Clinical outcome modelling

Dr Jim Briggs
Centre for Healthcare Modelling and Informatics (CHMI)
University of Portsmouth
Contents

- Background
- Clinical data: what's hot and what's not?
- What use is a model?
- Our models:
  - pathology
  - vital signs
  - latest developments
- Impact
- Future
Background

• People die in hospitals
  – 5% preventable (>50% chance)
  – = 12,000 per year in England

• Recent cases:
  – Mid-Staffs
  – Leeds paediatric cardiac surgery

• Often happens because:
  – a clinician (or team of) is less competent
  – someone of sufficient expertise sees patient too late

• Can data and information technology help?
History of our work

- David Prytherch (now visiting Prof) has been involved in outcome modelling since the mid-1990s
- Dave joined UoP in 2001 on secondment from Portsmouth Hospitals Trust (PHT)
- I got involved shortly thereafter
- Dave had previously worked (successfully) on data from surgical cases (P-POSSUM)
- Began to look at medicine cases
Clinical data: quality (poor)

- Some data in hospitals is poor quality for analysis:
  - much not stored electronically – therefore not easily accessible
  - some stored electronically has transcription errors
  - some not recorded until days/weeks/months after the fact
  - some is an administrator's judgement (e.g. what an episode is classified as for claims purposes)
  - some is a clinician's judgement (e.g. diagnosis)
Clinical data: quality (better)

- Some data is much more reliable:
  - most pathology data is taken automatically from quality-controlled testing equipment
    - and the lab is regularly quality-assured
    - most test results available in an hour
  - in Portsmouth, vital signs data is collected regularly at the bedside using portable data entry devices (iPod touch)
    - very good user interface (reduces data entry error)
    - data available immediately

- Has to be “operational” data
**Data we have available**

- **Patient administrative data**
  - patient id pseudonymised
  - age, gender
  - date/time of admission and discharge
  - whether admitted as an elective or emergency case
  - whether discharged dead or alive
  - which dept(s)/ward(s) the patient was in

- **Pathology data**
  - 7 most commonly performed blood tests

- **Vital signs data**
  - 7 routinely measured physiological indicators
OUR MODELS
BIOCHEMISTRY AND HAEMATOLOGY OUTCOME MODELLING (BHOM)
Pathology data used

• The "magnificent 7" blood tests:
  – albumin
  – creatinine
  – haemoglobin
  – potassium
  – sodium
  – urea
  – white cell count

• Over 12 months, 9497 patients discharged from "general medicine"

• Outcome measured: mortality on discharge

• Method: logistic regression
The BHOM model

\[ \ln \left( \frac{R}{1-R} \right) = -10.192 + (-0.013 \times \text{gender}) \\
+ (5.712 \times \text{mode of admission}) \\
+ (0.053 \times \text{age on admission}) + (0.018 \times \text{urea}) \\
+ (-0.001 \times \text{Na}^+) + (-0.101 \times \text{K}^+) \\
+ (-0.047 \times \text{albumin}) + (-0.037 \times \text{haemoglobin}) \\
+ (0.067 \times \text{white cell count}) + (0.001 \times \text{creatinine}) \\
+ (2.744 \times \text{urea/creatinine}) \]
BHOM model evaluated

- Two main evaluators:
  - calibration
    - does the model reflect the distribution of risk?
      - most patients are "low" (<5%) risk
  - discrimination
    - does the model discriminate between patients who died and those who didn't
      - AUROC ~ .76
VITAL SIGNS MODELS (VIEWS, NEWS AND DT-EWS)
Background to vital sign modelling

- 2006-2008 Knowledge Transfer Partnership with The Learning Clinic, developers of VitalPAC
- VitalPAC:
  - allows nurses to collect vital sign data at the patient’s bedside
  - data immediately stored in hospital systems
  - doctors use a tablet-based interface
- Now in use at Portsmouth Hospitals Trust and about 20 other hospitals
Vital sign data used

- Another "magnificent 7", vital signs:
  - pulse
  - respiration rate
  - temperature
  - blood pressure (systolic)
  - $O_2$ saturation
  - supplemental oxygen
  - AVPU score (alert or not)
**Digression: Early warning systems**

- Used widely to monitor patient deterioration
- Map each parameter onto a "score"
- Add the scores up
- If score is above a threshold, take appropriate action, e.g.
  - increase frequency of observation
  - call for a doctor
  - call for a doctor immediately
- Most EWSs based on "experience" of a single clinician or a committee of clinicians
ViEWS – VitalPAC Early Warning Score

• First EWS based on large scale data
• Derived from 198,755 observation sets from 35,585 acute medical admissions
• Outcome: mortality within 24 hours
• Evaluation
  – discrimination
    • does the model discriminate between patients who died and those who didn't
      – AUROC = .888
• Superior to 33 other published EWSs
Methods

• Initially, trial and error to optimise discrimination
• More recently, started using Decision Tree tools to develop models (Tessy Badriyah PhD work)
  – DT-EWS
• DT is a data mining method that produces models that are feasible for humans to apply
### Get a table like this (actually DT-EWS)

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiration Rate (bpm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;18</td>
<td>19-20</td>
<td>21-24</td>
</tr>
<tr>
<td><strong>S\textsubscript{p}O\textsubscript{2} (%)</strong></td>
<td>≤89</td>
<td>90-92</td>
<td>93-94</td>
<td>95-99</td>
<td>≥100</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplemental oxygen</strong></td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>≤35.8</td>
<td>35.9-36.0</td>
<td>36.1-36.4</td>
<td>36.5-37.1</td>
<td>37.2-37.9</td>
<td>≥38.0</td>
<td></td>
</tr>
<tr>
<td><strong>Systolic Blood pressure (mmHg)</strong></td>
<td>≤89</td>
<td>90-116</td>
<td>117-272</td>
<td></td>
<td></td>
<td></td>
<td>&gt;273</td>
</tr>
<tr>
<td><strong>Pulse rate (bpm)</strong></td>
<td>≤38</td>
<td>39-46</td>
<td>47-89</td>
<td>90-100</td>
<td>≥101</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level of consciousness</strong></td>
<td>Alert (A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Voice (V)</td>
<td>Pain (P)</td>
</tr>
</tbody>
</table>


Impact

- Embodied into VitalPAC
  - Alerts doctors
- Issue is where to set threshold for response
  - ~20% of obs have score of \( \geq 5 \) (medium alert)
  - ~10% of obs have score of \( \geq 7 \) (high alert)
  - Too low a threshold means too much work to do
  - Too high means you might be too late to save the patient
- ViEWS has been adapted by the Royal College of Physicians of England
- Now National Early Warning Score (NEWS) and recommended for adoption by all hospitals
Return to BHOM

• Could decision trees be used to develop an EWS based on pathology data?
  – Recent work by Jarvis, Kovacs, et al
**LDT-EWS (lab decision tree EWS): male**

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb</td>
<td></td>
<td>≤11.1</td>
<td>11.2-12.8</td>
<td>≥12.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCC</td>
<td></td>
<td></td>
<td></td>
<td>≤9.3</td>
<td>9.4-16.6</td>
<td>≥16.7</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td>≤9.4</td>
<td>9.5-13.7</td>
<td></td>
<td>≥13.8</td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td></td>
<td></td>
<td>≤114</td>
<td>115-179</td>
<td></td>
<td>≥180</td>
</tr>
<tr>
<td>Na</td>
<td></td>
<td>≤132</td>
<td>133-140</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>≤3.7</td>
<td>3.8-4.4</td>
<td></td>
<td>4.5-4.7</td>
<td></td>
<td>≥4.8</td>
</tr>
<tr>
<td>Alb</td>
<td></td>
<td>≤30</td>
<td>31-34</td>
<td>≥35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Future work

- condition-specific models
- combined BHOM/vital sign models
- other data
- other outcomes
- multi-centre studies
  - scale
  - validation
  - comparison
- commercial exploitation
Acknowledgements

- Prof David Prytherch, UoP/PHT
- Dr Stuart Jarvis, Caroline Kovacs (current CHMI research team)
- Tessy Badriyah (current PhD student)
- Prof Gary Smith (Bournemouth University)
- Dr Paul Schmidt and Dr Peter Featherstone (PHT consultant physicians)
- Dr Paul Meredith (PHT IT)
- Dr Mohammed Mohammed (Birmingham U & UoP visiting fellow)
Key references
