Predictive Risk Modelling Adverse Outcomes for Children: Case Studies from New Zealand

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Today’s Talk

1. Background

2. Outline two case studies of predictive risk modelling projects in New Zealand: (i) maltreatment; and (ii) hospitalisation.
Targeting Preventive Care

Home visitation to.. prevent maltreatment

Chronic disease management to.. prevent re-hospitalisation
How well do health and social care systems choose children for preventive services?
Threshold Models

Recruit people on the basis of a list of characteristics observed by a frontline clinician
Admissions criteria for a NZ home visiting program called “Family Start”

**FAMILY START Referral Criteria**

List A sets out the main criteria for Family Start. Families need to experience challenges in one of these areas to be referred.

List B sets out other areas where families may have challenges. If you feel that a parent has high needs but does not ‘fit’ into the Family Start criteria then explain, using indicators in List B, why an exception should be made for this family.

<table>
<thead>
<tr>
<th>LIST A. Family Start criteria</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>
| Mental health issues         | Either parent/carer has a mental health problem, for example:  
  - Post-natal depression  
  - Anxiety  
  - Depression  
  - Self-harm or suicidal tendencies  
  - Other (specify)  
  - Is this current or historic?  
  - Are they receiving any assistance or professional services for this? |
| Difficulties with drugs, alcohol or gambling | Either parent/carer has a problem with one of the following which affects parenting ability:  
  - Alcohol use  
  - Illicit drug use  
  - Gambling  
  - Are they are receiving any assistance from other professional services for this? |
| Childhood history of abuse   | Either parent/carer experienced abuse as a child or young person. |
Do they work?

• Qualitative evidence that frontline workers “distort” inputs to get the classification that they want

• “FRET (an actuarial tool for ) is fairly useless as it always gives high or very high – they do not automatically open very high cases as they do not have the staff to do so”

• P Gillingham and Humphreys (2010)(interview subjects quoted on p 9).
Threshold models in hospital avoidance programs

“Aged over 65 years old and has 2 or more admissions in the past 12 months”

Admissions criteria for a US hospital avoidance program called Evercare
For hospitalisation,
past utilisation
is not a good measure
of future utilisation?
Future Admissions vs, Past Admissions

Source: Auckland hospital episode statistics (2009-10)
Little difference in future use between high and low
Future Admissions vs. Past Admissions

...even some negative correlation

Source: Auckland hospital episode statistics (2009-10)
What’s wrong with threshold models?

• Operators distort inputs to get the outcomes they want

• Expensive to administer – so only a small population can be screened
What’s wrong with threshold models?

• Not developed or validated on the population
  
  – ODARA is used by the New Zealand police for family violence callouts but not validated on New Zealand population
  
  – LACE index is used in Ontario for readmission risk but found not to be valid for the NHS*

Predictive Risk Modeling (PRM)

Automatic risk scoring tool which generates a risk score for an adverse event based on large administrative dataset
Use of PRM in Health and Social Care

• Most advanced in the prediction of re-hospitalisation risk*

• Is known as “predictive analytics” – and routinely used in private firms

Advantages

• Cost effective screening of large populations e.g. all hospital admissions or all births

• No human factor involvement

• Risk score is a “continuum”

• Built from the same data as the population
Disadvantages

• “Black Box”
• Resistance by clinicians and frontline staff
• Only as good as the preventive intervention
• Risk is not the same as “amenability” to the intervention
Case Study 1: Predicting Child Maltreatment in New Zealand
Objective of this Project

Can PRM be used to identify children (and pre-births) at high risk of a finding of maltreatment?

What are the practical issues to doing this?
Two Prototypes Developed

*Prototype I:* Using the Public Benefit system to identify children at risk* (≈ 33% of a birth cohort)

*Prototype II:* “Using birth registry or public benefit system to identify children at risk** (≈94% of a birth cohort by age 3 months, ≈98% by age 6 months)


Prototype I: How it would work

A family registers on to the public benefit system

→ there is a <2-year-old child in the family
That **night** the system harvests

Public benefit data set..
✓ Demographics of Primary Caregiver
✓ Demographics of Partner
✓ Previous benefits

Child Protection Data Sets...
Was Caregiver themselves abuse victim or known to CYF care and protection or youth justice services?
✓ Previous children with CYF contact?
✓ Previous children taken into care?
That **night** the system harvests

“SWIFFT” Data..

✓ Time since last prison spell of caregiver
✓ Caregiver is a refugee
✓ Foreign Born
Applied at start of a spell for child under 2 years

Predicts their risk of maltreatment finding by age 5
Maltreatment is a substantiated finding of

EMOTIONAL NEGLECT
PHYSICAL or SEXUAL ABUSE

By age 5

Finding is only a subset of actual incidence due to under-reporting
Data

• linkages between New Zealand’s public benefit and child protection systems
• linked by the New Zealand Ministry of Social Development for the purposes of research
• Matched using a probabilistic algorithm that consisted of names, birth dates, and other personal identifiers
Cohort Used to Develop Algorithm

• Born between January 1, 2003, and June 1, 2006 and observed in the public benefit system between the start of the mother’s pregnancy and age 2.
• 103,397 public benefit spells, reflecting 57,986 unique children
• Used pseudonymised data – destroyed after use
5.4% of all children (born between 2003 and 2006) are maltreated by age 5

Of children seen on a benefit by age 2, 13% are maltreated by age 5

Of children never seen on a benefit by age 2, 1.5% are maltreated by age 5
## Baseline

<table>
<thead>
<tr>
<th>Percentage neglected</th>
<th>Percentage emotionally abused</th>
<th>Percentage physically/sexually abused</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6%</td>
<td>9.4%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

10 times the risk of breast cancer in women aged 50-60*

Source: Richardson, Cox and Small (2005), NZMJ, vol 118
Baseline

Of all children born between 1/03 and 06/06 who were maltreated by age 5

→ 83% are seen on benefits before age 2
Predictor Variables

The algorithm is a set of predictor variables and weights attached to each variable

We have a set of 224 predictor variable

We use stepwise probit to choose 132 variables

Develop model using 70% sample

Test on 30% sample
Examples of variables with large estimated marginal effects

| Description                                                                 | Marginal Effect | P>|z|     |
|----------------------------------------------------------------------------|-----------------|--------|
| Prior care and protection Police Family Violence notifications on child with primary CG (Count) | -4.3%           | 0.0020 |
| Prior court order on child while included in benefit of primary CG (Count)    | -4.3%           | 0.0140 |
| Prior family group conference on child (Count)                               | -4.0%           | 0.0900 |
| Primary CG is a refugee based on SWIFTT data (Dummy)                         | -4.0%           | 0.0000 |
| Proportion of time of primary CG on incapacity benefit 6-10 years ago (0.00-1.00) | 10.2%           | 0.0000 |
| Proportion of time of primary CG on sickness benefit 6-10 years ago (0.00-1.00) | 7.7%            | 0.0000 |
| Prior care and protection notifications by courts on child with primary CG (Count) | 7.2%            | 0.0640 |
| Single and male primary CG (Dummy)                                           | 7.1%            | 0.0000 |
| Prior care and protection Police Family Violence notifications on child (Count) | 6.2%            | 0.0000 |
Using this model we can generate risk scores from 1 to 10 for each child ...
... predicts actual maltreatment rates well
Half of children in decile 10 will have maltreatment finding by age 5.
... 2% of children in decile 1
... never seen on a benefit have a rate of **1.4%**
... and is correlated with other outcomes

- Maltreatment by age 5
- Neglect by age 5
- Emotional abuse by age 5
- Physical/sexual abuse by age 5
- Behavioural problem by age 7

Maltreatment Risk Decile (1st spell)
what proportion of finding will be “captured”? (Based on risk score of the first spell)
Targeting the first spells in the top 20 deciles capture about 40 - 50% of all findings that occur to children on the benefit.
Numbers Needed to Treat (NNT)

20,671 children start a spell aged less than 2 p.a.

Suppose we offered services to those in the top risk deciles
<table>
<thead>
<tr>
<th>Decile equal to or greater than...</th>
<th>Number of children</th>
<th>True Positives</th>
<th>False Positives</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5,398</td>
<td>1,624</td>
<td>3,773</td>
</tr>
<tr>
<td>9</td>
<td>3,284</td>
<td>1,211</td>
<td>2,073</td>
</tr>
<tr>
<td>10</td>
<td>1,425</td>
<td>681</td>
<td>744</td>
</tr>
</tbody>
</table>
Numbers Needed to Treat (NNT)  
(to avoid one maltreatment finding)

<table>
<thead>
<tr>
<th>Decile equal to or greater than...</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>33</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>27</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
NNT for statins as secondary prevention is around 30*

<table>
<thead>
<tr>
<th>Decile equal to or greater than...</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
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<td>8</td>
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<tr>
<td>9</td>
<td>27</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

Suppose we were to recruit children when they hit a certain risk score threshold
e.g. top 20%

at what age would they “hit” the threshold?
Age at Recruitment into a Service Based on risk score

Top 20%
Top 10%
Top 5%

% of all children seen on benefit by 2 identified as high risk

Age Group (Months)
Age at Recruitment into a Service Based on risk score

Three-quarters will be recruited by birth
Age at Recruitment into a Service Based on risk score

Highest risks get offered later

Top 20%
Top 10%
Top 5%
How long do we have after they get the service offering before there is a substantiated finding?
Being scored as in the top 20% and days to subsequent maltreatment finding

Percentage of children in top 20% of risk

Days to Substantiated Maltreatment Finding After Crossing top 20% risk Threshold

1 year | 2 years | 5 years

1 | 2 | 3 |

62 | 122 | 184 | 246 | 312 | 374 | 439 | 507 | 571 | 632 | 698 | 766 | 831 | 901 | 966 | 1034 | 1106 | 1175 | 1246 | 1325 | 1397 | 1474 | 1555 | 1626 | 1706 | 1788 | 1867 | 1962 | 2050 | 2143 | 2238 | 2338 | 2453 | 2584 | 2745 | 2943

43%
Being scored as in the top 20% and days to subsequent maltreatment finding

Majority of maltreatment is more than 2 years after hitting the top 20% threshold
Prototype II

• Data from public benefit, care and protection, Corrections, **birth and death registration** and **Ministry of Health** administrative systems

• linkages formed by matching on names and dates of birth

• Apply to all children with a birth registration or included in a main welfare benefit within three months of birth (~94% of all new-born children)
Results

Suppose we target the top 5% of children in the 2007 birth cohort

.... by age 5 \rightarrow 31\% \text{ have maltreatment finding} and 57\% \text{ had 1 notification}

... by age 10 (projected) \rightarrow 40\% \text{ have a finding} and 70\% \text{ have a notification}
## Prototype II -- Variables (base model)

### Child

- **Gender** of child (male / female)
- **Low birth weight** or pre-term (yes / no or unknown)

### Other children of the parents and/or caregivers

- **Parenting demands** (high demands - multiple birth child, other children under 2, or 3 plus other children / no other children / other children but not high demands)
- **Other children with care and protection** history in the last 5 years (yes / no)
Prototype II -- Variables (base model)

Parents and/or caregivers

• **Single** parent (yes / yes and father not listed on birth registration / no or unknown)
• At least one benefit caregiver is **not a birth registration parent** (yes / no / no birth registration by 3 months)
• **Age of mother** or primary benefit recipient when child was born (<20 / 20-24 / 25-29 / 30-34 / 35-39 /40+)
• Parents or caregivers with a **care and protection history** as a child (yes / no)
• Parents or caregivers with **findings of behavioural** or relationship difficulties as a child (yes / no)
• Mother or primary **benefit recipient's** time on benefit in the last 5 years (no time / 0-20% / 20-80% /80-100%)
• Parents’ or caregivers’ **mental health** in the last 5 years (no known substance abuse or other mental health disorder / substance abuse disorder / 3+ years in last 5 with substance abuse disorder / mental health disorder other than substance abuse / 3+ years in last 5 with mental health disorder other than substance abuse)
• Parents’ or caregivers’ **number of benefit address changes** in the last year (no address changes / 1-2 address changes / 3 plus address changes/missing - no benefit in last year)
• Parents’ or caregivers with a **Corrections history** in the last 5 years (no history / non-custodial sentence only / custodial sentence for non-violent crimes / custodial sentence for violent crimes)

Community / office

• **CYF service centre** (43 categories)
Of the highest 5% of risk scored children in the 2007 sample...

<table>
<thead>
<tr>
<th></th>
<th>% of all children</th>
<th>% of children with findings by age 2</th>
<th>% of the 3,000 children with the highest PRM scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male child</td>
<td>51.5</td>
<td>53.0</td>
<td>52.5</td>
</tr>
<tr>
<td>Low birth weight child or pre-term birth</td>
<td>8.2</td>
<td>10.7</td>
<td>8.2</td>
</tr>
<tr>
<td>Multiple birth child, other children under 2 or 3+ children</td>
<td>20.1</td>
<td>32.9</td>
<td>38.1</td>
</tr>
<tr>
<td>No other children (estimated)(2)</td>
<td>59.4</td>
<td>51.1</td>
<td>45.7</td>
</tr>
<tr>
<td>Other children with a care and protection history in the last 5 years</td>
<td>4.8</td>
<td>34.9</td>
<td>59.9</td>
</tr>
<tr>
<td>Other children with a Police family violence notification or contact record in the last year</td>
<td>0.8</td>
<td>8.6</td>
<td>12.4</td>
</tr>
<tr>
<td>Single parent</td>
<td>24.6</td>
<td>74.3</td>
<td>87.7</td>
</tr>
<tr>
<td>No birth registration at 3 months of age</td>
<td>6.3</td>
<td>26.1</td>
<td>35.5</td>
</tr>
<tr>
<td>Mother or caregiver aged under 25</td>
<td>25.3</td>
<td>53.5</td>
<td>54.6</td>
</tr>
<tr>
<td>Parents or caregivers with a care and protection history as a child</td>
<td>9.8</td>
<td>43.2</td>
<td>57.2</td>
</tr>
<tr>
<td>Parents or caregivers with findings of behavioural or relationship difficulties as a child</td>
<td>3.5</td>
<td>19.1</td>
<td>29.1</td>
</tr>
<tr>
<td>Child seen on benefit by 3 months of age</td>
<td>23.2</td>
<td>79.0</td>
<td>92.3</td>
</tr>
<tr>
<td>Mother or caregiver's spent 80-100% of time on benefit in the last 5 years</td>
<td>11.7</td>
<td>50.7</td>
<td>65.5</td>
</tr>
<tr>
<td>Parents or caregivers received benefit for a substance abuse disorder in the last 5 years</td>
<td>1.5</td>
<td>8.2</td>
<td>14.1</td>
</tr>
<tr>
<td>Parents or caregivers received benefit for other mental health disorder in the last 5 years</td>
<td>4.9</td>
<td>17.4</td>
<td>19.0</td>
</tr>
<tr>
<td>Primary caregiver's with 1+ address changes recorded in benefit data in the last year</td>
<td>11.6</td>
<td>26.1</td>
<td>30.4</td>
</tr>
<tr>
<td>Parents or caregivers with any sentence in the last 5 years</td>
<td>7.2</td>
<td>25.5</td>
<td>33.6</td>
</tr>
<tr>
<td>Parents or caregivers with a custodial sentence in the last 5 years</td>
<td>3.1</td>
<td>11.1</td>
<td>16.6</td>
</tr>
<tr>
<td>High deprivation neighborhood (deciles 8-10, of non-missing)</td>
<td>36.9</td>
<td>69.0</td>
<td>70.7</td>
</tr>
</tbody>
</table>
Confluence of Family Start and Risk Score

• MOIRA??
Auckland hospitalisation PRM model (365 days readmission risk)

• When patients are discharged from hospital they are risk scored
• The score indicates the risk of re-hospitalisation within 365 days
• Risk score sent to the General Practioner (Medical home)
• Case review high risk patients
• Currently being evaluated

Highest risk children at greater risk than low risk elderly.
Factors Used to Predict Readmission

- Age
- Past utilisation
- Charlson Index
- Distance to hospital
- Diagnosis
- Ethnicity
- Deprivation in neighbourhood
# Prognostic Strength

<table>
<thead>
<tr>
<th></th>
<th>Risk score threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
</tr>
<tr>
<td>No. of patients flagged</td>
<td>2,403</td>
</tr>
<tr>
<td>Share of those flagged who are re-admitted (PPV (%))</td>
<td>73.37</td>
</tr>
<tr>
<td>Share of those flagged who are <em>not</em> re-admitted (1-PPV, %)</td>
<td>26.63</td>
</tr>
<tr>
<td>Share of re-admitted patients correctly flagged (Sensitivity (%))</td>
<td>8.75</td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>98.64</td>
</tr>
<tr>
<td>Average number of re-admissions for correctly flagged patients</td>
<td>4.15</td>
</tr>
</tbody>
</table>
Conclusion

• Evaluation of PRM for hospitalisation is currently taking place

• Need to pull frontline into the discussion

• Building prediction models is easy ... convincing frontline to use them is hard!