitation (lots of blood products, fVIIa)
- Aggressive neuro tx (decomp crani, neuro crit care, hypertonic saline)
- A/E to USA on Day #2
- Neuro intact on Day #14, tx to PMR rehab for R AKA
How bad is military medical care of TBI?

It is better than civilian TBI care but still needs improvement
Present State of the Art

- **Civilian TBI clinical practice is inadequate**
  - Diagnosis is inconsistent
    - Only 10-15% of concussion victims are referred to MD
      - Most are seen by lay person (coach, parent, etc)
    - No standard approach to mild TBI treatment
  - No specific TBI treatments of any kind
    - In spite of promising preclinical data, there are >200 failed clinical trials in civilian TBI

- **Military TBI also needs improvement**
  - Incomplete knowledge on helmet performance
  - Currently, the assumption is injury results from blast “overpressure”
    - Is this the complete story?
Who gets screened?

“Anyone involved in an explosion/blast, fall, or MVA who was dazed, confused, “saw stars” or lost consciousness, even momentarily, should be considered to have suffered a concussion”

RED FLAGS: (serious sx$s w/in 48 hrs)

Double vision, breathing difficulty, worsening HA, can’t recognize people/places, can’t be awakened easily, behaves unusually or seems confused and irritable, seizures, slurred speech, unsteady on feet, repeated vomiting, weakness/numbness in arms/legs, progressively declining neuro exam
All medics carry the MACE

- Embedded in the MACE is the Standardized Assessment of Concussion (SAC), a widely used, validated, brief cognitive tool.
- Gross cognitive tool addressing 4 domains
  - Orientation
  - Immediate memory
  - Concentration
  - Memory recall
  - Max score is 30
  - ≤ 25 is significant
“New TBI” versus PTSD

Mild Blast TBI
- Difficulty sleeping
- Emotional liability
- Difficulty concentrating
- Decreased appetite
- Other:
  - May have post-concussive syndrome (headaches, etc)

PTSD
- Sleep disturbance
- Outbursts of anger
- Difficulty concentrating
- Hypervigilance
- Exaggerated startle
- Other:
  - Re-experience
  - Avoidance
    DSM-IV TR
Second Impact Syndrome (SIS)

Avoiding Second Impact Syndrome

- Patients who sustain initial mild TBI (usually a concussion) sustains a second head injury before having fully recovered.
- Leads to:
  - loss of cerebral autoregulation
  - diffuse cerebral swelling
  - uncontrolled elevated ICP (even without intracranial hematoma)
  - death
- Rare
- Mortality rate ~50%
### Grade 1 (mild)
- Remove from duty/work/play
- Examine immediately and at 5-minute intervals
- May return to duty/work if clear within 15 minutes

### Grade 2 (moderate)
1. Remove from duty for the rest of the day
2. Examine frequently for signs of CNS deterioration
3. Physician’s neuro exam as soon as possible (within 24 hours)
4. Return to duty after 1 full asymptomatic week (after being cleared by physician)

### Grade 3 (severe)
1. Take to emergency department
2. Neurologic evaluation, including appropriate neuroimaging
3. Consider hospital admission

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First large system-wide CPGs

- VA/DoD Clinical Practice Guidelines for Management of Concussion/mTBI
  - Evidence based
  - Released in March, 2009
- Focused on symptoms treatment

Cifu, Labutta and Ling (eds),
“VA/DoD Clinical Practice Guidelines for Management of Concussion/mTBI” (2009)

Download free at:
www.healthquality.va.gov/Rehabilitation_of_Concussion_mTBI.asp
or
www.mirecc.va.gov/docs/visn6/VADoD_CPG-Concussion-mTBImarch09.pdf
Treatment begins on the battlefield

Guidelines for Field Management of Combat-Related Head Trauma

Knuth, Letarte, Ling et al
Brain Trauma Foundation (2005)

Download available: www.braintrauma.org
Pre-Hospital Guidelines for Management of TBI

- **Avoid hypoxia**
  - $O_2$ Sats > 90 or $pO_2$ > 60mmHg
- **Artificial airway for GCS $\leq 8$**
- **Hyperventilation for cerebral herniation**
  - Not for ICP prophylaxis or routine use
- **Systolic BP > 90mmHg**
- **No specific resuscitation fluid is recommended**
  - Hypertonic saline has logistical advantages
- **Hypertonic saline at $\leq 500$cc boluses is acceptable**
  - Use for ICP management is an option
- **Mannitol for cerebral herniation if intravascular volume can be maintained**
• **Determine** GCS and pupil function as soon as possible
• **Triage** GCS 9 – 13 to CSH
• **GCS < 14** should not return to duty until normalized
• Sedation and analgesia as needed for transport
• Analgesics in small doses with proper monitoring
• Antibiotics for penetrating TBI is an option
“Guidelines for the management of severe traumatic brain injury”
The American Association of Neurological Surgeons
Download available: www.braintrauma.org

“Explosive Blast Neurotrauma”
Ling, Bandak, Armonda, Grant and Ecklund
Key Guidelines

- ICP < 25mmHg
- CPP > 60mmHg
- SBP > 90mmHg
- pO2 > 60mmHg or O2 sats > 90%
- HOB 30°
- Antiepileptic drug for 7 days (begin w/in 24 hours)
- pCO2 34-36mmHg if hyperventilating for herniation
- Hypertonic resuscitation fluids (NS or higher)
- HCT > 28
- Artificial airway for GCS ≤ 8
- Maintain normothermia
So what is it that is causing the injury?
### Mechanisms of Traumatic Brain Injury

<table>
<thead>
<tr>
<th>Penetrating Injury</th>
<th>Concussive Injury</th>
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<tbody>
<tr>
<td><strong>Cause:</strong> Physical disruption of cells and fiber tracks, hemorrhaging, cell apoptosis</td>
<td><strong>Cause:</strong> Mechanical loading leading to cell failure</td>
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<table>
<thead>
<tr>
<th>Hypoxia</th>
<th>Explosive Blast Injury</th>
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<tbody>
<tr>
<td><strong>Cause:</strong> Lack of $O_2$</td>
<td><strong>Cause:</strong> Mechanism of injury unknown</td>
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Is overpressure the main cause of explosive TBI?

- Many blast related TBI cases
- Few blast lung cases in isolation
- Few blast bowel cases
- Almost 50% of severe blast TBI patients suffer cerebral vasospasm
Preventing Violent Explosive Neurologic Trauma (PREVENT)
Methodically analyze explosive blast to *identify, understand and defeat* specific causes of Traumatic Brain Injury (TBI)

- **Background**: An explosive blast is composed of many physical forces (pressure, electrical, chemical), each of which can cause injury.
- **Purpose**: To determine which of these forces are the dominant contributors to TBI.
- **Approach**: Apply scientific methods to analyze each potential physical force to support or refute their contribution to blast induced TBI.
• What are the contributing mechanisms of injury?
• What is the “spectrum” of this disease?
• From this can rational therapeutics interventions and mitigation strategies be developed?

Return to first principles
PREVENT Vision

Vision: Protect soldiers from Traumatic Brain Injury through understanding the effects of explosive blast components

Phase 1

Milestone
- Identify physical mechanisms (pressure/shock; impulse; non-uniform loading; EMP; ejecta; fireball/thermal)
- Identify physiological mechanisms (reduced cerebral blood flow and oxygen concentration, vasospasm, edema and elevated ICP)
- Identify biochemical mechanisms (cell death pathways; necrotic and apoptotic; proteomic mediators of inflammation and DNA damage; bioenergetic failure)

Markers of Injury
- Cytokine expression
- Histopathology (cell damage and death; vascular and axonal damage)
- Physiological (reduction cerebral blood flow and oxygen tension; EEG and seizure activity, BBB disruption)
- Neurological (paralysis or gait impairment)
- Cognitive (memory and problem solving)

Phase 2

Milestones
- Refine Model
- Develop strategies, devices, and treatments to prevent injury from blast

Metric
- Prevention of injury as defined by achieving an injury severity score reduction of > 50%
**Approach**

- **Program Milestones**
  - Identify physical mechanisms: pressure/shock, impulse, non-uniform loading, EMP, ejecta, fireball/thermal; in isolation and in combination
  - Identify physiological mechanisms: reduced cerebral blood flow and oxygen concentration, vasospasm, edema and elevated intracranial pressure
  - Identify biochemical mechanisms: cell death pathways, necrotic and apoptotic, proteomic mediators of inflammation and DNA damage, bioenergetic failure
  - Develop strategies, devices, and treatments to prevent injury from blast.

- **Goal:** Develop strategies that achieve a reduction in injury severity by 50%

- **Measures of injury severity**
  - Cytokine expression: inflammation
  - Histopathology: cell damage and death, vascular and axonal damage
  - Physiological: reduction of cerebral blood flow and oxygen tension, EEG and seizure activity, blood-brain barrier disruption
  - Neurological: paralysis or gait impairment
  - Cognitive: memory and problem solving