Decision Analysis & Clinical Decision Support Systems

Amie Draper
Decision Analysis
What is decision analysis?

* “Discipline comprising the philosophy, theory, methodology and professional practice necessary to address important decisions in a formal manner”

* “A systematic approach to decision making under conditions of imperfect knowledge”

* “Quantitative description of the various choices and possible outcomes in a specific situation”
Types of Decision Analysis

* Descriptive
  * How decision makers *actually* make decisions

* Prescriptive
  * How decision makers *should* make decisions (what option is optimal based on some criteria?)
You admit a 60 year old female with CREST syndrome, primary biliary cirrhosis and longstanding hypertension for the evaluation of a mediastinal mass found on routine chest x-ray. A chest x-ray 18 months earlier showed no mass. CT-Scan and angiography revealed a saccular aneurysm of the ascending aorta, involving the innominate and left common carotid arteries. Cardiac cath revealed 80-90% stenoses of the RCA and LAD. (credit to Mark Roberts)

Should we operate on this aneurysm?
7 Steps of Decision Analysis

Step 1: **FRAME** the question
Step 2: **STRUCTURE** the clinical problem
Step 3: Estimate the **PROBABILITIES**
Step 4: Estimate the **VALUES** of the outcomes
Step 5: **ANALYZE** the tree (average out/fold back)
Step 6: **TEST ASSUMPTIONS** (sensitivity analysis)
Step 7: **INTERPRET** the results
Step 1: Frame the Question

* What’s the perspective?
  * Patient?
  * Provider?
  * Payer?
  * Society?

* Let’s model this from the patient’s perspective. Therefore, we will be maximizing life expectancy.
Step 2: Structure the Problem

- Construct decision tree to model problem
- How realistic is this tree?

**Situation**

60 yr old 
with 1\(^{st}\)PB, 
CAD, thoracic AA

**Options**

SURGERY

1\(^{st}\)BC, CAD, AAA

**Consequences**

Operative Death

Operative Success

1-p(DEATH)

**Values**

DEAD

1\(^{st}\)BC, CAD
Step 2: Structure the Problem

- Pick appropriate level of detail—want enough to be realistic but don’t want to overcomplicate

- Binary tree nodes are simpler to work with
Steps 3&4: Estimate the Probabilities and Values

- Sources of estimates:
  - randomized controlled trials
  - cohort studies
  - administrative databases
  - meta analysis
  - expert opinion
  - investigator estimates
  - literature, expert opinion
  - survival studies
  - patient input
Step 3&4: Estimate the Probabilities/Values

- **Surgery**
  - 0.15 Operative Death
    - DEAD
    - 0
  - 0.85 Operative Success
    - 1ºBC, CAD
    - 6.7

- **No Surgery**
  - 1ºBC, CAD, AAA
  - 2.3
**Step 5: Analyze the Tree**

- Average-out/fold-back the tree
- Expected value\( (X) = P(X) \times X \)
Irrespective of the complexity of the tree, the process of evaluation is straightforward. Starting at the right hand side of the tree, replace each chance node with it’s expected value, until the only branches left are the decision nodes.
Step 6: Test Assumptions

- Sensitivity analysis
  - Altering estimates to find threshold between decisions
Step 7: Interpret the Results

- What does this mean?
  - Surgery preferred up to 60% mortality

- What’s going on here?
  - Think about what we haven’t included in our model
What if probability of aneurysm not rupturing is high?

Also consider the difference in survival between elective surgery and emergency surgery.
How do decision trees relate to Bayes Theorem and contingency tables?

- Remember contingency tables:

<table>
<thead>
<tr>
<th>Truth</th>
<th>Disease</th>
<th>No Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
<td>TP</td>
<td>FP</td>
</tr>
<tr>
<td>No Disease</td>
<td>FN</td>
<td>TN</td>
</tr>
</tbody>
</table>

- Recall relevant ideas that utilize Bayes Theorem:

  - Sensitivity = TPR = TP / TP + FN = P(\text{Test+} \mid \text{Disease+})
  - Specificity = TNR = TN / TN + FP = P(\text{Test-} \mid \text{Disease-})
  - PPV = TP / TP + FP = P(\text{Disease+} \mid \text{Test+})
  - NPV = TN / TN + FN = P(\text{Disease-} \mid \text{Test-})
We can represent contingency tables as decision trees!

Which tree branch do each of the following concepts belong to?

- Prevalence = $p(\text{disease})$
- Sensitivity = $p(\text{Test+}|\text{Disease+})$
- Specificity = $p(\text{Test-}|\text{Disease-})$
- PPV = $p(\text{Disease+}|\text{Test+})$
- NPV = $p(\text{Disease-}|\text{Test-})$
Clinical Decision Support Systems
A phone survey by the National Patient Safety Foundation found that 42 percent of over 100 million Americans believed that they had personally experienced a medical mistake\(^1\)

In the United States medical error results in 44-98 K unnecessary deaths each year and 1 M injuries\(^2\)

Estimated 8.8 millions outpatient adverse drug events per year in the US and more than 3 millions are preventable\(^3\)

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\(^1\) Louis and Harris Associates, 100 million Americans see medical mistakes directly touching them as patients, friends, relatives, National Patient Safety Foundation, 2007


Types of Medical Errors

- Surgical errors
- Medication errors
  - Omission—failure to prescribe needed drug
  - Commission—prescribing wrong drug
- Diagnostic errors
How can technology help?

* Ideally,
How can technology help?

More realistically,
Fundamental Theorem for Medical Informatics

What is a Clinical Decision Support System (CDSS)?

- Idea of using computers to aid in healthcare goes back to 1950’s

- A CDSS is a system designed to help healthcare professionals make clinical decisions, deal with medical data about patients or deal with the knowledge of medicine necessary to interpret such data
Core Components of CDSSs

- Manual or Automated
- Data Collection
- Working Memory
- Inference Engine
- Knowledge Base
- Rule or Bayesian networks (knowledge engineering)
  - Diagnosis
  - Recommendation
  - Alerts
  (Communication to users)
- Patient facts (attribute-value pairs)
- Rules-based engine or Bayesian engine
- Database
- Vocabulary Service
- NLP
- Ontology service
- Automated approach
Benefits of CDSS

* Improved patient care
* Cost reduction
* 24/7 availability
* Portable/transferrable knowledge
Challenges of CDS

- Ethical/legal issues—if program guides healthcare and it gives incorrect advice, who is held responsible?
- Workflow integration
- Maintenance of knowledge bases
- Alert fatigue
Two types of alerts:
- Asynchronous—no workflow interruption
- Synchronous—interrupt workflow
  - Hard vs. soft-stop

Alert fatigue occurs when clinicians override or ignore alerts due to too many low-specificity alerts (reported to happen 49-96% of the time)
Some CDSS Applications

- Infectious disease monitoring
- Diagnostic aid
- Treatment aid
CDSSs Examples

* LitmusDX
* SimulConsult
* CADUCEUS
* Clinical Rules
* DiagnosisPro
* DxMate
* Dxplain
* ESAGIL
* MYCIN
* Prescriptor
* RODIA
* ISABEL
What’s next for technology in healthcare?