University of Portsmouth

Clinical outcome modelling

Dr Jim Briggs

Centre for Healthcare Modelling and Informatics (CHMI)

University of Portsmouth

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Background

- People die in hospitals
  - [Hogan et al, BMJ Quality and Safety, 2012] study of 1000 adults who died in 10 English hospitals in 2009
  - 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

- $\ln (R / 1-R) =$

  $-10.192 + (-0.013 \times \text{gender})$

  $+(5.712 \times \text{mode of admission})$

  $+(0.053 \times \text{age on admission}) + (0.018 \times \text{urea})$

  $+(-0.001 \times Na+) + (-0.101 \times K+)$

  $+(-0.047 \times \text{albumin}) + (-0.037 \times \text{haemoglobin})$

  $+(0.067 \times \text{white cell count}) + (0.001 \times \text{creatinine})$

  $+(2.744 \times \text{urea/creatinine})$

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)

	3	2	1	0	1	2	3
Respiration Rate (bpm)				≤18	19-20	21-24	≥25
S_pO_2 (%)	≤89	90-92	93-94	95-99	≥100		
Supplemental oxygen				No			Yes
Temperature (°C)	≤35.8	35.9-36.0	36.1-36.4	36.5-37.1	37.2-37.9	≥38.0	
Systolic Blood pressure (mmHg)	≤89		90-116	117-272			≥273
Pulse rate (bpm)	≤38		39-46	47-89	90-100	≥101	
Level of consciousness				Alert (A)			Voice (V) Pain (P) Unrp (U)

Impact

- Embodied into VitalPAC
  - Alerts doctors
- Issue is where to set threshold for response
  - ~20% of obs have score of >=5 (medium alert)
  - ~10% of obs have score of >=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

	3	2	1	0	1	2	3
Hb		≤11.1	11.2-12.8	≥12.9			
WCC				≤9.3	9.4-16.6	≥16.7	
U				≤9.4	9.5-13.7		≥13.8
Cr				≤114	115-179	≥180	
Na		≤132		133-140	≥141		
K			≤3.7	3.8-4.4	4.5-4.7	≥4.8	
Alb		≤30	31-34	≥35			

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)

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jim.briggs@port.ac.uk

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