Introduction to Decision Analysis
With Decision Trees

Henry A. Glick, Ph.D.

Medical Decision Making Workshop
August 18, 2009

www.uphs.upenn.edu/dgimhsr

Clinical Example

Clinical Background
• *Chlamydia trachomatis* infection is one of the most prevalent sexually transmitted diseases (STDs) in many parts of the world
• Prevalence in India less clear

<table>
<thead>
<tr>
<th>Sample</th>
<th>Prevalence</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Survey, Tamil Nadu</td>
<td>1.1% (PCR)</td>
<td>Joyee et al.</td>
</tr>
<tr>
<td>Urban slum dwellers, New Delhi</td>
<td>24.5% (PCR)</td>
<td>Singh et al.</td>
</tr>
<tr>
<td>Complaints, O/G OPD New Delhi</td>
<td>43.1% (PCR)</td>
<td>Singh et al.</td>
</tr>
</tbody>
</table>

• It is estimated that 50% to 90% of chlamydial infections in women are asymptomatic
Clinical Background (II)

- If untreated, chlamydial infections can lead to many complications and sequelae in infected women, including pelvic inflammatory disease (PID), ectopic pregnancy, tubal infertility, and chronic pelvic pain
- *C. trachomatis* infection can also be transmitted by women to male sexual partners, leading to urethritis and epididymitis

Clinical Background (III)

- Therefore, screening and treatment for women found infected have been recommended and implemented in many STD control programs
- A number of studies have assessed the cost-effectiveness or cost-benefit of screening for *C. trachomatis* in populations with diverse rates of chlamydial infection rates supporting more informed decisionmaking. However, economic analysis to assess the cost-effectiveness of prophylactic treatment for chlamydial infections in women seeking induced abortions has rarely been conducted

Clinical Background (IV)

- The authors therefore conducted a cost-effectiveness analysis, aiming to make recommendations for the health authority and health providers through evaluating the incremental cost-effectiveness of [universal screening strategy (with PCR assay) and] prophylaxis with azithromycin versus no intervention for women seeking induced abortions
  - For simplicity - and because the authors concluded that universal screening is dominated by prophylaxis - only their evaluation of prophylaxis vs do nothing is reviewed here
Steps in Decision Analysis
1. Imagine the model, and draw the tree
2. Identify the probabilities
3. Identify the outcome values
4. Calculate expected values
5. Perform sensitivity analyses

Types of Nodes
- Decision nodes (squares)
- Chance nodes (circles)
- Terminal nodes (branch endings)
Initial Choice

No Prophylaxis

Prophylaxis

No Prophylaxis, Chlamydia Yes/No

Chlamydia

No Prophylaxis

No Chlamydia

Rule 1

Node branches must be exhaustive and mutually exclusive.
Rule 2

At each chance node, the sum of the branch probabilities must equal 1.0

PID Yes/No

Symptomatic Yes/No
Steps in Decision Analysis

1. Imagine the model, and draw the tree
2. Identify the probabilities
3. Identify the outcome values
4. Calculate expected values
5. Perform sensitivity analyses

Outcome Probabilities

- Chlamydia: 0.048 (97 / 2020)
- PID: 0.63 (Literature)
- Symptomatic PID: 0.40 (Literature)
- Chlamydia | Azithromycin:* 0.04 (Literature)

* 1/24 not cured; No comparison group (Rustomjee)

Identify the Probabilities

![Decision Analysis Diagram]
Steps in Decision Analysis

1. Imagine the model, and draw the tree
2. Identify the probabilities
3. Identify the outcome values
4. Calculate expected values
5. Perform sensitivity analyses

Possible Outcome Measures

- Number of cases of PID avoided
- Percentage survival at 10 years
- Life expectancy
- Cost of choices (money value)
- Utility (e.g., QALYs)

Possible Outcome Measures

- **Number of cases of PID avoided (clinical outcome)**
- Percentage survival at 10 years
- Life expectancy
- **Cost of choices (money value) (cost outcome)**
- Utility (e.g., QALYs)
Cost Estimates

- Chlamydia and symptomatic PID * 1455 RMB
- Chlamydia and asymptomatic PID * 630
- Chlamydia alone * 42
- No chlamydia / no PID 0
- Azithromycin prophylaxis 40

* See next slides for detail

Chlamydia with Symptomatic PID

- PID inpatient care: 0.14 * 1617
- PID outpatient care: 0.86 * 696
- PID sequelae for women
  - Chronic pelvic pain: 0.18 * 1400 / 1.03^2
  - Ectopic pregnancy: 0.08 * 4408 / 1.03^3
  - Infertility: 0.12 * 0.25 * 2054 / 1.03^10
- Chlamydia transmission to men (p = 0.68)
  - Urethritis 0.40 * 140
  - Epididymitis 0.02 * 300
  = 1455

Chlamydia with Asymptomatic PID

- PID sequelae for women
  - Chronic pelvic pain: 0.18 * 1400 / 1.03^2
  - Ectopic pregnancy: 0.08 * 4408 / 1.03^3
  - Infertility: 0.12 * 0.25 * 2054 / 1.03^10
- Chlamydia transmission to men (p = 0.68)
  - Urethritis 0.40 * 140
  - Epididymitis 0.02 * 300
  = 630
Chlamydia, No PID

- Chlamydia transmission to men (p = 0.68)
  - Urethritis: 0.40 * 140
  - Epididymitis: 0.02 * 300

= 42

Identify the Outcomes

Symptomatic
- Chlamydia: 0.40
- No PID: 0.60

Asymptomatic
- Chlamydia: 0.60
- No PID: 0.40

PID: 0.63
No PID: 0.37

Chlamydia: 0.048
No Chlamydia: 0.952

Prophylaxis
- Symptomatic: (1455+40) / 0
- Asymptomatic: (630+40) / 0
- PID: 0.63
- No PID: (42+40) / 1

Steps in Decision Analysis

1. Imagine the model, and draw the tree
2. Identify the probabilities
3. Identify the outcome values
4. **Calculate expected values**
5. Perform sensitivity analyses
Two Methods of Calculation

• Average out and fold back
• Path probabilities

Average Out Formula

\[
\text{Expected Value} = \sum_{i=1}^{n} \text{Probability}_i \times \text{Outcome}_i
\]

Symptomatic / Asymptomatic Average Out Example

<table>
<thead>
<tr>
<th>State</th>
<th>Probability</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic</td>
<td>0.400</td>
<td>$1,455</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>0.600</td>
<td>$630</td>
</tr>
</tbody>
</table>

Expected Value:

\[
\text{Expected Value} = (0.400 \times 1,455) + (0.600 \times 630) = 582 + 378 = 960
\]
Fold Back PID and No PID Branches

Symptomatic

PID

$1,455; P = 0.25$

$396$

$0.400$

(0.63 * 960) + (0.37 * 42) = 620

Asymptomatic

No PID

$630; P = 0.37$

$0.600$

$620$

$0.37$

$308$

Average Out and Fold Back the Tree

Symptomatic

PID

$1,455.00 RMB; P = 0.012096$

$0.400000$

$396.00 RMB$

Asymptomatic

No PID

$630.00 RMB; P = 0.018144$

$0.600000$

$620.00 RMB$

PID

$960.00 RMB$

$0.630000$

$42.00 RMB; P = 0.017760$

$0.370000$

$42.00 RMB$

Chlamydia

$620.34 RMB$

$0.048000$

$660.00 RMB$

No Chlamydia

$0.00 RMB; P = 0.952000$

$0.952000$

Path Probabilities

- Determine the probability that each end node will be observed
  - Multiply all of the branch probabilities together
- For each decision branch, sum the product of the probability that the end node will be observed times the value of the end node

No Prophylaxis

$29.78 RMB$

Symptomatic

PID

$1,495.00 RMB$

$0.400000$

$1,008.00 RMB$

Asymptomatic

No PID

$670.00 RMB$

$0.600000$

$82.00 RMB$

PID

$42.00 RMB$

$0.370000$

$660.34 RMB$

No Chlamydia

$40.00 RMB$

$0.998080$

Prophylaxis

$41.19 RMB$

$0.001920$
No Prophylaxis Path Probabilities

$\begin{align*}
&\text{Symptomatic} \\
&\text{PID} \\
&1455 / 0.01209 \\
&\text{Asymptomatic} \\
&630 / 0.018144 \\
&\text{No PID} \\
&42 / 0.017760 \\
&\text{No Prophylaxis} \\
&0.048 \\
&\text{Chlamydia} \\
&0.63 \\
&\text{No PID} \\
&0.37 \\
&\text{No Chlamydia} \\
&0.992
\end{align*}$

$(0.012096 \times 1455) + (0.018144 \times 630) + (0.01776 \times 42) + (0.952 \times 0) = 29.78$

Point Estimates, Chlamydia Prophylaxis

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost</th>
<th>Incr Cost</th>
<th>Eff</th>
<th>Incr Eff</th>
<th>C/E</th>
<th>Incr C/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Proph</td>
<td>29.8</td>
<td>0.9698</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proph</td>
<td>41.2</td>
<td>11.4</td>
<td>0.9988</td>
<td>0.0290</td>
<td>44</td>
<td>393</td>
</tr>
</tbody>
</table>

• Is 393 RMB per case of PID averted good value?

Steps in Decision Analysis

1. Imagine the model, and draw the tree
2. Identify the probabilities
3. Identify the outcome values
4. Calculate expected values
5. Perform sensitivity analyses
Why Sensitivity Analysis?

- Even if the sample was representative of the target population in our analysis, the fact that different draws from the target population would result in different point estimates means that we can’t be certain that the results in the sample are the correct numbers for the population.

Prevalence of Chlamydia

- In the authors’ study, 97 out of 2020 women
  - Prevalence (probability of Chlamydia), 0.048
- Even if the sample is representative, natural variability in the sample implies we cannot rule out that the true probability was as low as 0.040 or as high as 0.058
  - i.e., 95% CI = 0.040 to 0.058

PID Given Chlamydia

- A study by Blackwell reported that 19 out of 30 patients with Chlamydia developed PID
  - Probability of PID, 0.633
- Even if the population had been representative, sample variation implies we cannot rule out that the true cure rate was as low as 0.455 or as high as 0.781
  - i.e., 95% CI = 0.455 to 0.781
Azithromycin Cure Rate

• A study by Rustomjee et al. reported that azithromycin cured 23 of 24 patients with Chlamydia.
  – Cure rate, 0.958 (rounded to 0.958)
• Even if the study design was a good one (there was no "No Treatment" comparison group) and the population had been representative, sample variation implies we cannot rule out that the true cure rate was as low as 0.798 or as high as 0.993.
  – i.e., 95% CI = 0.798 to 0.993

Representativeness of Chlamydia Prevalence?

• The authors report that they derived their sample from 2 family planning clinics in Jinan, the capital of Shandung province.
• Do we know if this sample is representative of the Shandung province in general (might there be urban rural differences in Chlamydia prevalence)? Of the PRC?
• If it is not representative, then the 0.040 to 0.058 range is probably much too optimistic.
  – Sensitivity analysis should use a wider range to account for the possible lack of representativeness.

Representativeness

“In women who do not seek abortion, it is estimated that 30% of women infected with C. trachomatis would develop PID, 40% of which would be asymptomatic. Under the condition of induced abortion, we estimated that a higher proportion of infected women would develop PID: 63%.”
  – Data?
Sensitivity Analysis

- To conduct sensitivity analysis, replace the numbers in the tree with variables
  - Probabilities
    - pChlamyd: 0.048
    - pPID: 0.63
    - pSympt: 0.40
    - pProtect: 0.96
  - Cost
    - cChlamyd: 42
    - cSympt: 1455
    - cAsympt: 630
    - cAzith: 40

Adding Variables to Tree

Interpreting the One-Way Graph

Sensitivity Analysis on
Probability, % cured w/azithromycin

Incremental Cost/Eff
$0.0  $100.0  $200.0  $300.0  $400.0  $500.0  $600.0  $700.0
0.700 0.843 0.895 0.948 1.000
Probability, % cured w/azithromycin

No Prophylaxis
Prophylaxis
Sensitivity Analysis on Probability, Chlamydia on Cost

Threshold Values:
- Probability, Chlamydia = 0.0
- EV = 41.7 RMB

Sensitivity Analysis on Probability, Chlamydia on Cases of PID

Threshold Values:
- EV = 29.8 RMB

Sensitivity Analysis on Cost, Azithromycin on Cost

Threshold Values:
- Cost, Azithromycin = 28.6
Two-Way Sensitivity Analysis on Probability, Chlamydia and Cost, Azithromycin on Cost

Other Issues

- The authors don’t model pre-existing PID along with chlamydia
  - What is the likely impact?
- Prevalence/incidence and the impact on cost-effectiveness as the program continues into the future?

Chen et al.’s Conclusions

- “Programs designed for early identification and treatment of asymptomatic chlamydial infections have the potential to prevent involvement of the upper reproductive tract..., averted medical costs associated with management of complications and sequelae”
- “To prevent postabortion complications of women in China, we recommend that [women attending a clinic for induced abortion] receive universal prophylactic treatment for C. Trachomatis infection with a single dose of 1 g azithromycin”
- Do you agree? Why / why not?
Advantages of Decision Analysis

- Forces a systematic examination of the problem
- Forces the assignment of explicit values
- Controls complexity and thus avoids processing errors

Disadvantages of Decision Analysis

- Time consuming
- Results difficult to explain
- Methods not well understood or trusted by policy makers

Chen's Complete Tree for Prophylaxis
How to Use Decision Analysis

- To organize the issues for traditional decision making
- To identify a critical element for intensive study
- To provide information (not answers) for decision making