Shaken Baby Syndrome on Trial

Problems with Causality and Sources of Contextual Bias

Maria Cuellar

Advisor: Stephen Fienberg
Working group: Clifford Spiegelman, Lucas Mentch, William Thompson

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Agenda

1. Trudy Muñoz’s trial
2. Historical background of Shaken Baby Syndrome
3. Example of Maguire's statistical model
   • Problem 1: Model asks the wrong causal questions
   • Problem 2: Model suffers from contextual bias
4. Recommendations
Motivation:
Trudy Muñoz’s Trial

February 2, 2011
Research question and contribution

• **Ongoing controversy** — Can you really tell whether a baby was shaken from certain medical findings?

• **Goal** — What are the statistical arguments that have been made about SBS? Are they correct? If not, how could they be improved?

• **My contribution** — I point out two serious problems commonly made in arguments about SBS and provide solutions to them.
History of Shaken Baby Syndrome (SBS)

- 1971 — Guthkelch hypothesizes shaking might cause symptoms.
- 1980s — The first convictions were made on the basis of the triad.
- 2009 — Tuerkheimer questions the diagnosis (followed by Moran 2012).
- 2012 — CDC publishes definition of SBS.
- 2016 — Innocence projects have helped exonerate 15 wrongful convictions.

**CDC definition**: “An injury to the skull or intracranial contents of an infant or young child (<5 years of age) due to inflicted blunt impact and/or violent shaking.”
Maguire’s statistical model to predict abuse

Maguire et al. (2011) propose a tool (logistic regression) to make diagnosis of SBS more objective.

Authors’ suggestion: New child needs diagnosis? Doctor can use the tool!

⇒ New child in the ER, physician can use model to make a more objective diagnosis.
Data used by Maguire’s statistical model

• Obtained (proprietary) data from 6 physicians
• Children under age 3 with intracranial injury
• Sample size is 1,053 (348 were abused)
• Large portion of missing data
• Criteria: “Abuse confirmed in court or admitted by perpetrator or confirmed by multidisciplinary assessment.”

<table>
<thead>
<tr>
<th>Abuse?</th>
<th>Retinal hemorrhage?</th>
<th>Rib fracture?</th>
<th>Long bone fracture?</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>.</td>
<td>Yes</td>
<td>.</td>
<td></td>
</tr>
</tbody>
</table>

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Problems with Maguire’s statistical model

Minor:
• It has sample selection bias.
• It imputes missing values by assuming “missing at random”.
• It performs model selection using p-values.
• Others.

Major:
• The authors are asking the wrong causal question.
• The model’s outcome variable is biased.
Problem 1: Maguire statistical model asks the wrong causal question
Problem 1: Maguire statistical model asks the wrong causal question

- **Forecasting**: If a child is shaken, how likely is it that he will have the triad of injuries?

- **Backcasting**: If a child has the triad of injuries, how likely is it that he was shaken?

- **Attribution**: *This child* was shaken and got the triad of injuries. How likely is it that the shaking, and not something else, caused the triad of injuries?
### Notation for Causes of Effects and Effects of Causes

<table>
<thead>
<tr>
<th>Random variables</th>
<th>Equals 0 when</th>
<th>Equals 1 when</th>
</tr>
</thead>
<tbody>
<tr>
<td>E: Exposure</td>
<td>Not exposed to shaking</td>
<td>Exposed to shaking</td>
</tr>
<tr>
<td>R: Response</td>
<td>Does not get injuries</td>
<td>Gets injuries</td>
</tr>
</tbody>
</table>

- **R₀**: Potential response when E=0, i.e. child is not shaken
  - Does not get injuries when not shaken
  - Gets injuries when not shaken

- **R₁**: Potential response when E=1, i.e. child is shaken
  - Does not get injuries when shaken
  - Gets injuries when shaken

<table>
<thead>
<tr>
<th>Question</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects of Causes (forecasting, backcasting)</td>
<td>P(R=1</td>
</tr>
<tr>
<td>Causes of Effects (attribution)</td>
<td>Pc(R₀=0</td>
</tr>
</tbody>
</table>

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*Dawid, Musio, Fienberg, “From statistical evidence to evidence of causality”, Bayesian Analysis (2016).*
Causes of Effects
probability of causation

Need potential responses
R0 (was not shaken) and
R1 (was shaken).

For the sake of argument,
say someone runs a randomized
trial and the children get the
triad of injuries:
No shaking: 12%
Shaking: 30%.

<table>
<thead>
<tr>
<th></th>
<th>R₀=0</th>
<th>R₀=1</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>R₁=0</td>
<td>88–x</td>
<td>x–18</td>
<td>70</td>
</tr>
<tr>
<td>R₁=1</td>
<td>x</td>
<td>30–x</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>12</td>
<td>100</td>
</tr>
</tbody>
</table>

Causes of Effects probability of causation (assumptions):

\[ PC = P_c(R_0=0 \mid R_1=1, E=1) = \frac{x}{30} \]

\[ 18 \leq x \leq 30 \]

\[ PC \geq 60\% \]
My suggestion: Causes of Effects analysis for SBS

• Instead of doing **backcasting** they should do **attribution**.

• Could perform a Causes of Effects analysis by using the Effects of Causes results (under assumptions).

• But we cannot perform a randomized trial!

• Some have already performed experiments: Simulations, dolls with force censors, pigs, monkeys, cadavers.

⇒ **Best case scenario to answering “were these injuries caused by shaking?” is an interval for the probability of the CoE causation.**
Problem 2: Maguire statistical model suffers from bias
Problem 2: Maguire statistical model suffers from bias

• **Authors determined abuse indirectly** — Abuse was positive if it was: confirmed in court, admitted by perpetrator, confirmed by a multidisciplinary team.

• **Gold standard unknown** — The truth about whether the child was abused is unknown.

  • **Circularity** — the outcomes are determined by the clinical features themselves.

  • **Bias** — influence of expert witness on jury, false or coerced confessions, improper interrogations.

\[\Rightarrow\text{Can we eliminate the circularity and the bias?}\]
Restriction of task-irrelevant information

National Commission suggests removing the contextual evidence that might bias the results.
Cause versus manner

For medical examiner/physician:

- **Cause of death/Diagnosis** — e.g. bullet wound through head.
- **Manner of death/External causes** — e.g. suicide, accident, shot by someone.

*But the same individual decides both cause and manner!*

Problems:

- Very difficult for individual to “forget” contextual information (Dror 2006).
- Physician tells medical examiner his/her medical opinion (Williams 2016).
- **For SBS, the diagnosis conflates the manner and cause!**

**CDC definition:** “An injury to the skull or intracranial contents of an infant or young child (<5 years of age) due to inflicted blunt impact and/or violent shaking.”
A solution: Remove contextual evidence, separate tasks, change definition

1. Remove contextual evidence to decide cause of death/diagnosis.

2. Physician should not speak with medical examiner who determines the cause.

3. Separate tasks: Four individuals should make the diagnosis: 2 doctors (one for diagnosis, one for external causes), 2 medical examiners (one for cause and one for manner of death).

4. Change the definition (and name) of Shaken Baby Syndrome so it does not include the manner in which the head injuries occurred.
Author of seminal study suggests changes

Norman Guthkelch (2012) suggests the name “Shaken Baby Syndrome” or “Abusive Head Trauma” be changed to:

“Infant retino-dural hemorrhage with minimal external injury.”
Recommendations

Physicians, medical researchers, and attorneys should:

1. **Ask correct causal questions** — Can use Causes of Effects framework.

2. **Implement blinding** — Only the task-relevant information should be provided to the individual who determines the diagnosis.

3. **Change the definition** — It should not include the section about the manner in which the injuries were caused.

⇒ *This might help reduce the number of wrongful convictions related to Shaken Baby Syndrome that have occurred and continue to occur.*
Future research

1. Communicate these concepts to medical and legal professionals.

2. Expand the use of the Causes of Effects framework beyond SBS where other legal causal claims are made.

3. Get a better understanding of contextual bias and how task-relevant information restriction could effectively be used in other forensic cases.
Thank you!
For the sake of argument, say someone runs a randomized trial and the children get the triad of injuries: No shaking: 12% Shaking: 30%.

<table>
<thead>
<tr>
<th></th>
<th>E=0 Not shaken</th>
<th>E=1 Shaken</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R=0</strong>&lt;br&gt;Did not have injuries</td>
<td>88</td>
<td>70</td>
</tr>
<tr>
<td><strong>R=1</strong>&lt;br&gt;Had injuries</td>
<td>12</td>
<td>30</td>
</tr>
</tbody>
</table>

**Effects of Causes probability of causation:**

\[
PC = P(R=1 \mid E=1) - P(R=1 \mid E=0) = 30\% - 12\% = 18\%.
\]

=> Probability that shaking makes one have the injuries.
Why not just use backcasting?

Probability of causation in backcasting is
\[ P(E=1 \mid R=1) - P(E=1 \mid R=0). \]

By Bayes rule,
\[ P(E=1|R=0) = P(R=0|E=1)P(E=1)/P(R=0). \]

Then,
\[ P(E=1|R=1) - P(E=1|R=0) = P(E=1|R=1) - P(R=0|E=1)P(E=1)/P(R=0) \]
\[ = 1 - 0. \]

⇒ Backcasting tells you nothing new.
Gelman and Imben’s approach

Forecasting:

<table>
<thead>
<tr>
<th>Given this, what is the probability of this?</th>
<th>Probability statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R=1</td>
<td>P(E1=1</td>
</tr>
<tr>
<td>E1=1</td>
<td></td>
</tr>
<tr>
<td>E2=1</td>
<td>P(E2=1</td>
</tr>
<tr>
<td>E3=1</td>
<td>P(E3=1</td>
</tr>
<tr>
<td>…</td>
<td></td>
</tr>
<tr>
<td>En=1</td>
<td>P(En=1</td>
</tr>
</tbody>
</table>

The highest of these probabilities gives you the cause.

E: exposure
R: response
R1,R0: potential response that eventuates when E=1,0 [resp.]
Data

**EPIC** — Epidemiology and Prevention for Injury Control
- Small sample (not useful for rare events)
- Not representative of the US population.

**KID** — Kids’ Inpatient Database:
- Only contains information from hospital records.
- Biased by several factors.

**Physician’s records** — not available to the public.

**Others**
Assumptions for calculating CoE bounds

For an attribution question about Ann, for example, we require:

1. Conditional on my knowledge of the pre-treatment characteristics of Ann and the trial subjects, I regard Ann’s potential responses as exchangeable with those of the treated subjects having characteristics H (all bg knowledge I have of Ann).
2. Same as assumption 1 but for untreated subjects.
3. H is exogenous (determined by a factor outside the model).
4. H is sufficient for Ann’s response, \((R_0, R_1) \perp\!\!\!\!\!\!\perp_A E | H\) where \(\perp\!\!\!\!\!\!\perp_A\) is the conditional independence in my distribution PA for Ann’s characteristics.

The narrowest bound we can get then is:

\[
\min \left\{ 1, \frac{\Pr_A(R_0 = 0 | H, E = 1)}{\Pr_A(R_1 = 1 | H, E = 1)} \right\} \geq PC_A \geq \max \left\{ 0, 1 - \frac{\Pr_A(R_0 = 1 | H, E = 1)}{\Pr_A(R_1 = 1 | H, E = 1)} \right\}.
\]