Extent and Emerging Public Health Issues Related to TBI

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Emerging Public Health Issues Related to TBI

1. Youth concussions
2. Aging and falls
3. Lifetime TBI and adult disability
4. TBI as a chronic health condition

Youth Sports Concussion Treated in the Emergency Department
[rates per 100,000 for persons < 20 years old]

High School RIO Overall Concussion Rates

MMWR October 7, 2011; 60 (39).
Boys’ sports

Girls’ sports

Youth Sports Concussion Treated in the Emergency Department
[rates per 100,000 for persons < 20 years old]

Youth Concussions

Early childhood TBI, even if mild, may pre-dispose to later behavioral problems.

MMWR October 7, 2011; 60 (39).
Natural History of TBI to Age 25
(McKinlay et al., 2008)

- 1,265 children born in 1977 in Christchurch, New Zealand and followed to age 25
- Annual assessments from 4 months to age 16, then at 18, 21 and 25
- Verified through medical records all TBI’s diagnosed by a professional (MD office, ED, hospitalized)
- 79.3% successfully followed through age 25

Early Injury as Predictor of Later Problems

- Compared to no TBI and outpatient only, by early adolescence (10-13 y.o.) those hospitalized with a mild TBI before age 6 were:
  - More hyperactive and inattentive as rated by parent and teacher
  - More likely dx’d with ADHD, conduct disorder or oppositional defiant behavior
  - More likely to have substance abuse problems
  - More likely to demonstrate mood disorders

Early Injury as Predictor of Later Problems (continued)

- By late adolescence and early adulthood (16-25 years old):
  - Those hospitalized with 1st TBI before age 6, 3 times more likely to have a diagnosis of either alcohol or drug dependence by age 25
  - Those hospitalized with 1st TBI 16-21, 3 times more likely to be diagnosed with drug dependence
  - TBI highly associated with likelihood of arrest

Association between TBI and Arrests

- Relative Risk Ratios
- * p<0.05
- ** p<0.01

<table>
<thead>
<tr>
<th></th>
<th>1st TBI 0-5</th>
<th>1st TBI 6-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>1.65*</td>
<td>1.63*</td>
</tr>
<tr>
<td>Outpatient</td>
<td>3.52**</td>
<td>5.46**</td>
</tr>
<tr>
<td>Inpatient</td>
<td>3.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Correlates of Lifetime TBI among Adolescents (Ilie et al., 2014)

<table>
<thead>
<tr>
<th>Behavior</th>
<th>No TBI*</th>
<th>Lifetime TBI*</th>
<th>Odds** (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevated psychological distress</td>
<td>32.4%</td>
<td>39.2%</td>
<td>1.52 (1.19, 1.94)</td>
</tr>
<tr>
<td>Suicidal ideation</td>
<td>9.2%</td>
<td>15.2%</td>
<td>1.93 (1.42, 2.63)</td>
</tr>
<tr>
<td>Suicide attempt</td>
<td>2.0%</td>
<td>5.9%</td>
<td>3.39 (2.15, 5.35)</td>
</tr>
<tr>
<td>Sought counseling through a crisis help line</td>
<td>1.8%</td>
<td>3.5%</td>
<td>2.10 (1.18, 3.75)</td>
</tr>
<tr>
<td>Prescription for anxiety &amp;/or depression</td>
<td>2.7%</td>
<td>5.9%</td>
<td>2.45 (1.08, 5.56)</td>
</tr>
<tr>
<td>Took a car without owners' permission</td>
<td>4.4%</td>
<td>12.7%</td>
<td>3.47 (1.96, 6.15)</td>
</tr>
<tr>
<td>Beat up or hurt someone on purpose</td>
<td>7.1%</td>
<td>14.7%</td>
<td>2.21 (1.57, 3.12)</td>
</tr>
<tr>
<td>Sold marijuana or hashish</td>
<td>4.1%</td>
<td>9.6%</td>
<td>2.58 (1.45, 4.61)</td>
</tr>
</tbody>
</table>

* TBI if ≥ 5 minutes loss of consciousness or overnight hospital stay
** Odds ratio adjusted for grade, sex and sampling strata

TBI Model Systems: Earlier life TBI & pre- and post-rehabilitation substance misuse (N=4,464)

In Summary

• Early developmental TBIs have later consequences even when mild
• How early TBIs interact with other aspects of development, particularly child maltreatment, is not known
• How mild a TBI needs to be to not be harmful is not known
• Consequences are particularly related to impulsivity and reduced self-regulation
Public Health Issues

1. Youth concussions
2. Aging and falls
3. Lifetime TBI and adult disability
4. TBI as a chronic health condition

CDC Facts on Older Adult Falls

- Annually, 33% of those 65 or older will fall, but less than half are reported to healthcare providers
- Falls are the leading cause of both fatal and nonfatal injuries among older adults
- 20%-30% of people who fall suffer moderate to severe injuries which reduce independence and increase the risk of early death
- In 2000, 46% of fatal falls among older adults were due to TBI

Age by Year of Rehabilitation Admission
**Why is this occurring?**

- Not because the general population is getting older (proportions far exceed general population or change in general population).
- Not because rehab industry may have changed either its admission or coding practices in response to CMS rules.
- Older adults have more active lifestyles and thus may be exposed to more risks for falls and moving vehicle crashes.
- A new source of impairment may be causing older adults to fall (e.g., poly-prescription of drugs?).
- More older adults may be surviving the initial injury but have residual impairment—as a result of the TBI or due to debilitation from hospitalization.
- Older adults may not be so readily “relegated” to institutionalization, thus rehab deemed more appropriate.

**In Summary**

- >50% of adults in rehabilitation with a primary diagnosis of TBI are 65 years old or older
- Growth of this segment parallels increases in acute hospitalizations, especially with moderate, severe or penetrating TBI’s
- When compared to younger adults in rehab for TBI, older adults are more likely:
  - Women, married or once married, (also Caucasian, with Medicare as primary insurance)
  - Incurred TBI in fall, admitted sooner post-injury, have better cognition but worse motor function upon admission
  - Spend approximately 2-weeks in rehab & are less likely to have prolonged stays

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**Population-based study of TBI among adults in Colorado**

- Random digit dialed 2,700 Colorado adults administered computer assisted telephone interview based on OSU TBI-ID
- 200 called back no sooner than 6 months later to verify reliability

- 42% recalled at least 1 TBI in their lifetime
- 24% at least 1 TBI with loss of consciousness
- 6% at least 1 moderate or severe TBI
Relative Prevalence of Poor Balance, Memory and Concentration

Compared to those with no injuries after controlling for age, gender, race and treatment received (i.e., hospital, ED, office, none)

Relative Prevalence of Activity Limitations, Poor Physical Health and Life Dissatisfaction

Compared to those with no injuries after controlling for age, gender, race and treatment received (i.e., hospital, ED, office, none)

History of TBI among Adults in Colorado

Compared to adults without head injuries those with at least 1 TBI with LOC were:
- 1.5 times more likely to experience mental health problems
- 1.7 times more likely to be misusing alcohol
- greater than 2 times more likely to have any limitation due to physical, mental or emotional problems;
- greater than 3 times more likely to have a disability.

Disability as defined by BRFSS responses
Lifetime History of TBI:

<table>
<thead>
<tr>
<th></th>
<th>Any TBI</th>
<th>TBI with LOC</th>
<th>Mod/Severe TBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult population of Colorado (Whiteneck, et al.)</td>
<td>43%</td>
<td>24%</td>
<td>6%</td>
</tr>
<tr>
<td>Colorado adults with disability (Whiteneck, et al.)</td>
<td>57%</td>
<td>38%</td>
<td>11%</td>
</tr>
<tr>
<td>OEF/OIF veterans (Fortier, et al.) [including combat related]</td>
<td>32% [67%]</td>
<td>22% [38%]</td>
<td>4% [4%]</td>
</tr>
<tr>
<td>Prisoners (*Shrioma et al; **Bogner &amp; Corrigan)</td>
<td>60%*</td>
<td>50%*</td>
<td>14%**</td>
</tr>
<tr>
<td>SUD treatment (Corrigan &amp; Bogner)</td>
<td>65%</td>
<td>53%</td>
<td>17%</td>
</tr>
<tr>
<td>Psychiatric inpatients (Burg et al.)</td>
<td>68%</td>
<td>36%</td>
<td>20%</td>
</tr>
<tr>
<td>Homeless (*Hwang et al.; **Bremner et al., Solliday-McRoy et al.)</td>
<td>53%*</td>
<td>47%**</td>
<td>12%*</td>
</tr>
</tbody>
</table>

Frontal lobe damage is the “fingerprint” of TBI

Frontal areas of the brain, including the frontal lobes, are the most likely to be injured as a result of TBI, regardless the point of impact to the head.

The brain is set into motion along multiple axial planes

Interior Skull Surface

- Bony ridges
- Injury from contact with skull
Loss of gray matter one year post-injury (Bigler, 2007)

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Simplified Brain Behavior Relationships

Frontal Lobe
- Initiation
- Problem solving
- Judgment
- Inhibition of impulse
- Planning/anticipation
- Self-monitoring
- Motor planning
- Personality-emotions
- Awareness of self
- Organization
- Attention and concentration
- Mental flexibility
- Speaking

Parietal Lobe
- Sense of touch
- Differentiation of shape, color
- Spatial perception
- Visual perception

Temporal Lobe
- Memory
- Hearing
- Understanding language
- Organization and sequencing

Cerebellum
- Balance
- Coordination
- Skilled motor activity

Occipital Lobe
- Vision

Health and Social Outcomes 5 Years after Rehabilitation

- TBI Model Systems subjects admitted to rehabilitation 10/01/2001 to 12/31/2007

- Status 5 years later (weighted for national population characteristics):
  - 84.4% known outcome
  - 10.0% lost to follow-up
  - 5.7% withdrew/refused/unknown
  - for 1 in 4, the known outcome is “dead”
21.7% dead within 5 years

Of the average annual 13,700 admissions to U.S. IRF’s* with a primary diagnosis of TBI, an estimated annual average of more than 2,965 died in the first five years after injury.

*October 1, 2001 and December 31, 2007

Final Analyses
Re-weighted outcomes to reflect the U.S. population who were over the age 15 when they received inpatient rehabilitation with a primary diagnosis of TBI and are still alive 5 years later.

12.3% are institutionalized 5 years post-injury

16-19 20-29 30-39 40-49 50-59 60-69 70-79 80+

1% 2% 4% 4% 10% 9% 21% 28%

Confidence intervals:
at 50% ± 1.89%
at 10% ± 1.16%
at 1% ± 0.43%

Will always be age at injury

Of the average annual 13,700 admissions to U.S. IRF’s* with a primary diagnosis of TBI, an estimated annual average of more than 1,680 were institutionalized 5 years after injury.

*October 1, 2001 and December 31, 2007

49.7% are re-hospitalized at least once in the first 5 years post-injury

16-19 20-29 30-39 40-49 50-59 60-69 70-79 80+

39% 38% 46% 51% 43% 55% 56% 61%

Of the average annual 13,700 admissions to U.S. IRF’s* with a primary diagnosis of TBI, an estimated annual average of more than 6,810 were re-hospitalized in the 5 years after injury.

*October 1, 2001 and December 31, 2007
34.6% receive some supervision by another person each day at 5 years post-injury

Of the average annual 13,700 admissions to U.S. IRF’s with a primary diagnosis of TBI, an estimated annual average of more than 4,735 receive supervision 5 years after injury.

*October 1, 2001 and December 31, 2007

57.8% have moderate or severe disability at 5 years post-injury

Of the average annual 13,700 admissions to U.S. IRF’s with a primary diagnosis of TBI, an estimated annual average of more than 7,920 had moderate or severe disability 5 years after injury.

*October 1, 2001 and December 31, 2007

38.8% declined from an earlier outcome to their status at 5 years post-injury

Of the average annual 13,700 admissions to U.S. IRF’s with a primary diagnosis of TBI, an estimated annual average of more than 5,320 declined from an earlier outcome to status at 5 years post-injury.

*October 1, 2001 and December 31, 2007

Possible Sources of Deterioration

- TBI triggers a progressive, degenerative process (i.e., Parkinson’s Disease, Alzheimer’s Disease, Chronic Traumatic Encephalopathy).
- TBI causes loss of functional independence which interacts with normal aging to increase poor health.
- Frontal lobe damage endemic to TBI causes changes in self-regulation which lead to death and disability from risky behaviors.
- All, or some, of the above.
Summary & Implications

- Strong interaction of aging with TBI to make medical & functional outcomes worse.
- Deterioration is not unique to older adults, though basis for loss may be different for younger versus older survivors.
- Unique quality of life issues for younger patients (limits on participation in society, poorer subjective well-being, greater substance misuse).

Life Expectancy following Rehabilitation for TBI in the U.S.

- 7,366 TBI Model Systems participants admitted for rehabilitation after 09/30/2001 and discharged by 12/31/2010 with vital status tracked until 12/31/2011. (20,314 person-years of data)
- Weighted for national population characteristics to represent 156,447 individuals admitted to U.S. inpatient rehabilitation facilities with a primary diagnosis of TBI ages 16+ during same time period.
- Used U.S. population mortality rates from 2005 and 2010 to calculate standardized mortality ratios and life expectancy.

<table>
<thead>
<tr>
<th>Observed Deaths</th>
<th>Expected Deaths</th>
<th>Standardized Mortality Ratio (SMR)</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>All participants</td>
<td>1,325.4</td>
<td>2.23</td>
<td>2.11, 2.35</td>
</tr>
<tr>
<td>If alive 1 year post-injury</td>
<td>879.2</td>
<td>570.7</td>
<td>1.54</td>
</tr>
</tbody>
</table>

- Individuals with TBI were 2.23 times more likely to die compared to individuals in US general population of similar age, gender and race.
- Excess mortality decreased for those who survived at least until their 1 year post-injury anniversary.

<table>
<thead>
<tr>
<th>Age at injury (years)</th>
<th>Observed Deaths</th>
<th>Expected Deaths</th>
<th>SMR</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-19</td>
<td>7.6</td>
<td>0.7</td>
<td>11.58</td>
<td>3.37 - 19.79</td>
</tr>
<tr>
<td>20-24</td>
<td>17.1</td>
<td>2.5</td>
<td>6.86</td>
<td>3.60 - 10.11</td>
</tr>
<tr>
<td>25-34</td>
<td>26.9</td>
<td>3.3</td>
<td>8.24</td>
<td>5.12 - 11.35</td>
</tr>
<tr>
<td>35-44</td>
<td>46.6</td>
<td>4.9</td>
<td>9.56</td>
<td>6.82 - 12.31</td>
</tr>
<tr>
<td>45-54</td>
<td>104.2</td>
<td>12.2</td>
<td>8.55</td>
<td>6.91 - 10.19</td>
</tr>
<tr>
<td>55-64</td>
<td>107.5</td>
<td>21.3</td>
<td>5.04</td>
<td>4.09 - 5.99</td>
</tr>
<tr>
<td>65-74</td>
<td>245.1</td>
<td>55.6</td>
<td>4.41</td>
<td>3.86 - 4.96</td>
</tr>
<tr>
<td>75-84</td>
<td>530.0</td>
<td>200.8</td>
<td>2.64</td>
<td>2.41 - 2.86</td>
</tr>
<tr>
<td>85+</td>
<td>240.3</td>
<td>293.5</td>
<td>0.82</td>
<td>0.72 - 0.92</td>
</tr>
</tbody>
</table>

Generally, as age at injury increased, excess mortality decreased, but still remained elevated to age 84.
Independent risk factors for death

- Older age at injury
- Being male
- Divorced, widowed or separated
- Unemployed
- Less education
- Fall related TBI
- Later year of injury
- Not having a spinal cord injury
- Not discharged home
- Lower functional independence
- Greater disability

<table>
<thead>
<tr>
<th>Cause of Death by Organ System (ICD-9-CM Codes)</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory: (390-459)</td>
<td>340.8</td>
<td>26%</td>
</tr>
<tr>
<td>Respiratory: (460-519)</td>
<td>176.6</td>
<td>13%</td>
</tr>
<tr>
<td>Neoplasm: (140-239)</td>
<td>116.3</td>
<td>9%</td>
</tr>
<tr>
<td>External causes of injury: (injuries &amp; poisoning, E800-E999)</td>
<td>92.8</td>
<td>7%</td>
</tr>
<tr>
<td>Infectious disease: (081-139)</td>
<td>85.2</td>
<td>6%</td>
</tr>
<tr>
<td>Nervous System: (dementias &amp; neurodegenerative, 320-389)</td>
<td>63.8</td>
<td>5%</td>
</tr>
<tr>
<td>Mental Disorders: (290-319)</td>
<td>47.4</td>
<td>4%</td>
</tr>
<tr>
<td>Genitourinary system: (580-629)</td>
<td>35.9</td>
<td>3%</td>
</tr>
<tr>
<td>Digestive: (520-579)</td>
<td>27.4</td>
<td>2%</td>
</tr>
<tr>
<td>Other signs, symptoms, ill-defined conditions: (780-799, not 780.3)</td>
<td>24.4</td>
<td>2%</td>
</tr>
<tr>
<td>Endocrine, immune, etc.- (240-279)</td>
<td>21.2</td>
<td>2%</td>
</tr>
<tr>
<td>Seizure: (780.3)</td>
<td>13.3</td>
<td>1%</td>
</tr>
<tr>
<td>Congenital anomalies: (747)</td>
<td>10.4</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Diseases of blood: (280-289)</td>
<td>2.7</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Diseases of the skin, subcutaneous, connective tissue: (680-739)</td>
<td>0.8</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Unknown cause</td>
<td>266.5</td>
<td>20%</td>
</tr>
</tbody>
</table>

Deaths due to Accidental Poisoning

- Opiate primary 55%
- Opiate involved 64%
- Alcohol primary 23%
- Alcohol involved 41%
In Summary

- Individuals with TBI are more than 2 times more likely to die compared to individuals in US of similar age, gender and race.
- Excess mortality decreases once surviving to 1 year post-injury.
- While there are more deaths with greater age, younger age groups have more excess mortality.
- There are opportunities to decrease the most common causes of death as well as the causes of greatest excess mortality.

U.S. Population >15 years old receiving acute rehabilitation for a primary diagnosis of TBI

5 years after injury:
- 1 in 5 will die
- 4 of 10 who survive will decline from a previously attained outcome

Chronic Brain Injury (CBI)

Consensus from 2012 Galveston BI Conference:

“Injury to the brain can evolve into a lifelong health condition termed chronic brain injury (CBI). CBI impairs the brain and other organ systems and may persist or progress over an individual’s life span. CBI must be identified and proactively managed as a lifelong condition to improve health, independent function and participation in society.”
Managing TBI as a chronic health condition (IOM, 2010)

“The committee recommends that the Department of Veterans Affairs conduct research to determine the potential efficacy and cost-effectiveness of developing protocols for the long-term management of service members who have polytrauma and TBI. The approaches considered should include:

• prospective clinical surveillance to allow early detection and intervention for health complications;

• protocols for preventive interventions that target high incidence or high risk complications;

• protocols for training in self-management aimed at improving health and well-being;

• access to medical care to treat complications; and

• access to rehabilitation services to re-optimize functional abilities.”

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