Medical thinking: towards a unified view

John Fox
Advanced Computation Laboratory
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The CREDO trial

PRO forma process modelling

Technologies

Applications

Clinical trials

Theory to practice

Cognitive theory

Experiments & simulations

Theory to practice
Overview

• The problem
• Case analysis:
  – detection, diagnosis and management of breast cancer
• What do we know?
  – it depends who you are
  – three views
• Towards a unified approach
• Is this useful? Evidence of value
• Conclusions
“Medicine is a humanly impossible task”

- Up to 97,000 unnecessary deaths p.a. in the US are due to medical error. Total national costs ... between $17B and $29B
  
  Institute of Medicine, *To Err is Human* 1999

- In NHS hospitals “overall rate of preventable adverse events of 11.7%. [A third of which] led to ... disability or death, ... others are frequent, minor events ... but together have massive economic consequences”

  Vincent et al, *BMJ* 2001
... and in oncology ...

• “Perhaps 16,000 lives could be saved if all current knowledge of cancer were properly applied”
  ICRF Vision for Cancer, 1995

• “There have been undoubted improvements in service delivery but there is still a sense that progress has been patchy and that much has yet to be achieved.”
# The Quality of Health Care Delivered to Adults in the United States

The New England Journal of Medicine

## Table 5. Adherence to Quality Indicators, According to Condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. of Indicators</th>
<th>No. of Participants Eligible</th>
<th>Total No. of Times Indicator Eligibility Was Met</th>
<th>Percentage of Recommended Care Received (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senile cataract</td>
<td>10</td>
<td>159</td>
<td>602</td>
<td>78.7 (73.3–84.2)</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>9</td>
<td>192</td>
<td>202</td>
<td>75.7 (69.9–81.4)</td>
</tr>
<tr>
<td>Prenatal care</td>
<td>39</td>
<td>134</td>
<td>2920</td>
<td>73.0 (69.5–76.6)</td>
</tr>
<tr>
<td>Low back pain</td>
<td>6</td>
<td>489</td>
<td>3391</td>
<td>68.5 (66.4–70.5)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>37</td>
<td>410</td>
<td>2083</td>
<td>68.0 (64.2–71.8)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>27</td>
<td>1973</td>
<td>6643</td>
<td>64.7 (62.6–66.7)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>36</td>
<td>104</td>
<td>1438</td>
<td>63.9 (55.4–72.4)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>10</td>
<td>101</td>
<td>210</td>
<td>59.1 (49.7–68.4)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>20</td>
<td>169</td>
<td>1340</td>
<td>58.0 (51.7–64.4)</td>
</tr>
<tr>
<td>Depression</td>
<td>14</td>
<td>770</td>
<td>3011</td>
<td>57.7 (55.2–60.2)</td>
</tr>
<tr>
<td>Orthopedic conditions</td>
<td>10</td>
<td>302</td>
<td>590</td>
<td>57.2 (50.8–63.7)</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>3</td>
<td>598</td>
<td>648</td>
<td>57.3 (53.9–60.7)</td>
</tr>
<tr>
<td>Colorectal cancer</td>
<td>12</td>
<td>231</td>
<td>329</td>
<td>53.9 (47.5–60.4)</td>
</tr>
<tr>
<td>Asthma</td>
<td>25</td>
<td>260</td>
<td>2332</td>
<td>53.5 (50.0–57.0)</td>
</tr>
<tr>
<td>Benign prostatic hyperplasia</td>
<td>5</td>
<td>138</td>
<td>147</td>
<td>53.0 (43.6–62.5)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>7</td>
<td>519</td>
<td>643</td>
<td>48.6 (44.1–53.2)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>13</td>
<td>488</td>
<td>2952</td>
<td>45.4 (42.7–48.3)</td>
</tr>
<tr>
<td>Headache</td>
<td>21</td>
<td>712</td>
<td>8125</td>
<td>45.2 (43.1–47.2)</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>13</td>
<td>459</td>
<td>1216</td>
<td>40.7 (37.3–44.1)</td>
</tr>
<tr>
<td>Community-acquired pneumonia</td>
<td>5</td>
<td>144</td>
<td>291</td>
<td>39.0 (32.1–45.8)</td>
</tr>
<tr>
<td>Sexually transmitted diseases or vaginitis</td>
<td>26</td>
<td>410</td>
<td>2146</td>
<td>36.7 (33.8–39.6)</td>
</tr>
<tr>
<td>Dyspepsia and peptic ulcer disease</td>
<td>8</td>
<td>278</td>
<td>287</td>
<td>32.7 (26.4–39.1)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>10</td>
<td>100</td>
<td>407</td>
<td>24.7 (18.4–30.9)</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>9</td>
<td>110</td>
<td>167</td>
<td>22.8 (6.2–39.5)</td>
</tr>
<tr>
<td>Alcohol dependence</td>
<td>5</td>
<td>280</td>
<td>1036</td>
<td>10.5 (6.8–14.6)</td>
</tr>
</tbody>
</table>

* Condition-specific scores are not reported for management of pain due to cancer and its palliation, management of symptoms of menopause, hysterectomy, prostate cancer, and cesarean section, because fewer than 100 people were eligible for analysis of these categories. CI denotes confidence interval.
Case study

Detection, diagnosis and management of patients with or at risk of contracting breast cancer
Multidisciplinary care pathway for breast cancer
65 Decisions

• If compliance with best practice is 99% then 50% of women will get “perfect care” (0.99^{65})

• If compliance is 95% then 3% of women will get perfect care (0.95^{65})

• Overall, studies suggest actual departures from quality standards can be between 10 and 30%!
What can we do?

“Knowledge management”
Disseminating knowledge of best practice
... but

• Busy clinicians have little time to read
• Even if there is time, memories are unreliable, working pressures acute
• Conventional guidelines address general principles of care, not the needs of individual patients
**Breast cancer**

**Triple Assessment**

- What are the patient’s presenting symptoms?
  - [ ] lump or lumpiness
  - [x] nipple discharge
  - [ ] nipple inversion
  - [ ] asymmetry of breast
  - [ ] swelling
  - [ ] breast skin changes
  - [ ] other

- Does patient have a family history of any cancer?
  - [ ] no
  - [x] yes

- Does the patient have pain in the breast?
  - [ ] no
  - [x] yes

- If the patient has pain in the breast, is it cyclical or non-cyclical?
  - [ ] cyclical
  - [ ] non-cyclical

- If the patient has pain in the breast, what is the severity?

- What was the age at menarche?

- What is the patient’s menopausal status (premenopausal: period in last 12 months, postmenopausal: no period in last 12 months)?
  - [ ] premenopausal
  - [ ] postmenopausal
  - [ ] perimenopausal

- What was the start date of the last menstrual period?

- Is the patient currently pregnant?
  - [ ] no
  - [ ] not known
  - [ ] yes

- Is the patient currently lactating?
  - [ ] no
  - [ ] not known
  - [ ] yes
Which radiology?

Decision: Select the relevant intervention to link to arguments for and against

Candidates
- [x] Do an ultrasound of the affected area
- [ ] Neither
- [x] Do a mammogram of both breasts

commit
Decision: Select the relevant intervention to link to arguments for and against.

Candidates

☐ Do an ultrasound of the affected area
  ☐ The clinical impression at examination was not entirely benign (P3 or higher) and patient is less than 35yrs. More...
  ☐ The patient has a palpable breast lump More...

☒ Neither

☒ Do a mammogram of both breasts
  ☒ The patient is younger than 35yrs More...
  ☒ The clinical impression at examination was equivocal (P3) More...
  ☒ The patient has a palpable breast lump More...

Which radiology?
<table>
<thead>
<tr>
<th>Candidate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔</td>
<td>Do an ultrasound of the affected area. The clinical impression at examination was not entirely benign (P3 or higher) and patient is less than 35yrs. More...&lt;br&gt; The patient has a palpable breast lump. More...</td>
</tr>
<tr>
<td>✗</td>
<td>Neither.</td>
</tr>
</tbody>
</table>
Assessing and communicating risk

Coulson and Glasspool *Meth. Inf. Med* 2001

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The following information applies ONLY to the highlighted path.

This patient is at moderate risk of being a gene carrier because, on the highest-risk path of inheritance found by the program:

- The mother of the presenting patient is affected, which indicates an increased risk level.
- One first-degree relative (FDR) is affected. Each affected FDR indicates an additional risk factor.
- One affected FDR has an onset age under 50, indicating a moderate increase in risk.
- The combination of one breast and one ovarian cancer indicates a moderate increase in risk level.

However, this is balanced to some extent by the following factors which indicate lower risk level:

- The oldest affected second-degree relative has an age of onset over 60. Genetic predisposition is more likely to be associated with lower ages of onset, and this age indicates a considerable reduction in risk level.
- Genetic predisposition is less likely in a person over 40 who has not developed cancer.

Overall, the likelihood that this patient is a gene carrier is moderate.
What do we know that could guide an effective knowledge management strategy?

It depends who you are
Theoreticians

- e.g. Decision theory,
- Mathematical logic,
- Planning

Scientists

- e.g. Psychologists,
- Sociologists,
- Health services researchers

Engineers

- e.g. Decision aids
- Expert systems,
- Modelling and simulation
Understanding medical thinking

• The cognitive scientist:
  – What is the nature of medical thinking?
  – What are the sources of error?

• The theoretician:
  – What rational principles/axioms should medical thinking embody?

• The engineer:
  – What pragmatic norms and tradeoffs should a clinical decision maker adopt in practice?
Can we integrate what we know?

“Tetrahedron not triangle”

A general framework which can inform researchers of all kinds and promote discussions between communities?
Three views of medical thinking:

1. Understanding knowledge
Semantic networks and ontologies

WOMAN WITH POSSIBLE BREAST CANCER
HAS-HEALTHCARE-PHENOMENON
BREAST CANCER HYPOTHESIS
IS-HYPOTHESIS-OF
MALIGNANT NEOPLASM OF BREAST
HAS-HEALTHCARE-PHENOMENON
CANCER PATIENT
IS_A
PATIENT
BREAST CANCER PATIENT

HYPOTHESIS
IS_A
BREAST DISEASE
IS_A
BREAST FINDING
IS-RANGE-OF-DOMAIN-OF
MALIGNANT NEOPLASM
IS_A
BREAST SPECIALIST
IS-SPATIAL-PART-OF
BREAST STRUCTURE

ADVANCED BREAST CANCER
HAS-WE-STATE
ADVANCED CANCER
IS_A
BREAST CANCER STAGE I
IS_A
NEOPLASTIC PROCESS
IS_CREATIVE_RESULT_OF
MALIGNANT NEOPLASM
IS_A
MALIGNANT
IS_A
NEOPLASM
IS_A
CANCER PATIENT

Scenarios & tasks
- Woman with possible breast cancer
- Triple assessment
- Family history for risk assessment

Rules & schemas
- More than 2 FDRs AND early onset BrCa suggests genetic predisposition
- Elderly OR frail patient contraindicates chemotherapy

Descriptions
- Nipple is-spatial-part-of Breast Structure
- Infiltrating ductal carcinoma is-a breast cancer
- Breast cancer is a reproductive system disorder

Concepts
- Infiltrating ductal carcinoma
- Nipple
- Reproductive system disorder

Symbols
M 8500/3

Three views of medical thinking:
The “intentional stance”
(Daniel Dennett)
Explaining behaviour: the intentional stance (Dennett)

“... we often gain predictive power when moving from the physical stance to the design stance. Often, we can improve our predictions yet further by adopting the intentional stance [in which] we interpret the behavior of the entity in question by treating it as a rational agent whose behavior is governed by intentional states. ... such as beliefs and desires”
An intentional account of medical thinking

E.g. Risk assessment in genetics

- Assess risk
- Clinical goals
- Clinical options
- Population: Moderate
  High
- Beliefs about patient
- Worried patient
- Arguments & decisions
- Moderate risk
- Actions & orders
- Care plans
- Genetics, epidemiology & other knowledge
E.g. Triple assessment (imaging decision)

Clinical goals

Pain, discharge, nodule??

Beliefs about patient

Order Mammogram & ultrasound

Plan & pathways

Mammogram, ultrasound

Clinical options

Ultrasound, Mammogram, CT etc.

Investigate symptoms for possible Ca

Clinical options

Symptoms, Family history, Hypotheses, Anatomy

Arguments & decisions

Beliefs about patient

Order Mammogram & ultrasound

Clinical goals

Mammogram, ultrasound
Three views of medical thinking:

Medical expertise as reified “tasks”
Reification: from intention to design

J Fox and S Das, Artificial Intelligence in Hazardous Applications MIT Press 2000
Designing decisions and processes
**WhichRadiologyDecision**

<table>
<thead>
<tr>
<th>Candidate</th>
<th>Caption</th>
<th>Argument</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>mammogram</td>
<td>Do a mammogram of both breasts</td>
<td>- patientAge &lt; 35</td>
<td>netsupport(WhichRadiologyDecision, mammogramCandidate) &gt;= 1</td>
</tr>
<tr>
<td>ultrasound</td>
<td>Do an ultrasound of the affected area</td>
<td>patient_latestMammography_appearance includes &quot;mass lesion&quot; or patient_latestMammography_appearance includes &quot;asymmetric density&quot;</td>
<td>netsupport(WhichRadiologyDecision, ultrasoundCandidate) &gt;= 1</td>
</tr>
<tr>
<td>neither</td>
<td>No imaging is necessary</td>
<td></td>
<td>netsupport(WhichRadiologyDecision, ultrasoundCandidate) &lt; 1 AND netsupport(WhichRadiologyDecision, mammogramCandidate) &lt; 1</td>
</tr>
</tbody>
</table>

**Medical need, clinical requirements**

- **Task model**
- **Specify and verify**
- **Test and validate**
- **Deploy**
Does the unified approach have practical value?
Evidence (1)

• Prescribing for common conditions

• Interpretation of mammograms in screening
  – Taylor et al, *Medical Image Analysis* 1999

• Genetic risk assessment

• Management of HIV+ patients
Evidence (2)

• Dose adjustment in ALL in children
  – Bury et al *BJ Haematology* 2005

• Planning care of women at proven risk for BrCa
  – Glasspool et al, *under revision*

• Triple assessment of women with suspected breast cancer
  – Hurt, Patkar et al, *submitted*
Triple assessment of women with suspected breast cancer

V Patkar, C Hurt, R Steele, T Rose, M Williams, J Fox  (in submission)

**Objective:**

– Assess effect of PROforma decision support with respect to national guidelines for “Triple Assessment”.

**Process model**

– Included 4 decisions (genetic risk, type of imaging, type of biopsy, and management).

**Materials and methods:**

– 15 hypothetical paper cases developed by expert panel of 5 judges (2 breast surgeons, 1 breast pathologist, 1 radiologist and 1 geneticist) and optimal management for each case was agreed by consensus.

– 24 doctors asked to manage 5 cases with and 5 without computer support. A balanced block design used to allocate cases.
## Triple Assessment Study – Results

V Patkar, C Hurt, R Steele, T Rose, M Williams, J Fox

24 participants (17 consultants, 5 specialist registrars, 1 nurse practitioner)
Average number of years in speciality = 9.3 (range 1 - 23)

<table>
<thead>
<tr>
<th>Deviations / errors</th>
<th>Without DSS</th>
<th>With DSS</th>
<th>Total decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All deviations</td>
<td>60 (50%)</td>
<td>16 (13%)</td>
<td>120 In each arm</td>
</tr>
<tr>
<td>Critical errors</td>
<td>16 (13%)</td>
<td>1 (0.8%)</td>
<td></td>
</tr>
<tr>
<td>Critical errors that escaped peer-check</td>
<td>10 (8.3%)</td>
<td>1 (0.8%)</td>
<td></td>
</tr>
</tbody>
</table>
From processes to organisations
The problem: decisions are embedded in very complex pathways
Liz Black *AgentLink News 2003*
### In silico referral experiments: data

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Average waiting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>256 cycles</td>
</tr>
<tr>
<td>Provisional bookings</td>
<td>184 cycles</td>
</tr>
<tr>
<td>Provisional bookings with prioritised patients</td>
<td>All patients: 193 cycles</td>
</tr>
<tr>
<td></td>
<td>Urgent patients: 79 cycles</td>
</tr>
<tr>
<td></td>
<td>Non-urgent patients: 235 cycles</td>
</tr>
</tbody>
</table>
From theory to design

PROforma process definitions

Specialist services

General hospitals

Research/centres of excellence

Primary care

Home and self care
Conclusions

• Humans are fallible (individually and organisationally)
• What do we know that can help?
  – Answer depends on whether you are a scientist, a theoretician or an engineer; all these viewpoints have a contribution
  – We have reviewed medical thinking as: knowledge representation and use, the application of “rational” logical methods, decision-making and planning as tasks that can be rigorously engineered
• PROforma unifies these perspectives in a formal but natural and versatile model
• Current evidence suggests that technologies based on PROforma are useful and professionally acceptable
Thanks to …

Computer science and software engineering

– David Glasspool
– David Sutton
– Ali Rahmanzadeh
– Rory Steele
– Liz Black
– Paul Taylor
– Richard Cooper
– Paul Krause
– Simon Parsons
– Chris Hurt
– Richard Thomson
– Michael Humber

Clinicians

– Alyssa Alabassi
– Jon Bury
– Vivek Patkar
– Robert Dunlop
– Jon Emery
– John Toy
– Richard Begent
– Arnie Purushotham
– Andrzej Glowinski
– Mike O’Neill
– Robert Walton
– Jean-Louis Renaud-Salis
Further information

Publications at lab web site:
www.acl.icnet.uk

The PROforma approach

General background:
www.openclinical.org

More theory
www.argumentation.org