Leveraging Trauma Data for TBI Research

TBIMS National Database (TBIMS NDB) has rich long-term outcome data after TBI
- Acute trauma data is limited

National Trauma Databank (NTDB) is the largest aggregation of trauma registry data in the United States
- No long-term outcomes

TBIMS NDB and NTDB Merger
- Inclusion criteria for TBIMS is admission to acute care trauma center
- All Level I/II trauma centers report their trauma registry information to the NTDB.
- Therefore, we know individuals in the TBIMS are also represented in the NTDB
- Linking these two datasets would provide a rich dataset with both acute and long-term data

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- Linking these two datasets would provide a rich dataset with both acute and long-term data
Linkage Nomenclature

**Deterministic Linkage**
- Matches two datasets based on a known identifier
  - Study ID
  - SSN
  - Medical Record Number
  - First/Last Name

**Probabilistic Linkage**
- Matches two datasets based on a set of common non-identifiable variables between datasets
  - **Basic premise:** if several variables have exact values for an individual in dataset I as well as for dataset II, it is likely they are the same person

Creating a TBI--Trauma Merged Dataset

- Leveraged local Pitt TBI-MS and PA Trauma Outcome Study (PTOS) to create a known merged dataset.
- Developed probabilistic matching algorithm and tested against known matches i.e. deterministic match.
- Assessed sensitivity and positive predictive value of matching algorithm.

GOAL: Creating a Merged Dataset

- Probabilistic linkage based on common data elements between TBIMS NDB and NTDB
- 3 blocking variables used to create cluster
  - Age
  - Sex
  - Year of injury
- 10 matching variables within a cluster
  - Initial systolic BP
  - Respiratory rate in the ER
  - Blood alcohol concentration
  - Intubation status
  - Initial GCS
  - Cause of Injury
  - Head injury pattern (fracture of base of skull or calvarium)
  - Race
  - Cranial surgery
  - Acute care LOS
Creating the Merged Dataset: Single Site

1. Started with 241 cases from local Pitt TBIMS data set between 2003 and 2007
   - 121 randomly selected cases were used for the algorithm generation set
   - Remaining 120 cases were used in a validation set

2. There were a total of 14,389 cases of trauma in PTOS trauma registry in same time frame
   - Narrowed to 5,338 cases by restricting to cases with TBI (using ICD-9 TBI-specific codes)

Creating the Merged Dataset: Single Site

1. After blocking, the algorithm generation had 1281 potential comparisons consisting of 1091 cases from trauma database joined to 121 cases from TBIMS dataset
   - 9:1 ratio of trauma: rehab cases

2. After blocking, the validation set had 1347 potential comparisons consisting of 1147 cases from trauma database joined to 120 cases from TBIMS
   - 9.6:1 ratio trauma:rehab cases
Creating the Merged Dataset: Single Site

- Each trauma-rehab case comparison within a cluster receives a **weight**
  - Depending on the **probability of random agreement**, a given matching variable will contribute more or less to the weight
  - Variables with a great degree of specificity, and low likelihood of having the same value by chance alone, will contribute more to the weight
    - **Race**: low specificity
    - **Systolic blood pressure** (admission): high specificity

Algorithm generation set Validation set

Creating the Merged Dataset

- **Case weight difference (CWD): the difference in weights** between the two highest comparisons within a cluster
  - **Goal**: maximize CWD, meaning that magnitude of difference between the two highest weights for a comparison within a cluster is large
    - Cluster defined as the comparison between 1 TBI model system case and all possible trauma case matches having the same blocking criteria
    - If CWD is very small, it appears that there are two trauma cases matching to one rehab case, which we know is impossible
  - Impose a margin of error for CWD of 5.34, corresponding to the 90th percentile of CWD for false matches
    - Throw out all comparisons within the cluster having a margin of error (<5.34), as we are not confident which is the true match between the two highest weighted comparisons
    - Setting stringent margin of error for the CWD provides a very conservative match criteria with very high percentage of true matches.
Probabilistic Matching with NTDB and TBIMS: Progress, Products, and Possibilities.
Amy Wagner, MD
Raj Kumar, MPH

Assessing the Quality of the Matching Algorithm

- **Sensitivity**: tells percentage of actual matches that screen as positive matches in our algorithm.

- **Positive Predictive Value**: tells us percentage of screened positive matches that are actual matches

<table>
<thead>
<tr>
<th>Algorithm generation set</th>
<th>Validation set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity=88%</td>
<td>Sensitivity=83%</td>
</tr>
<tr>
<td>Specificity=99.9%</td>
<td>Specificity=99.8%</td>
</tr>
<tr>
<td>PPV=99%</td>
<td>PPV=99%</td>
</tr>
<tr>
<td>NPV=98.7%</td>
<td>NPV=98.4%</td>
</tr>
</tbody>
</table>

First methodology paper for the local Pitt match is published:

Next Steps: Validation and Expansion of the TBI Trauma Merged Dataset

Validation

- Partnering with Carolinas Rehabilitation to validate the matching algorithm
  - another known matched local TBIMS and Trauma dataset
- Producing a Protocol Manual with detailed instructions on how to prepare data, complete probabilistic linkage
  - SAS and STATA code
  - QC merged dataset.

Creating a Merged National Dataset

- Probabilistic linkage based on common (non-PHI) data elements across TBIMS NDB and NTDB
  - 3 blocking (age, sex, year of injury)
  - 10 matching variables
- Yielded a dataset of 3,575 participants injured between 1997-2012

Funding support provided by: Center for Large Data Research & Data Sharing in Rehabilitation (P2CHD065702)
### Expansion of TBI Trauma Merged Dataset

- Merge TBIMS & NTDB data from 2013-2015
- **Pittsburgh Data Set:** Assessing sensitivity and specificity of the merged dataset in the context of variable changes in the TBIMS and NTDB
  - Implications of adding/deleting variables
  - **For example:** Systolic blood pressure (removed from TBIMS) - single best matching variable in probabilistic matching algorithm
  - *Variable addition/deletion recs

#### An Exemplar Analysis:

Acute trauma factor associations with suicidality across the first 5 years after traumatic brain injury


### Suicidal Ideation and Attempt

#### In TBI
- Heightened risk after TBI
- Link to TBI severity is mixed
- Limited examination of extracranial injury effects on suicidality after TBI

#### In major trauma
- Heightened risk with Injury Severity Score (ISS) >12
- May be associated with higher prevalence of substance abuse

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Objective
To determine whether severities of
- Head Injuries
- Extra-cranial Injuries (ECI)
were associated with
- Suicidal Ideation (SI)
- Suicide Attempt (SA)
in the first 5 years after traumatic brain injury (TBI)

Measures

**TBIMS NDB Variables**

**OUTCOMES:**
- Suicidal Ideation: Yes/No based on PHQ9 Q#9. Coded as YES if >1
- Suicide Attempt: Yes/No based on self-reported attempt in the previous year

**NTDB Variables**
- Head injury severity: Head Abbreviated Injury Scale (AIS):
- Extra-cranial injury severity: Injury Severity Scale (ISS), Coded as none (0), mild (1-8), moderate (9-15), severe (>15)
- Infectious Burden: Y/N infectious complication
- Alcohol use at time of injury: Blood alcohol concentration
- Drug use at time of injury: Positive screen (blood draw)
- Intent: accident, assault, self-inflicted

Data Analysis
1. Compared those with SI (no SA) to those with No SI/SA
2. Compared those with SA to those with No SI/SA
3. Random-effects models to identify predictors of SI and SA across the first 5 years post-injury
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Descriptive Results:
Those with SI were more likely than those with no SI/SA to have:
• Drug use at time of injury
  (41.3% vs 33.2%)
• Substance abuse at follow-up
  ❖ 20.8-26% vs. 12.5-15.8% 1-5 yrs after TBI
• Clinically significant depression symptoms
  ❖ 9-11 vs. 2-3 1-5 yrs. after TBI

Descriptive Results:
Those with SA were more likely than those with no SI/SA to have:
• Drug use at time of injury
  (46.2% vs 33.2%)
• Substance abuse at follow-up
  ❖ 24-32.4% vs 12.5-15.8% 1-5 yrs. Post-TBI
• Clinically significant depression symptoms
  ❖ 6-11 vs 2-3 1-5 yrs. Post-TBI

*Those with SA also had less education

Multivariate Results: Predictors of SI
### Model 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-injury Suicide Attempt</td>
<td>1.05</td>
<td>0.97-1.13</td>
<td>0.87</td>
<td>0.38</td>
</tr>
<tr>
<td>Depression (PHQ8) (at follow-up)</td>
<td>1.27</td>
<td>1.12-1.45</td>
<td>2.32</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Extra Head Injury (ISS)†</td>
<td>1.32</td>
<td>0.97-1.82</td>
<td>1.60</td>
<td>0.11</td>
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### Model 2

<table>
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<tbody>
<tr>
<td>Pre-injury Suicide Attempt</td>
<td>1.03</td>
<td>0.94-1.12</td>
<td>1.17</td>
<td>0.24</td>
</tr>
<tr>
<td>Depression (PHQ8) (at follow-up)</td>
<td>1.25</td>
<td>1.14-1.36</td>
<td>3.10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Extra Head Injury (ISS)†</td>
<td>1.25</td>
<td>0.95-1.65</td>
<td>1.08</td>
<td>0.29</td>
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### Multivariate Results: Predictors of SA

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<tbody>
<tr>
<td>Race (white)</td>
<td>1.01</td>
<td>0.99-1.03</td>
<td>0.34</td>
<td>0.73</td>
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<tr>
<td>Sex (male)</td>
<td>1.00</td>
<td>0.96-1.05</td>
<td>0.94</td>
<td>0.34</td>
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<tr>
<td>Age (years)</td>
<td>1.02</td>
<td>1.01-1.03</td>
<td>3.06</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Drugs</td>
<td>1.02</td>
<td>0.99-1.05</td>
<td>0.55</td>
<td>0.59</td>
</tr>
<tr>
<td>Injury Site</td>
<td>1.00</td>
<td>0.98-1.03</td>
<td>1.11</td>
<td>0.27</td>
</tr>
<tr>
<td>Alcohol Blood Level</td>
<td>1.00</td>
<td>0.93-1.08</td>
<td>1.29</td>
<td>0.20</td>
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<tr>
<td>Problems Associated (pre-injury)</td>
<td>0.84</td>
<td>0.78-0.90</td>
<td>2.77</td>
<td>&lt;0.01</td>
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<tr>
<td>Education (12+ years)</td>
<td>0.98</td>
<td>0.95-1.01</td>
<td>1.91</td>
<td>0.06</td>
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<tr>
<td>Any Substance Use</td>
<td>1.83</td>
<td>1.73-1.95</td>
<td>10.59</td>
<td>&lt;0.01</td>
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### Depressive Symptoms (PHQ8) (at follow-up)

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<tr>
<td>Time to Follow Commands (Days)</td>
<td>1.00</td>
<td>0.98-1.02</td>
<td>1.41</td>
<td>0.16</td>
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<tr>
<td>Total Head AIS</td>
<td>1.00</td>
<td>0.98-1.02</td>
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**Conclusions:**
- Those with severe ECI at greatest risk for SI post-TBI
- Drug use at time of injury and substance abuse at follow-up were associated with SI
- Head injury severity was NOT associated with greater risk for SI or SA post-TBI
- Functional status (FIM) was not associated with SI
  - Ceiling effects with FIM
- ECI was not a predictor of depressive symptoms.
  - Associations with suicidality independent of depression

**Significance:**
- ECI severity is an important factor with regard to long-term post-TBI outcomes
  - Corroborates ECI and suicidality linkages in Polytrauma populations
  - Not just presence/absence of ECI
  - Implications for triage, treatment, and long-term monitoring
- Findings may be related to poorer recovery, longer time to recovery, and functional limitations in higher level activities not captured by FIM
- Substance abuse – particularly drug abuse – before, at time of, and after TBI should be assessed, monitored, and addressed

**Next Steps:**
**ECI and Suicidality**
Evaluating causal and inferential associations across the clinical care spectrum between extra-cranial injury and suicidality after moderate to severe TBI
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Amy Wagner, MD
Raj Kumar, MPH

Diagram 1: Characterize demographics, acute care factors/complexity, and long-term outcomes of individuals with TBI, with/without ICT.
- Extra-cranial Injuries/Severity
- Acute Care Factors/Complexity
- Substance Use & Time to Employment
- Suicidal ideation
- Sex
- Age

Diagram 2: Identify demographic and psychosocial factors that influence the relationship between extra-cranial injury and suicidal ideation after TBI.
- Extra-cranial Injuries/Severity
- Acute Care Factors/Complexity
- Substance Use & Time to Employment
- Suicidal ideation
- Sex
- Age

Diagram 3: Determine whether acute care factors and complexity explain relationships between extra-cranial injury, psychosocial outcomes, and suicidal ideation after TBI.
- Extra-cranial Injuries/Severity
- Acute Care Factors/Complexity
- Substance Use & Time to Employment
- Suicidal ideation
- Sex
- Age
Other Projects: Acute Complications and Long-term Outcomes

Creation of a Matched Non-TBI Trauma Database

- Matching for Propensity Analyses
  - Create a matched dataset (n~5000) of TBI patients and no-TBI polytrauma patients within the NTDB
  - Will match based on baseline variables within the NTDB (e.g. age, sex, education, race, mechanism of injury, pre-morbid conditions, injury severity score)

- “Trauma Control” dataset
  - Tease out TBI-specific vs General Trauma acute care outcomes
  - Evaluate rates of acute care complications and procedures between TBI cases and no-TBI polytrauma.
  - Evaluate acute outcomes and healthcare utilization among matched trauma population with/without TBI

Funding support provided by: Center for Large Data Research & Data Sharing in Rehabilitation (P2CHD065702)

NDB Notification: Acute factors associated with outcomes TBI MS sample

- H1: Patients with acute complications will have poorer long-term outcomes compared to similar patients without complications
  - Current analysis: IAP and multidimensional outcome
  - Plan to examine Sepsis
- H2: Patients with concomitant injuries will have poorer long-term outcomes compared to similar patients with TBI only.
  - Current analysis: TBI Relevant Early Injury Factors and Injury Type: Associations with Depression, Suicidality, and Multidimensional Outcomes.
- H3: Patients undergoing surgical procedures (e.g. tracheostomy) will have poorer long-term outcomes compared to similar patients not undergoing surgical procedures.
  - ~1000 procedure codes in current Matched National Dataset.
  - Non-TBI polytrauma matched controls: propensity analysis for complications, healthcare utilization
  - Matched analysis: TBI with vs. without procedure or complication of interest to assess outcome
Possibilities:

- Create other Trauma (SCI, Burn) Merged datasets leveraging MS and NTDB datasets
- Create other matched control polytrauma datasets for Burn and SCI MS linked patients.
- Future TBI-MS Notifications
  - Comparative assessment of acute care complications and procedures across MS populations
- Future Funding Opportunities?
  - CDC, NIDILRR, PCORI, NIH

Thank you!