Evidence of Child Abuse: Inferring the Causes of Effects

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Statistical Study Predicting Abuse

- N. Best, D. Ashby, F. Dunstan, D. Foreman and N. McIntosh (2013)

Density strip plots of the posterior credence distribution of $\Pr(\text{abuse} \mid \text{bleed, ALTE})$
Abusive Head Trauma (Shaken Baby Syndrome)

• “SBS is injury to skull or intracranial contents of infant or young child due to inflicted blunt impact and/or violent shaking.”

• The Triad: constellation of 3 medical findings, subdural hematoma, retinal bleeding, and brain swelling.

• Violent shaking ➔ Triad (and death)

• We observe triad (and death). Was the cause violent shaking?
Questions

• What are the data?
  – Provenance of the data.
  – Biases in evaluation.
  – Biases in interpretation.
  – Blinding in assessment?

• What is the science?

• What statistical question do we want to answer?
  – Predictions? Conditional on what quantities?
  – Causation?
Causes of Effects

• **Effects of Causes (EoC):** *Does violent shaking of infants cause the specific triad symptoms in infants?*

• **Causes of Effects (CoE):** *Was violent shaking the cause of triad symptoms observed in infant?* [Can we eliminate alternative possible causes.]

• Is a question about CoE essentially the same as one about EoC? If not how do they differ?
Traditionally we would address this question with high quality experimental data, and odds ratio or risk ratio.

What is available?

Problem: Misclassification and misdiagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Triad</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Shaking</td>
<td>160??</td>
<td>113??</td>
</tr>
<tr>
<td>Short Fall</td>
<td>78??</td>
<td>3646??</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>3724??</td>
</tr>
</tbody>
</table>
Understanding Causes of Effects in Simpler Setting

- **Effects of Causes (EoC):** I have a headache. Will taking aspirin help?
- **Causes of Effects (CoE):** Was it the aspirin I took 30 minutes ago that caused my headache to disappear?
- Is a question about CoE essentially the same as one about EoC?
- If not how do they differ?
Assessing Causes of Effects

• *Was it the aspirin I took 30 minutes ago that caused my headache to disappear?*

• Recovery rates (in randomized trial):
  – No aspirin: 12%
  – Aspirin: 30%

• Odds Ratio:

\[ \alpha = \frac{30 \times 88}{12 \times 70} = 3.14 \]

• [This what statisticians traditionally would have liked to do in SBS setting, but we could not because of the poor data available.]
Probability of Causation

• Potential responses:
  
  \( R_1 \) to aspirin; \( R_0 \) to no aspirin

• **Probability of Causation:**

  \[ PC = \Pr(R_0=0 \mid R_1=1) \]

• Requires **JOINT DISTRIBUTION** of \((R_0, R_1)\)
  
  – Cannot estimate!
    
    • *Only know marginal probabilities*

• What can we say?
Probability of Causation

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

Know \(18 \leq x \leq 30\)

So \(PC \geq 60\%\)
Probability of Causation

• In general, this argument shows
  \[ PC \geq 1 - 1/RR \]
  where \( RR = \Pr(R_1 = 1)/\Pr(R_1 = 0) \)
  is the (experimental) risk ratio.

• In particular,
  \[ RR > 2 \text{ and } PC > \frac{1}{2} \]
  –“proof on the balance of probabilities”
  –*But converse is false!*
Probability of Causation for SBS

• Causes: violent shaking =1, no violent shaking =0
• Potential responses: triad=1, no triad=0
  \[ R_1 \] to shaking; \[ R_0 \] to no shaking
• **Probability of Causation:**
  \[ PC = \Pr(R_0=0 \mid R_1=1) \]
• Requires JOINT DISTRIBUTION of \( (R_0, R_1) \)
  – Cannot estimate!
  • No experimentsl data
  • *We can only ESTIMATE marginal probabilities, for \( R_0 \) and \( R_1 \).*
• **Bounds on PC.**
• **Bayesian analysis** for observational data.
Case Study in Dawid, Musio, and Fienberg (2015)

• Data from Best et al. (2013) involving diagnosis of abuse in an infant child, presenting with an acute life-threatening event (“ALTE”).
  • **Attribution**: If the child suffers ALTE, what is the **probability** this was **caused** by abuse?
  • Full Bayesian Analysis with observational data.
  • Individual-focused uncertainty interval for **PC** is (0, 0.043)
  • Upper bound does not meet the balance of probabilities criterion for civil litigation.
Moral for Child Abuse Evidence

- Most statisticians and epidemiologists seek out quality data to address tradition scientific question of effects of causes.
  - Gold Standard of randomized experiments unavailable.
  - We only have deeply flawed observational data.
- But real question is one of causes of effects.
  - New statistical approaches are required, with much greater uncertainty.
- This is an overlay to the issues addressed by other speakers today.
References

