Exploring the Effects of mild Traumatic Brain Injuries using Temporal Events

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Introduction

- During the last few years a significant amount of attention has been given to the understanding of the effects of mild TBI.

- In the US
  - over 1.7 million TBIs occur each year\(^1\)
  - sports-related brain injuries is estimated over 300,000 a year\(^1\)
  - Over 313,816 service members (SMs) have sustained a traumatic brain injury (TBI)\(^2\)

- Despite the large number of clinical elements that are collected during the evaluation and treatment of mTBI patients
  - the pathophysiological changes in the brain following a mTBI remain poorly understood
  - many questions still remain regarding the short- and long-term effects of TBI.

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\(^1\) Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths, 2002-2006 (CDC 2007).
\(^2\) DCoE, DoD worldwide numbers for TBI 2014
Objective

- Perform a large-scale population study to analyze the short- and long-term effects of mTBI

- Underlying study objectives:
  1. Describe the prevalence and incidence of different symptoms before / after mTBI events
  2. Model the clinical / healthcare path followed by SMs post mTBI using temporal events
  3. Develop predictive and forecasting analytical tools for mTBI

- Caveat about population studies
  - Pros:
    - Large dataset
    - Collected retrospective
    - Great for finding general patterns
  - Cons:
    - Uncertainty in the data
    - Many unknowns
    - Many valid (but different) ways to perform data interpretation
Background:
TBI Coding Guidelines

TBI Coding Algorithm

- **Initial Diagnosis**
  - Primary Code: Brain Injury 8xx
  - Secondary Dx: V-code
  - Other ICD-9 codes (e.g. cognitive 310.1)

- **Subsequent Visits**
  - Primary: Chief Complaint
  - Secondary Dx: V-code
  - Late Effect (90x)

**TBI Screening**
Code with V80.01

Positive Screen?

- Yes
  - Initial TBI Diagnosis
  - Initial or Subsequent Visit

- No
  - No additional TBI coding needed
  - Initial or Subsequent Visit

**Initial TBI Diagnosis**

**Subsequent TBI Visits**

**Department of Defense Coding Guidance for Traumatic Brain Injury Fact Sheet**

**IMPORTANT NOTE:** This guidance is being submitted to the Unified Biostatistical Utility for inclusion in the Coding Guidebook. This Fact Sheet will be updated as needed.

**CODING INITIAL ENCOUNTER FOR TBI:** The initial visit is coded using an 8XX series codes as the primary code followed by the appropriate TBI V code, any symptom codes and the appropriate deployment status code. An injury code for TBI from the 8XX series is used only once and is used for the initial encounter. An initial encounter does not refer to the first time the patient is seen by each clinician for that particular TBI. Rather, an initial encounter is defined as the first time the patient is seen by any medical professional for the TBI, regardless of when the injury took place even if it occurred several weeks, months, or years prior to the encounter. Clinical documentation must clearly indicate that the encounter coded is the initial encounter for that particular injury. If may be associated with skull fracture (800-801 or 803-804) or without skull fracture (850-854). A fourth digit is required that further describes the 8XX series codes. A fifth digit is required to describe the level of consciousness associated with the TBI. In order to ensure the most accurate and appropriate level of coding, documentation must clearly state if there was a loss of consciousness (LOC) due to the injury and, if so, the duration of LOC. If documentation does not clearly define that unspecified state of consciousness must be coded.

**The initial visit is coded using an 8XX series codes as the primary code followed by the appropriate TBI V code, any symptom codes and the appropriate deployment status code.**
Common symptoms associated with TBI

- Hearing
- Neurologic
- Headaches
- Cognitive
- Psychiatric
- Sleep
- Emotional / Behavioral Symptoms

TBI may be associated with skull fracture (800-801 or 803-804) or without skull fracture (850-854). A fourth digit is required that further describes the 8XX series codes.
1. 8 years (96 months) worth of data
2. Identify all diagnosis of mTBI
3. Determine distinct set of patients

98,342 mTBI Patients
Dataset

- Longitudinal healthcare encounter data
- Constraint the problem to only TBI-related encounters

**Patient #1**

<table>
<thead>
<tr>
<th>Encounter 1</th>
<th>Encounter 2</th>
<th>Encounter 3</th>
<th>Encounter 4</th>
<th>Encounter 5</th>
<th>Encounter 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>t₁</td>
<td>t₂</td>
<td>t₃</td>
<td>t₄</td>
<td>t₅</td>
<td>t₆</td>
</tr>
<tr>
<td>- Concussion</td>
<td>- Fever</td>
<td>- Headache</td>
<td>- Rash</td>
<td>- Sleep Disorder</td>
<td>- PTSD</td>
</tr>
<tr>
<td>- Headache</td>
<td>- Sore throat</td>
<td>- Sleep Disorder</td>
<td>- Skin Cancer Screening</td>
<td>- Anxiety</td>
<td>- Anxiety</td>
</tr>
<tr>
<td>- Pain</td>
<td></td>
<td></td>
<td></td>
<td>- Depression</td>
<td>- Depression</td>
</tr>
</tbody>
</table>

**Definition:** “TBI-related” encounter
1. mTBI patient
2. Include neurobehavioral symptoms / diagnosis known to be associated with mTBI
3. Only from type 1 and 2 providers
4. Only top three diagnosis were analyzed

<table>
<thead>
<tr>
<th>Num Patients</th>
<th>Num Encounters</th>
<th>Num Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>98,342</td>
<td>5,305,607</td>
<td>8,716,746</td>
</tr>
</tbody>
</table>
Dataset

- After removing patients with limited longitudinal data (< 30 days) and history of severe TBI

<table>
<thead>
<tr>
<th>Num Patients</th>
<th>89,840</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>29.79 (±8.73)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>88.14%</td>
</tr>
<tr>
<td>Female</td>
<td>11.86%</td>
</tr>
<tr>
<td>Branch</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>65.86%</td>
</tr>
<tr>
<td>USMC</td>
<td>12.52%</td>
</tr>
<tr>
<td>USAF</td>
<td>12.01%</td>
</tr>
<tr>
<td>USN</td>
<td>9.60%</td>
</tr>
</tbody>
</table>
Events Modeling

- Strings

```
“AAAABCCCCA”
```

- Automata

![Diagram showing a sequence of events with transitions labeled A, B, and C.]
Example: mTBI Path

- D depression
- N neuro
- k nonskull_fracture
- P ptsd
- S sleep_disorder
- T Vcode
Example: mTBI Path from mTBI to PTSD
*Filtered for patients with 365 days of data and limited to 1,000 patients.
# of mTBI

Mean: 3.98  
Std Dev: 5.684

<table>
<thead>
<tr>
<th># mTBI</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>395</td>
</tr>
<tr>
<td>2</td>
<td>186</td>
</tr>
<tr>
<td>3</td>
<td>109</td>
</tr>
<tr>
<td>4</td>
<td>69</td>
</tr>
<tr>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>39</td>
</tr>
<tr>
<td>7+</td>
<td>840</td>
</tr>
</tbody>
</table>
Male vs Female

Male

Female
TBI-Related Symptoms & Diagnoses
Pre-Existing Conditions

*Diagnoses 90 days prior to first concussion

286 have no diagnoses
First 30 Days Post Concussion

226 have no diagnoses

PTSD and Depression occur together
First 90 Days Post Concussion

88 have no diagnoses
First 365 Days Post Concussion
Pre-Existing Conditions

- **Headaches**
  - Mean: 16 days 9.44 hrs 52 s
  - Median: 8 days 0 ms
  - SD: 21 days 21:26 hrs 29 s

- **PTSD/Depression**
  - Mean: 11 days 2:23 hrs 57 s
  - Median: 5 days 0 ms
  - SD: 16 days 2:12 hrs 35 s

- **Sleep**
  - Mean: 15 days 14:40 hrs 55 s
  - Median: 8 days 0 ms
  - SD: 17 days 8:47 hrs 48 s
First 30 Days Post Concussion

PTSD/Depression

Second mTBI

Sleep
First 90 Days Post Concussion

PTSD/Depression

Second mTBI

Sleep
First 365 Days Post Concussion

PTSD/Depression

Second mTBI

Sleep
Related mTBI symptoms: Before and After 1st mTBI

Top Dx Changes between before and after 1st mTBI (N=89,840)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Before 1st mTBI</th>
<th>After 1st mTBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>30.6</td>
<td>28.5</td>
</tr>
<tr>
<td>Sleep</td>
<td>49.89</td>
<td>48.75</td>
</tr>
<tr>
<td>Neurology</td>
<td>48.75</td>
<td>50.8</td>
</tr>
<tr>
<td>Depression</td>
<td>32.73</td>
<td>43.37</td>
</tr>
<tr>
<td>Anxiety</td>
<td>27.18</td>
<td>16.4</td>
</tr>
<tr>
<td>PTSD</td>
<td>21.64</td>
<td>31.1</td>
</tr>
<tr>
<td>Audiology</td>
<td>13.79</td>
<td>1.95</td>
</tr>
<tr>
<td>Speech</td>
<td>9.01</td>
<td>9.01</td>
</tr>
</tbody>
</table>

Percentage of Patients

Before 1st mTBI
Conclusion

- Perform a large-scale population study to analyze the short and long-term effects of mTBI
- The late effects of mTBI are clear in the analysis of longitudinal data
- The effects of a concussion on the next diagnosis can be seen in distribution graphs
- Apply predictive and forecasting tools to clinical paths
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Questions?

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