Establishing a Statewide Brain Injury Consortium

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Disclosures

- None
A Primer on Traumatic Brain Injury
National Epidemiology

- Traumatic Brain Injury (TBI) is the leading cause of death and disability in children and adults from ages 1 to 44.
- CDC estimates the annual incidence of 1.4 million people in the US
  - 50,000 will not survive the trauma
  - 235,000 will be hospitalized
  - 1.1 million will be treated and released from the ER
- Men 1.5X greater risk
- Most common in first three decades of life
  - Although, those over 75 had a 4 fold increase incidence of death related to TBI
- 5.3 million in US alone (2% of population) require assistance with ADLs secondary to TBI
  - 80,000-90,000 added each year due to permanent neurological injury
- Moderate & severe head injury are associated with a 2.3 and 4.5 times increased risk of Alzheimer’s disease, respectively.
- Cost of TBI
  - $56 Billion per year in direct and indirect costs


National Epidemiology

- Falls 28%
  - Most prevalent 0-4 years and >75
- Motor vehicle 20%
  - Most common 15-19 years
- Struck by object 19%
- Assault 11%
- Bicycle 3%
- Unknown 9%
Types and Treatment of Traumatic Brain Injury
History

- Neurosurgical intervention is perhaps one of the oldest specialties
- Trepanation performed 5000 BC in Europe
  - Performed for a multitude of reasons
    - Spirits
    - Epilepsy
    - Headaches
    - Osteomyelitis
    - Trauma
History

- **Intracranial Pressure**
  - Lundberg 1960
  - Langfitt, Klatzo 1965-1967
    - Cerebral autoregulation and edema
  - Rosner and Becker 1984
    - A waves
  - Obrist, Bouma, Muizelaar 1986-1991
    - Cerebral ischemia and bloodflow dynamics
    - Led to cerebral perfusion pressure
History

- Clinical
  - GCS 1974
    - Jennett and Teasdale
  - Secondary Insults 1977
    - Miller and Becker
  - Hypotension 1993
    - Chesnut
History

- **Imaging**
  - CT
    - 4 hour window 1981
    - Seelig
    - Marshall’s Criteria 1991

- **Data Collection**
  - TCDB 1983

- **Monitoring Techniques**
  - SJVO$_2$ 1991
    - Dearden
  - PbO$_2$ 2004
  - Hemedex 2005
    - Jaeger
Grading the Injury
Mild TBI

- GCS 13-15
- Difficult to get true numbers, due to the rarity of admission to hospital
- Recovery is rapid
  - 15% will have symptoms for greater than 3 weeks → post concussive syndrome
- Spectrum of symptoms
  - Blurred vision, headache, nausea, vomiting, dizziness, emotional lability/depression, cognitive dysfunction
  - 30-40% have depression or anxiety
- Need for early neurorehabilitation
- Lost productivity from MTBI totaled an estimated $12 billion in the United States in 2000
Moderate TBI

- GCS 9-12

- General Features
  - Similar pathology to severe head injury
  - More common in younger age groups
  - “Gray Zone” of treatment
  - 90% able to have functional independence
Severe TBI

- GCS 3-8
- Multiple etiologies for hemorrhage type
- Overwhelming indications for ventriculostomy
- 40% mortality
- Less than 20% have functional independence
Biomechanics and Biochemistry of Traumatic Brain Injury
Mechanism of Injury

- **Biomechanics**
  - Contact injuries cause focal injuries
    - No inertial load
    - “coup” injuries
      - Contusions
      - Skull fractures/EDH
  - Translational acceleration injuries
    - Inertial load is high
    - “contracoup” injuries
    - Contusions, ICH, SDH
  - Angular acceleration is a combination of translational and rotational acceleration
    - Most common
    - DAI, et al.
Mechanism of Injury
Mechanism of Injury

- Calcium
  - Trauma increase causes activation of phospholipases A$_2$ and C, resulting in release of free fatty acids and diacylglycerol.
  - Free fatty acids may further damage the blood brain barrier and increase cerebral edema.
  - May also affect electron transport at the inner membrane of the mitochondria, inhibiting ATP production and worsening anaerobic metabolism and increasing intracellular lactate.

Mechanism of Injury

- **Biochemical**
  - **Glutamate**
    - Excitatory amino acid (Glutamate and Aspartate)
    - Binds NMDA (N-methyl-D-Aspartate), which normally regulates Na\(^+\) and Ca\(^{2+}\)
      - Regulation is through Magnesium (Mg\(^{2+}\)) binding to the receptor
    - Excessive levels of excitatory amino acids cause cell death in two ways:
      - Acute increase in Na\(^+\) and Cl\(^-\) cause intracellular edema
      - Increase in intracellular Ca\(^{2+}\)
Mechanism of Injury

- Other chemicals implicated
  - P53 up-regulation
  - Free radical damage
  - Leukotrienes, thromboxane (Arachadonic Acid derivatives)
  - PARP
  - Calpain
Management of Traumatic Brain Injury
Guidelines for the Management of Severe Traumatic Brain Injury

3rd Edition

A Joint Project of the

Brain Trauma Foundation

Improving the outcome of brain trauma patients worldwide

and

American Association of Neurological Surgeons (AANS)

Congress of Neurological Surgeons (CNS)

AANS / CNS Joint Section on Neurotrauma and Critical Care

New York, 2007
Prehospital Management of TBI

- Multitude of caregivers
  - First-responders, EMTs, RNs
- ATLS protocols
  - ABCD
  - A and B:
    - Hypoxia should be avoided and is prognostic
    - Reliable airway should be secured as soon as possible
- C
  - A single episode of SBP<90 doubles mortality
  - Give isotonic fluids
    - ??Hypertonic

<table>
<thead>
<tr>
<th>O₂ sat</th>
<th>Mortality</th>
<th>Severe Disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;90%</td>
<td>14.3%</td>
<td>4.8%</td>
</tr>
<tr>
<td>60-90%</td>
<td>27.3%</td>
<td>27.3%</td>
</tr>
<tr>
<td>&lt;60%</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>
Prehospital Management of TBI

- ATLS protocol (continued)
  - D
    - GCS
      - *Postresuscitation* GCS
      - Most widely utilized clinical measurement for TBI
      - GCS of 3-5 has a 70% predictive value of poor outcome
      - Motor component most predictive
      - Great disparities between medical personnel
        - 40% discrepancy
  - Pupils
    - Pupillar asymmetry (Anisocoria) is >1mm difference in diameter
    - Examine for orbital trauma, postresuscitation
    - Braakman, et al.
      - Bilateral fixed, dilated pupils has a 91% mortality
      - Unilateral fixed pupil has good outcome in 54%
      - Preponderance of epidural hematomas

- E (Exposure and other injuries)
  - Other injuries….how about the spine?
  - 21% of patients with severe TBI have cervical spine injuries

Neurointensive Care
Understanding Neurointensive Care

- It’s all about oxygen delivery!!!!
  - Optimize arterial oxygenation
  - Optimize Oxygen carrying capabilities
  - Optimize blood pressure
  - Understand the forces helping or hindering $O_2$ delivery
    - MAP/CBF (Hemedex)
    - ICP
  - Checking the end product
    - $SjO_2$
    - $PbO_2$
Intracranial Pressure

How high is too high?

- Marmarou (1991) 1030 severe TBI patients found that an ICP of 20 greatest predictive threshold for outcome at 6 months.

- Retanalert (2004) evaluated outcome in patients with ICP of 25 vs. 20 and found no difference
  - CPP > 70, SjO$_2$ > 54%
  - Only 27 patients


Cerebral Perfusion Pressure

- What is it?
- CPP = MAP - ICP
- More emphasized than ICP-guided treatment
- Ties into hypotension as poor outcome
- Rosner and Daughton (1990)
  - CPP > 70 had superior outcomes
  - Serious complications, including ARDS

Cerebral Perfusion Pressure

- CPP <50-60 associated with worse outcomes
  - Usually confounded by severely elevated ICP
  - Which is more predictive?
    - CPP (Andrews, 2002)

- Therefore, goal CPP is 60-90

- Newest monitoring
  - Licox (Brain tissue pO₂)
  - Hemedex (Cerebral Blood Flow)

Osmotic Therapy

Mannitol

- How does it work?
  - Decreases blood viscosity
    - Immediate plasma expansion/reduces hematocrit
    - Improved rheology (deformability of the RBC) and increases oxygen delivery to injured areas
  
- Osmotic Effect
  - Delayed 15-30 minutes after dose
  - Unpredictable duration of treatment (90min-6hrs)
  - Use with caution in patients with hypotension, sepsis, nephrotoxic drugs or those with impaired kidney function
Osmotic Therapy

Mannitol (continued)

- How to give it?
  - No reliable answer
  - Marshall, et al. report a faster infusion has a safer and more reliable effect, and possibly longer
    - 1g/kg
    - Effects become less after multiple (3-4) doses

- Does it work every time?
  - NO!
  - Autoregulation
    - Muizelaar, et al. found Mannitol is effective in those with intact autoregulation.
      - Rheological effect possibly more important than osmotic effect.


Osmotic Therapy

Hypertonic Saline

- How does it work?
  - Direct increase of solute load in vasculature

- How to give it?
  - Multiple formulations
    - 3%, 5%, 7.5%, 23.4%
  - For increased ICP
    - Bolus over 10-20 min
  - Caution with CHF
  - Contraindicated as bolus in hyponatremia

- Battison, et al. evaluated ICP control in severe TBI in a randomized controlled trial of Hypertonic Saline vs. Mannitol vs. Dextran
  - HS at least as effective as Mannitol for controlling ICP
  - Small sample size

Secondary Injuries
Secondary Injuries

- **Hypoxia**
  - **What is it?**
  - **How often does it occur?**
    - Survey of first-responders to patients with severe head injury found pre-intubation hypoxia (\(\text{SaO}_2<85\)) occurred 55% of the time.
    - Over 50% of the time, hypotension was also present.
    - In those with \(\text{SaO}_2<60\%\) pre-intubation, mortality rate was 50% and all survivors had severe disability.

Secondary Injuries

- **Hypotension**
  - Defined as SBP < 90
  - Most powerful predictor of poor outcome
    - Single episode of hypotension doubles the mortality rate.
    - Increased frequency and duration of hypotension has also been shown to be an independent predictor of poor outcome
  - More focus should be paid to MAP/CPP, CBF, PbO₂ to determine adequate perfusion

Pediatric Head Injury

- General Concepts
  - Hypotension should, in kind, be avoided
    - Defined as systolic blood pressure less than the fifth percentile for age group or signs of shock
      - Quick formula: Hypotension = 70 mm Hg + 2(age in years)
  - Hypoxia with worsened outcome ($\text{PaO}_2 < 65$)
    - Hypotension + Hypoxia is only slightly worse than hypotension alone.
      - Mortality as high as 85% in some reports
Prognosis

<table>
<thead>
<tr>
<th>GCS score</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>65%</td>
</tr>
<tr>
<td>4</td>
<td>45%</td>
</tr>
<tr>
<td>5</td>
<td>35%</td>
</tr>
<tr>
<td>6</td>
<td>24%</td>
</tr>
<tr>
<td>7-13</td>
<td>10-15%</td>
</tr>
</tbody>
</table>

TBI Mortality

GCS

Mortality

0% 10% 20% 30% 40% 50% 60% 70%
Newer Neuromonitoring

How do we know if the therapy is effective at delivering oxygen to the brain?

- Jugular Venous Saturation Monitoring (SjO₂)
  - Late 1980s and early 1990s
  - Gives global cerebral information
  - Labor intensive

- Brain Tissue Oxygen Monitor (Licox)
  - 2000-present
  - Gives partial pressure of Oxygen in brain parenchyma
  - Observed levels of ischemia
  - Currently, more of a prognostic tool. However, promising guidelines are emerging
  - Capable of microdialysis
  - Discernable levels of PBO₂ for ischemia and poor outcome
Licox
Hemedex
Trauma Care in Oregon
Oregon Trauma System

- 1982 – Dr. Daniel Lowe evaluated 762 trauma cases from 26 Portland-area hospitals
  - He found 25% of the fatalities and 16% of all outcomes were “inappropriate” for the severity of the injury
  - Average response time for trauma surgeon was more than an hour
- 1983 – State Senators Steve Starkovich and John Kitzhaber M.D., introduced Senate Joint Resolution 23, which authorized Oregon Health Services (OHS) to develop a plan for a statewide trauma system.
- 1985 – Senate bill 147 provided the authority to establish a statewide trauma system
- 1988 – Oregon Trauma System begins
Oregon Trauma System

- It was the first state to develop a system that included small rural hospitals as well as large urban facilities and that was voluntarily entered into by the hospitals.
- Organized and centralized trauma care
- Under the direction of the State Trauma Advisory Board (STAB)
- The state is divided by geography and population into nine Area Trauma Advisory Board (ATAB)
  - Report to STAB
Oregon Trauma System

Facts about the Oregon Trauma System

• Since its inception, 133,859 trauma patients have been treated within the Oregon Trauma System, and 21,474 patients have been transferred within the system to a higher level of care.

• Forty-four hospitals throughout Oregon participate in the trauma system.

• The trauma system includes six hospitals outside of Oregon -- four in Washington, one in Idaho and one in California.

• Trauma patients are transported by 169 EMS agencies within the trauma system.
Oregon Trauma Systems

A few facts about injury prevention

- The unintentional death rate for Oregon children ages 0-14 has dropped 54 percent since 1996.
- An Allstate Insurance study ranked the Portland metropolitan area as one of the top 10 safest places for teenage drivers.
- Oregon is a leader in the nation for passing safety legislation, including primary safety belt use; motorcycle helmet use; bike, skateboard, roller blade and scooter helmet use for children under 16; graduated licensing laws for teens; and child safety seats and booster seat use.
Oregon Trauma Registry

Data Points

- Mechanism of injury
  - fall height
  - MVA speed
  - composite description of what happened to the patient

- Response time
  - 911 call and scene times
  - EMS agency was the first responder/ transporter

- Mode of transport
  - whether pt. arrived by ground or air

- Field vitals at multiple time points
- GCS
- Airway status
  - number of intubation attempts (ETCO2 values)
  - other field interventions such as IV, IO and C-Collar.

- Intracranial pressure monitor insertion and tracheostomies
- ICU length of stay
- Total length of stay
- Outcome
- Disposition
Sounds great, but how are we doing?
American College of Emergency Physicians
2008 Report Card

The National Report Card on the State of Emergency Medicine

## Oregon

<table>
<thead>
<tr>
<th></th>
<th>Rank</th>
<th>Grade</th>
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<tbody>
<tr>
<td>Access to Emergency Care</td>
<td>41</td>
<td>F</td>
</tr>
<tr>
<td>Quality &amp; Patient Safety Environment</td>
<td>36</td>
<td>D+</td>
</tr>
<tr>
<td>Medical Liability Environment</td>
<td>37</td>
<td>D-</td>
</tr>
<tr>
<td>Public Health &amp; Injury Prevention</td>
<td>9</td>
<td>B</td>
</tr>
<tr>
<td>Disaster Preparedness</td>
<td>42</td>
<td>D</td>
</tr>
<tr>
<td>Overall</td>
<td>47</td>
<td>D</td>
</tr>
</tbody>
</table>

### Top ranked states (highest to lowest)
1. Massachusetts
2. District of Columbia
3. Rhode Island
4. Maryland
5. Nebraska
6. Minnesota
7. Maine
8. Kansas
8. Pennsylvania
10. Delaware
10. North Dakota
10. Utah

### Bottom ranked states (lowest to highest)
47. Oregon
46. Idaho
45. Arizona
44. Kentucky
43. Michigan
42. Wyoming
51. Arkansas
50. Oklahoma
49. New Mexico
48. Nevada
# ACCESS TO EMERGENCY CARE

<table>
<thead>
<tr>
<th>Measure</th>
<th>Score</th>
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<tbody>
<tr>
<td>Board-certified emergency physicians per 100,000 pop.</td>
<td>13.4</td>
</tr>
<tr>
<td>Emergency physicians per 100,000 pop.</td>
<td>15.6</td>
</tr>
<tr>
<td>Neurosurgeons per 100,000 pop.</td>
<td>2.5</td>
</tr>
<tr>
<td>Orthopedists and hand surgeon specialists per 100,000 pop.</td>
<td>9.4</td>
</tr>
<tr>
<td>Plastic surgeons per 100,000 pop.</td>
<td>1.8</td>
</tr>
<tr>
<td>ENT specialists per 100,000 pop.</td>
<td>3.9</td>
</tr>
<tr>
<td>Registered nurses per 100,000 pop.</td>
<td>804.6</td>
</tr>
<tr>
<td>Additional primary care FTEs needed</td>
<td>37.0</td>
</tr>
<tr>
<td>Additional mental health FTEs needed</td>
<td>9.0</td>
</tr>
<tr>
<td>Level I or II trauma centers per 1M pop.</td>
<td>1.3</td>
</tr>
<tr>
<td>% of population within 60 minutes of Level I or II trauma center</td>
<td>76.4</td>
</tr>
<tr>
<td>Accredited chest pain centers per 1M pop.</td>
<td>0.3</td>
</tr>
<tr>
<td>% of population with an unmet need for substance abuse treatment</td>
<td>8.5</td>
</tr>
<tr>
<td>Pediatric specialty centers per 1M pop.</td>
<td>2.7</td>
</tr>
<tr>
<td>Physicians accepting Medicare per 100 beneficiaries</td>
<td>2.9</td>
</tr>
<tr>
<td>Medicaid fee levels for office visits as a % of the national average</td>
<td>96.3</td>
</tr>
<tr>
<td>% change in Medicaid fees for office visits (2004-05 to 2007)</td>
<td>0.4</td>
</tr>
<tr>
<td>% of adults with no health insurance</td>
<td>19.3</td>
</tr>
<tr>
<td>% of children with no health insurance</td>
<td>13.1</td>
</tr>
<tr>
<td>% of adults with Medicaid</td>
<td>7.1</td>
</tr>
<tr>
<td>Emergency departments per 1M pop.</td>
<td>15.7</td>
</tr>
<tr>
<td>Hospital closures in 2006</td>
<td>0</td>
</tr>
<tr>
<td>Staffed inpatient beds per 100,000 pop.</td>
<td>210.8</td>
</tr>
<tr>
<td>Hospital occupancy rate per 100 staffed beds</td>
<td>65.9</td>
</tr>
<tr>
<td>Psychiatric care beds per 100,000 pop.</td>
<td>28.8</td>
</tr>
<tr>
<td>State collects data on diversion</td>
<td>NR</td>
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</tbody>
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Traumatic Brain Injury in Oregon
Oregon TBI Epidemiology

- There were over 681 deaths in Oregon associated with TBI in 2007.
- Over 3,000 hospitalizations associated with TBI in 2007.
  - Males have higher rates of TBI associated death and hospitalization.
- Firearms are the most frequent cause of TBI death.
- Falls are the most frequent cause of TBI hospitalization.
- TBI was associated with over $145 million in hospitalization charges in 2007.
Oregon TBI Statistics

Mortality

- The age-adjusted mortality rate due to TBI declined between 1999 and 2006, yet increased in 2007 from 2006
  - Increased public awareness
  - Improved access to care
  - ?? Helmet Law
- The rate in 1999 was 20.0 per 100,000, while the 2007 rate was 17.5 per 100,000.
- In total, there were 4,506 deaths in Oregon associated with TBI between 1999 and 2007.
Oregon TBI Statistics

Traumatic Brain Injury Mortality
Age-adjusted Rate, 1999-2007

*Vertical bars indicate 95% confidence intervals for age-adjusted rate.
Oregon TBI Statistics

- The rate of TBI is higher in males than females, typically three times the female rate from year to year.
- In 2007, the male rate was 28.7 per 100,000 compared to the female rate of 7.2 per 100,000.
Age and Sex

- Age distribution of TBI rates shows that rates generally increase with age, and that the highest rates are among males 85 and older.
- The rate for males in this age group is 137.4 per 100,000 population, while the rate for females in the same age group is 71.0 per 100,000.
- The high rate among older men generally reflects the higher risk and mortality due to falls, motor vehicle traffic deaths, and firearms.
- Pre-existing medical conditions were reported for 81.7% of geriatric patients.
Oregon TBI Statistics

Mechanism of Injury

The leading causes of TBI-related death indicate that

- Firearms were involved in 43%
- 29% were the result of MVT injury
- 17% were due to falls
- 10% were due to a variety of other causes.
Mechanism of Injury in the Elderly

- The most common mechanism was
  - ground level fall (31.4%)
  - falls from steps or stairs (19.5%)
    - increases as the patients’ age increases.
  - third most common mechanism of injury was a fall from a ladder (17.3%), which decreases in frequency as age increases.

- These three types of falls accounted for 68.2% of the known fall injuries
Oregon TBI Statistics

Hospitalization

- TBI-associated hospitalization rates have increased since 1997

*Vertical bars indicate 95% confidence intervals for age-adjusted rate.*
Oregon TBI Statistics

Leading mechanisms of traumatic brain injury hospitalization by percent, 2007

- Falls: 42.9%
- MVT: 30.9%
- Struck by/against: 9.0%
- Other: 7.3%
- Other transport: 5.9%
- Pedal cyclist, other: 4.9%
Oregon TBI Statistics

Traumatic Brain Injury Hospitalization
Rate by age and sex, 2007

Rate per 100,000

Gender: F, M

Age groups:
- <1
- 1-4
- 5-14
- 15-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75-84
- 85+

The chart shows the rate of traumatic brain injury hospitalization by age and sex in Oregon for the year 2007.
Establishing a Statewide Brain Injury Consortium
What is a brain injury consortium?

- Multiple centers, centralized reporting
  - Routine review of trauma statistics and patterns
- Trauma designation/Tertiary referrals
  - Centralize the care
  - Directed at extending efficient care to local and rural areas
- Neurotrauma specialists
- Full-spectrum care
  - Pre-hospital/transport
  - Acute care
  - Rehabilitation
Who is involved?

.....Everyone

- First Responders
- Emergency Department
- Trauma Service
- Neurosurgeons
- Intensivists
- Neurologists
- PM&R
- PT/OT/ST
- Neuropsychology
- ICU and floor RNs
- Many, many more
What are the goals of a brain injury consortium?

- Organized, consistent care
  - Clear guidelines (algorithms) for decision-making
  - “right patient, right facility, right treatment.”

- Timely access to specialty care

- Public service
  - Public education

- Potential for research
What are the resources needed?

- Multiple sites for care implementation
  - SHRB
  - OHSU
  - Legacy Emanuel
  - Based on ATABs
- Trauma Coordinators
- Neurotrauma director & liason
- Expansion of data collection points
- Cooperation of rehab/longterm care facilities
- Funding??
Are there models in place?

- Current Head injury consortiums
  - Massachusetts
    - Not directed at the acute management
    - Focused on Rehab/Long term care
    - State-based resources for the injured
“No head injury was too trivial that it should be ignored or too severe that it be despaired of.”

Hippocrates, 400 BC
Thank you