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Health and Disability Risks with Lifetime History of TBI

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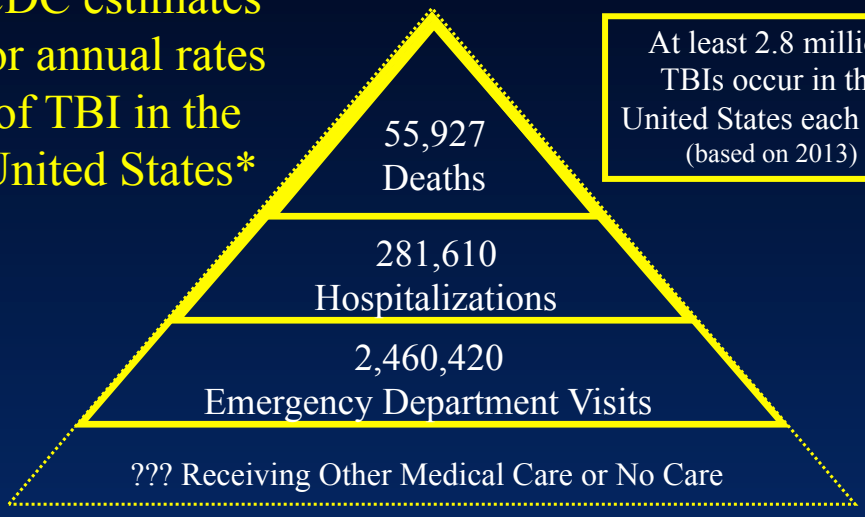
CDC estimates for annual rates of TBI in the United States*



At least 2.8 million TBIs occur in the United States each year (based on 2013)

* Taylor, CA, JM Bell, MJ Breiding and L Xu: Traumatic brain injury-related emergency department visits, hospitalizations, and deaths - United States, 2007 and 2013. MMWR Surveill Summ 66(9): 1-16, 2017

Lifetime History of TBI:	Any TBI	TBI with LOC	Mod/ Severe TBI
OEF/OIF veterans (Fortier, et al.) [including combat related]	32% [67%]	22% [38%]	4%
Prisoners (*Shrioma et al; ** Bogner & Corrigan)	60%*	50%*	14%**
SUD treatment (Corrigan & Bogner)	65%	53%	17%
Psychiatric inpatients (Burg et al.)	68%	36%	20%
Homeless (*Hwang et al.; **Bremner et al., Solliday-McRoy et al.)	53%*	47%**	12%*

What About Prevalence of TBI in the General Population?

- Disability due to TBI
- Lifetime TBI as "exposure"
  - Prevalence?
  - Consequences?

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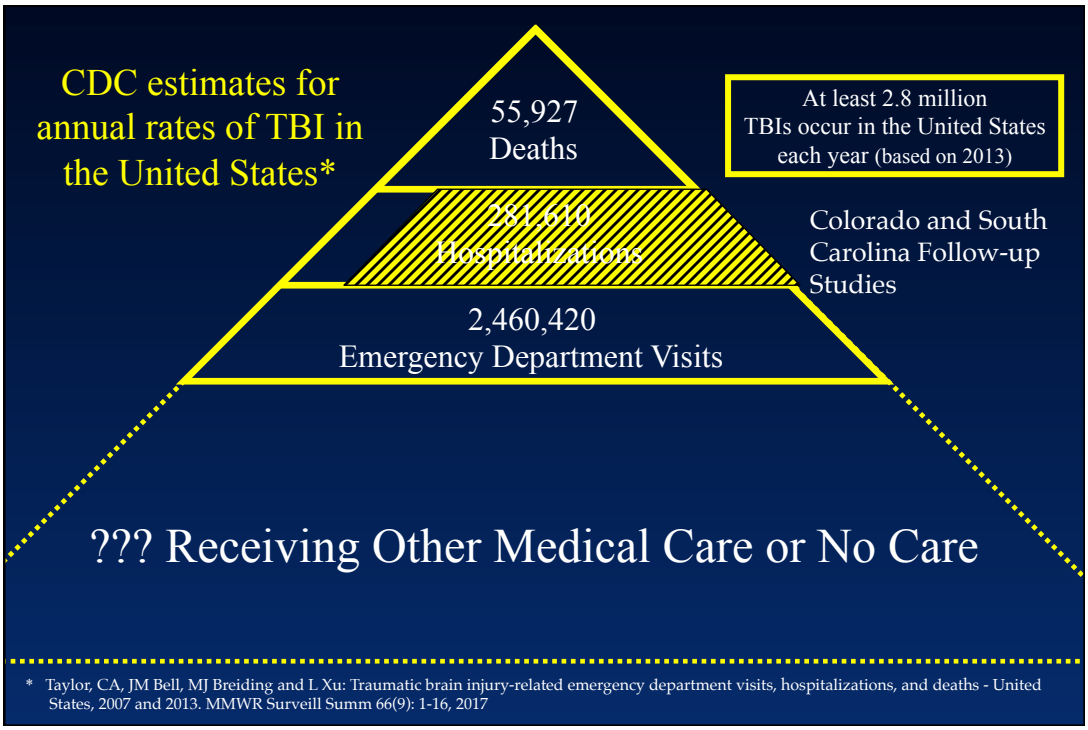
Prevalence of Disability Due to TBI



Prevalence of Disability Due to TBI

- Projected from 1 year outcomes following hospitalization
- Datasets did not include children
- Made assumptions about persistence of disability and mortality

✓In 1996, based on Colorado data: 2.0%

✓In 2005, based on South Carolina data: 1.1%

Survey Data & Disability Due to TBI

- Whiteneck et al.: if disability is not limited to TBIs requiring hospitalization, rate could be 3 x larger.

- Jourdan et al. from the French National Disability and Health Survey:

Survey Data & Disability Due to TBI

- Whiteneck et al.: if disability is not limited to TBIs requiring hospitalization, rate could be 3 x larger.
- Jourdan et al. from the French National Disability and Health Survey: 0.7%

Summary: Prevalence of Disability Due to TBI

- Estimates have ranged from 0.7%–2.0%
- US studies likely underestimates due to:
  - Starting with disability 1 year after hospitalization
  - Having to make assumptions about permanence and mortality
  - Not including TBIs occurring in childhood
- What if the effect of the TBI is not apparent immediately but in time results in disability?

Prevalence of "Exposure" to TBI

"Exposure" to TBI

The study of toxic exposures considers the nature of the relationship between exposure and effect.

If TBI was a chemical we would ask:

- what is the relationship between the dose of the exposure and the effect on the person?
- does a single exposure of any dose cause the effect?
- can there be cumulative effects of repeated exposures?
- how does development interact with both exposure and the manifestation of the effect?

Traumatic Brain Injury (TBI)

"...an insult to the brain caused by an external force that results in an altered state of consciousness."

Conceptualizing "Exposure" to TBI

- Has a person's head been exposed to sufficient forces to result in TBI?
- Has a person ever had altered consciousness due to external forces?—i.e., ever exposed to a TBI
- Has a person ever had a TBI of a certain magnitude of altered consciousness?—i.e., severity as dose

Conceptualizing "Exposure" to TBI (continued)

- How many TBIs has a person had?—i.e., number as the source of cumulative effects
- What was the timing of those TBIs?—i.e., spacing as the source of cumulative effects
- How old was a person when TBI occurred?—i.e., interaction with the stage of development

What do we know about prevalence of exposure to TBI?

- Not enough!
- Research on exposure to *g* forces is marked by inconsistencies and would appear to be impractical for getting lifetime prevalence data.
- Research on TBI during one's lifetime has used self-report based on single item elicitation of "yes/no" using a variety of case definitions.
- Use of standardized instruments for elicitation has been limited, at least to date.

Prevalence in Single Item Surveys

10% (1998); 13% (1999) –New Hampshire BRFSS "ever diagnosed with a concussion or a brain injury that was the result of trauma or drowning?"

37%–2001 Colorado BRFSS "how many times have you ever been injured where you were knocked out or unconscious?"

9%–New Haven Connecticut "experienced a severe head injury that was associated with a LOC or confusion?"

17%–2011 Ontario survey "head injury that resulted in being unconscious (knocked out) for at least 5 minutes, or requiring a stay in the hospital for at least one night?"

6%–2 Australian cities "TBI in your lifetime that resulted in 15 minutes or longer LOC?"

Lifetime History of TBI in General Population Surveys using Standardized Instruments

Colorado: CDC funded survey of 2,701 adult, non-institutionalized residents of Colorado ≥ 18 years old. Conducted from 2008-2010 and weighted to 2010 census data. CATI of the OSU TBI Identification Method research version.

Ohio: State optional module included in 2014 BRFSS administered to 6,998 adult, non-institutionalized Ohioans ≥ 18 years old. Used adapted OSU TBI Identification Method.

Prevalence of TBI in the Adult, General Population

	Colorado	Ohio
% with Any TBI	42.5%	n/a
% with Loss of Consciousness	24.4%	21.7%
% with Moderate or Severe TBI	6.0%	2.6%
% with Loss of Consciousness before age 15	6.7%	9.1%
% either LOC < 15 or mod/sev TBI	11.5%	10.8%

Summary: Prevalence of TBI Exposures

- "Exposure" is a paradigm shift in previous approaches to prevalence
- Accounts for effects of TBI that are not immediate and continuous
- May be more important when considering the public health burden of TBI
- Do not know enough about prevalence of exposure
- What do we know about consequences of lifetime exposure?

Consequences of Exposure to TBI

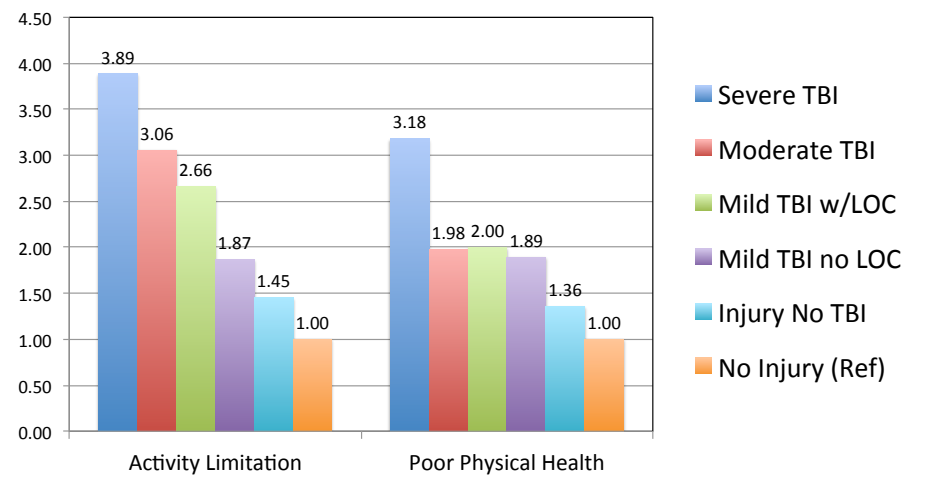
Province of Ontario (Ilie et al. 2015a,b,c)

Lifetime history of TBI with ≥ 5 minutes loss of consciousness or hospital stay

- More likely to smoke cigarettes (AOR=2.15) use cannabis (AOR=2.80) and use nonprescription opioids (AOR=2.90)
- More likely to be experiencing psychological distress (AOR=1.97)
- More likely to screen + for ADHD (AOR=2.49) or have been diagnosed with ADHD (AOR=2.64)
- More likely to have had a motor vehicle crash with injuries (AOR=1.79)
- More likely to have engaged in serious driver aggression during past 12 months (AOR=4.39)

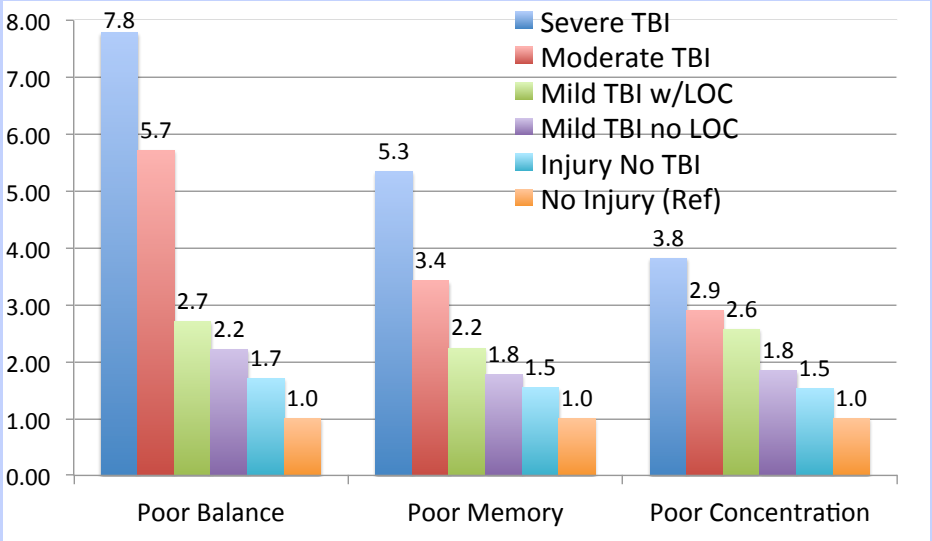
*Adjusted for sex, age and education

Colorado: Relative Prevalence of Activity Limitations and Poor Physical Health



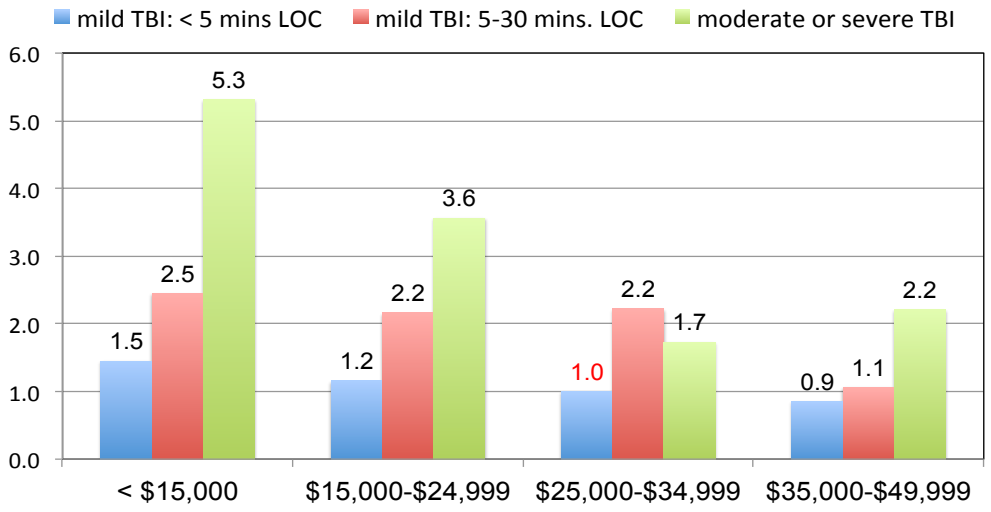
Compared to those with no injuries after controlling for age, gender, race and treatment received (i.e., hospital, ED, office, none)

Colorado: Relative Prevalence of Poor Balance, Memory and Concentration



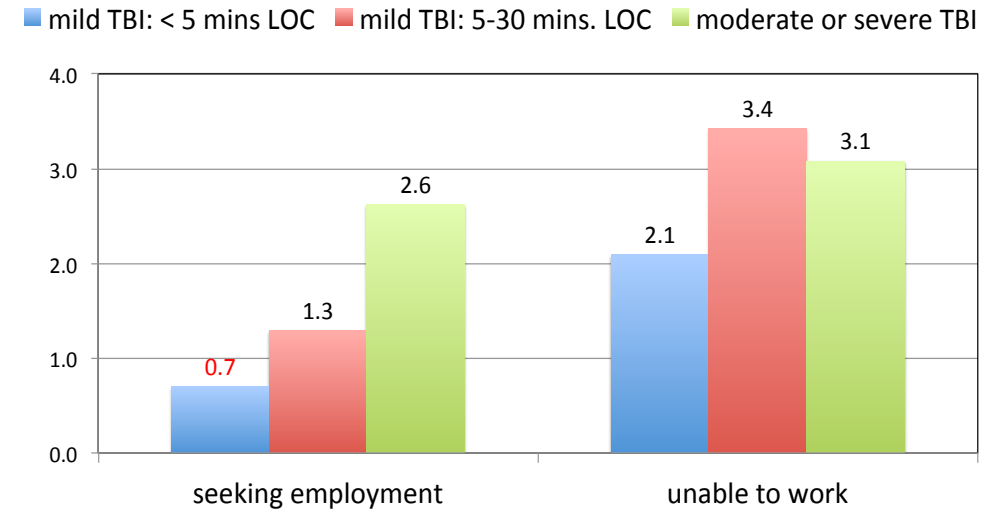
Compared to those with no injuries after controlling for age, gender, race and treatment received (i.e., hospital, ED, office, none)

Adjusted Odds* of Income by Severity of Worst Lifetime TBI



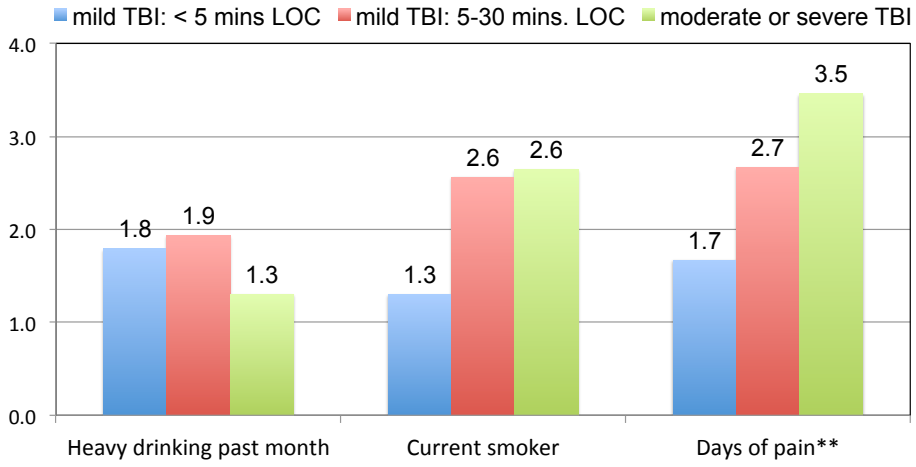
*Compared to Ohioans with no TBI with loss of consciousness, adjusted for age, gender and race/ethnicity

Adjusted Odds* of Unemployment by Severity of Worst Lifetime TBI



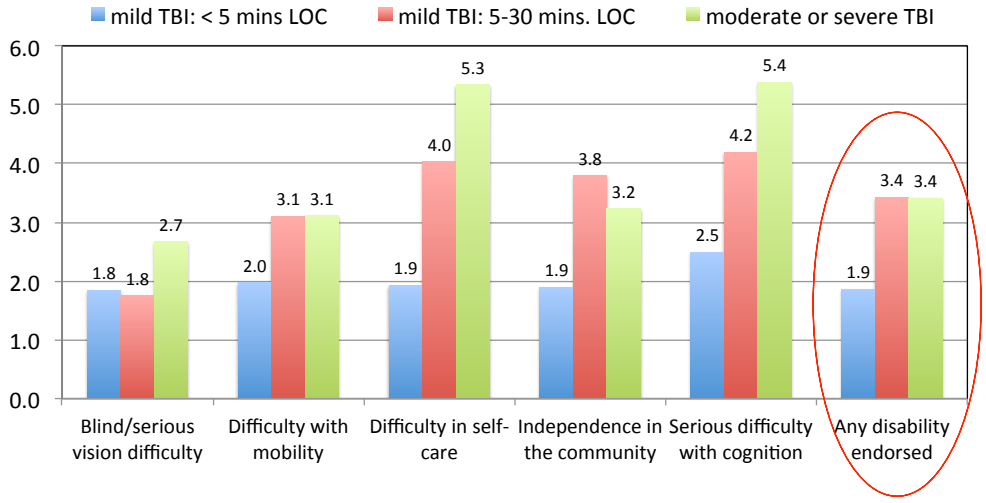
*Compared to Ohioans with no TBI with loss of consciousness, adjusted for age, gender and race/ethnicity

Adjusted Odds* of Unhealthy Conditions by Severity of Worst Lifetime TBI



*Compared to Ohioans with no TBI with loss of consciousness, adjusted for age, gender and race/ethnicity
**4th quartile vs 1st + 2nd quartile

Adjusted Odds* of Disability by Severity of Worst Lifetime TBI



*Compared to Ohioans with no TBI with loss of consciousness, adjusted for age, gender and race/ethnicity

Developmental Contributions

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

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

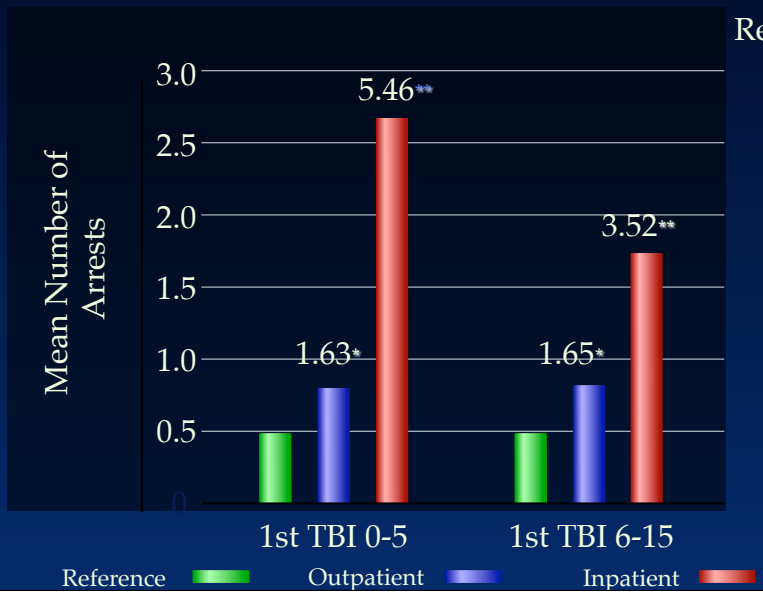
Early Injury as Predictor of Later Problems (continued)

By late adolescence to 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

Developmental

Association between TBI and Arrests



Relative Risk Ratios

* $p<0.05$

** $p<0.01$

Swedish Population Registry

- 1.1 million Swedish citizens born between 1973 and 1985 and followed to 2013
- 9.1% had a medically treated TBI by age 25
- Compared outcomes to general population, siblings without TBI and persons with orthopedic injuries
- Looked at likelihood of the following outcomes:
  - psychiatric treatment
  - psychiatric hospitalization
  - premature mortality
  - disability from work
  - receiving welfare benefits
  - low educational attainment

Adjusted Odds of Negative Consequences Compared to Uninjured Siblings

	Any TBI	Mild TBI	Mod/Sev TBI	Recurrent TBI
Disability pension	1.49	1.36	2.06	2.22
Psychiatric visit	1.31	1.31	1.34	1.24
Psychiatric hospitalization	1.57	1.51	1.75	1.53
Premature mortality	1.40	1.26	1.92	1.59
Low education	1.28	1.25	1.37	1.28
Welfare recipiency	1.19	1.18	1.21	1.13

Adj. Odds of Negative Consequences x Age at 1st Injury

	Ages 0-4	Ages 5-9	Ages 10-14	Ages 15-19	Ages 20-24
Disability pension	1.39	1.37	1.58	1.85	1.97
Psychiatric visit	1.18	1.19	1.40	1.60	1.78
Psychiatric hospitalization	1.24	1.33	1.68	2.04	2.47
Premature mortality	1.28	1.40	1.45	1.76	2.25
Low education	1.32	1.24	1.43	1.73	1.67
Welfare recipiency	1.33	1.35	1.40	1.56	1.70

Adj. Odds Negative Consequences x Age 1st Injury Compared to Uninjured Siblings

	Ages 0-4	Ages 5-9	Ages 10-14	Ages 15-19	Ages 20-24
Disability pension		1.29	1.28	1.49	1.73
Psychiatric visit		1.11	1.28	1.24	1.53
Psychiatric hospitalization			1.42	1.62	1.92
Premature mortality				1.24	1.59
Low education		1.10	1.22	1.41	1.34
Welfare recipiency			1.19	1.20	1.24

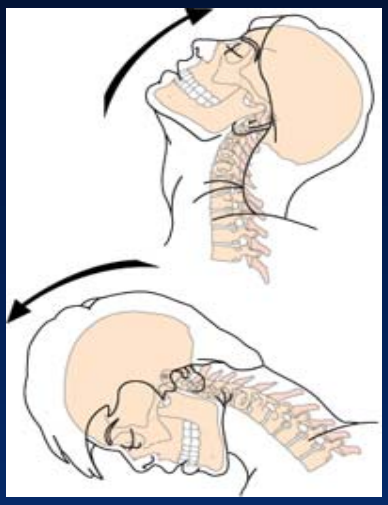
Pathophysiology

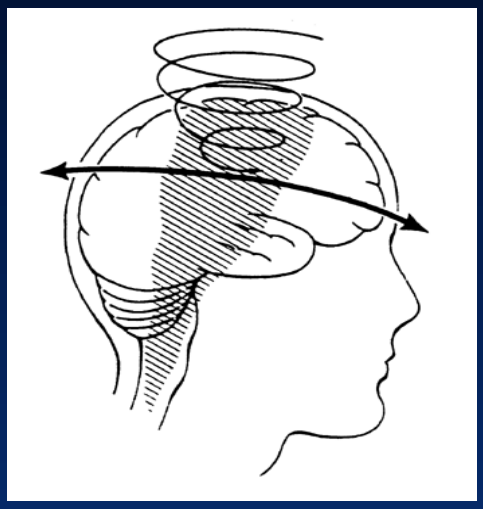
The "Fingerprint" of TBI

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

Pathophysiology

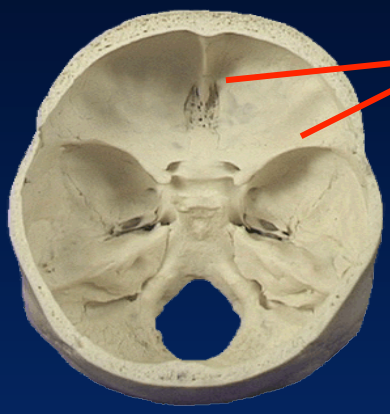
The brain is set into motion along multiple axial planes



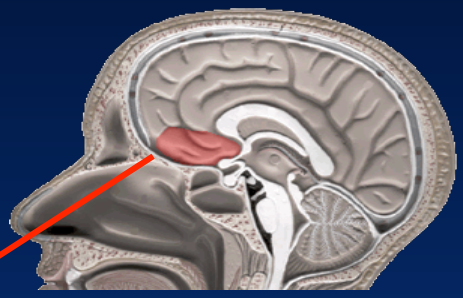


Pathophysiology

Interior Skull Surface

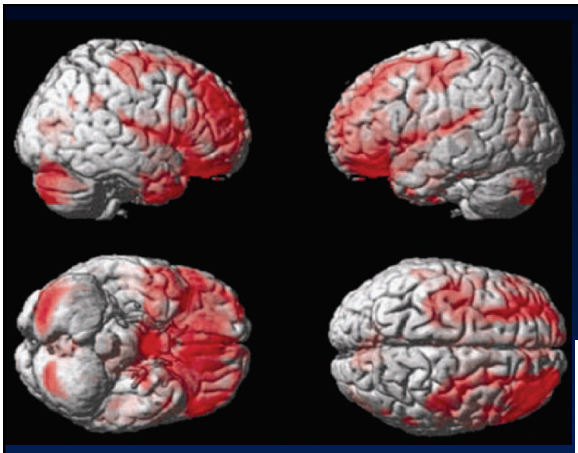


Bony ridges



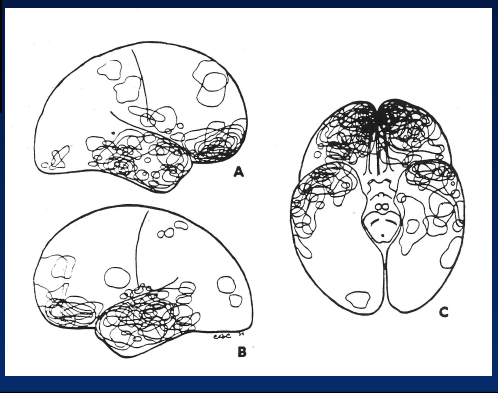
Injury from contact with skull

Pathophysiology



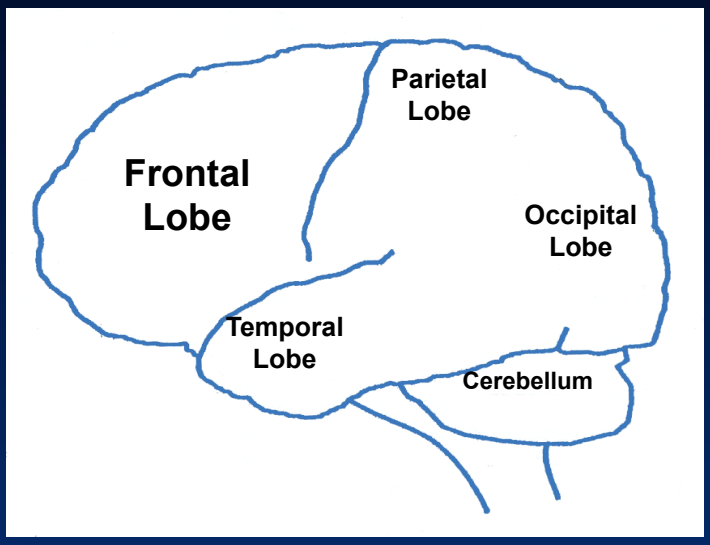
Loss of gray matter one year post-injury (Bigler, 2007)

Areas of contusion in (Courville, 1950)



Simplified Brain Behavior Relationships

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



Summary

- Significant associations between lifetime history of TBI and health and social consequences supports an "exposure" approach to examining the public health burden of TBI.
- There is much to learn about dose, cumulative and developmental effects.
- Research on how to measure exposure will be needed.
- BRFSS data could contribute to a body of research that will advance our knowledge of TBI exposure.

THANK YOU

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