Introduction to Cost-Effectiveness Analysis

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Objectives

• Define types of health-economic models
• Introduce decision analysis
• Introduce utilities and QALYs
• Review solution to “competing choice” problem
• Examine role of sensitivity analysis
• Discuss shortcomings of cost-effectiveness analysis
  – Introduce budget impact models as alternative
Taxonomy of Health-Economic Analyses

**Decision Analysis**

- Cost-Effectiveness Analysis (CEA)
- Cost-Minimization Analysis (CMA)
- Cost-Benefit Analysis (CBA)
- Cost-Utility Analysis (CUA)
- Budget Impact Model (BIM)

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**Health Economic Models**

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Numerator</th>
<th>Denominator</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>$</td>
<td>Health Outcome</td>
<td>Cost per ulcer bleed prevented</td>
</tr>
<tr>
<td>CUA</td>
<td>$</td>
<td>QALY</td>
<td>Cost per QALY</td>
</tr>
<tr>
<td>CBA</td>
<td>$</td>
<td>$</td>
<td>Cost per willingness-to-pay (WTP) for IBS symptom relief</td>
</tr>
<tr>
<td>CMA</td>
<td>$</td>
<td>None</td>
<td>Overall cost of using cox-2 inhibitor instead of ibuprofen</td>
</tr>
<tr>
<td>BIM</td>
<td>$</td>
<td>None</td>
<td>Per member per month (PMPM) cost of screening for varices in cirrhosis</td>
</tr>
</tbody>
</table>
Example Questions

• Is it cost-effective to screen for esophageal varices in cirrhosis?

• What is the cost-utility of using cox-2 inhibitors instead of non-selective NSAIDs in arthritis?

• How sensitive and specific must a hypothetical pancreatic cancer tumor marker be in order for it to be cost-effective?

• What is the incremental PMPM cost of using rifaximin instead of lactulose for hepatic encephalopathy?

Guiding Principles of Health Economics

• Resources are limited

• If you spend money in one place, then you can’t spend it in another

• Aim to provide the most good to most people

• Litmus test: “Is the juice worth the squeeze”

• Dying younger is cheaper

• “Rule of rescue” can throw off a perfectly rationale argument
  – Computers are amoral. Humans are not.
When Does Money Matter?

• When budgets are tight (e.g. always!)
• When competing strategies are equally effective (principle of CMA)
• When one strategy is significantly more effective than another, but also more expensive
• When people live a long time with a condition
• When a condition is highly prevalent

Ways to Save Money

• Don’t do things that are ineffective & expensive
• Skip low yield steps or cut corners
• Use lower cost stuff, even if it’s less effective
• Use lower cost people, even if it’s less effective
• Downgrade to a less expensive settings
• Do nothing at all
Decision Analysis Example: Irritable Bowel Syndrome

- 45 yo with irritable bowel syndrome
- Symptoms severe
- Co-morbid depression

Which therapy to start with?

- “Usual Care”
- Paroxetine
Suppose there are two factors that drive the decision:

- Will the symptoms improve?
- Will there be side-effects?

Which therapy?
Defining the Outcomes

<table>
<thead>
<tr>
<th></th>
<th>No Side Effects</th>
<th>Side Effects Occur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms Improve</td>
<td>😊</td>
<td>😞</td>
</tr>
<tr>
<td>Symptoms Persist</td>
<td>😞</td>
<td>😞</td>
</tr>
</tbody>
</table>

Which therapy?

Feels Better 0.40
- Side Effects 0.15
  - No Side Effects 0.85

Does not Feel Better 0.60
- Side Effects 0.15
  - No Side Effects 0.85

Feels Better 0.53
- Side Effects 0.10
  - No Side Effects 0.90

Does not Feel Better 0.47
- Side Effects 0.10
  - No Side Effects 0.90
Defining the Outcome: Utilities

Utilities

Perfect Health

Direct Rating Scale

Death

Perfect Health
Indirect Rating: Time Trade-Off

Present

39 years

40 years

Present

Indirect Rating: Time Trade-Off

Present

38 years

40 years
Indirect Rating: Time Trade-Off

Calculating the Time Trade-Off Utility

Utility = \frac{\text{time willing to spend in perfect health}}{\text{total remaining lifespan}}

\text{Utility} = \frac{35 \text{ years}}{40 \text{ years}} = 0.87
Other Utility Elicitation Techniques

- Standard gamble
- Multi-attribute scales (EuroQol, HUI)
- SF-36 conversions
- Conjoint analysis

Quality-Adjusted Life-Years

- QALY is a year of life, adjusted for the quality in which it is lived
- One year lived with utility of 0.87 = 87% of year lived in perfect health
- 87% of year lived in perfect health = 0.87 QALY
Quality-Adjusted Life-Years

5 QALYs

Year

Quality-Adjusted Life-Years

3.2 QALYs

Year

Treatment A

Treatment B

Discontinue B
Which therapy?

Feels Better
0.40

Does not Feel Better
0.60

Feels Better
0.53

Does not Feel Better
0.47

Side Effects
0.15
No Side Effects
0.85

Side Effects
0.15
No Side Effects
0.85

Side Effects
0.10
No Side Effects
0.90

Side Effects
0.10
No Side Effects
0.90

Feels Better
0.47

Does not Feel Better
0.53

Feels Better
0.40

Does not Feel Better
0.60

Feels Better
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Does not Feel Better
0.47

Side Effects
0.15
No Side Effects
0.85

Side Effects
0.15
No Side Effects
0.85

Side Effects
0.10
No Side Effects
0.90

Side Effects
0.10
No Side Effects
0.90

0.87
1.0

0.87
0.87
1.0
0.63
0.87
“Rolling Back” the Tree

Calculate the expected value of each arm

\[0.60 \times 0.15 \times 0.63 = 0.0567\]

Which therapy?

<table>
<thead>
<tr>
<th>Side Effects</th>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Side Effects</th>
<th>No Side Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.423</td>
<td>0.48</td>
</tr>
<tr>
<td>0.03</td>
<td>0.046</td>
</tr>
<tr>
<td>0.0522</td>
<td>0.34</td>
</tr>
<tr>
<td>0.51</td>
<td>0.0567</td>
</tr>
</tbody>
</table>

Which therapy?

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<tr>
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<td>0.47</td>
</tr>
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</table>
Summing the Arms

\(0.0522 + 0.34 + 0.0567 + 0.51\)

\(0.046 + 0.48 + 0.03 + 0.423\)

\(0.95 < 0.98\)
Question

SSRI provides 0.03 more QALY vs. “usual care.” That’s 10.95 additional quality adjusted days per year.

So, “is the juice worth the squeeze?”

Juice = QALYs
Squeeze = $

Costs

- Cost estimates depends upon perspective
  - Third party payer perspective
    - Medicare reimbursement
    - Average wholesale drug prices
  - Patient perspective
    - Days lost from work
    - Transportation costs for doctor visits
  - Societal perspective
    - Includes all up-front, induced, and averted costs
Sequence of Costs

- **Initial**: Costs initially incurred upon initiation of a strategy
- **Induced**: Costs resulting from an intervention
- **Transition**: Costs associated with transitioning between health states
- **Averted**: Costs associated with events avoided by intervention
- **Terminal**: Costs of death

Some Issues with Costs

- **Cost vs. charges**
- **Comprehensiveness** of resources included in the model
- **Discounting** future costs
- **Updating old costs using medical services component of CPI**
- **Problems with AWP**
Example Cost Estimates

<table>
<thead>
<tr>
<th>GI Resource</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per tablet of SSRI</td>
<td>$3.00</td>
</tr>
<tr>
<td>Cost per day of Metamucil</td>
<td>$0.50</td>
</tr>
<tr>
<td>GI office visit</td>
<td>$52</td>
</tr>
<tr>
<td>Colonoscopy</td>
<td>$624</td>
</tr>
<tr>
<td>Upper endoscopy</td>
<td>$624</td>
</tr>
<tr>
<td>Flexible sigmoidoscopy</td>
<td>$125</td>
</tr>
<tr>
<td>ERCP</td>
<td>$1213</td>
</tr>
<tr>
<td>Abdominal XR / Upper GI Series / BE</td>
<td>$541</td>
</tr>
<tr>
<td>Abdominal ultrasound</td>
<td>$541</td>
</tr>
<tr>
<td>Elective abdominal surgery</td>
<td>$13,531</td>
</tr>
</tbody>
</table>

Obtaining Cost Estimates

• Outpatient services

• Inpatient services
Cost-Effectiveness

$850 / year

$1350 / year

Cost-Effectiveness

\[
\frac{\$850}{\text{.95}}
\]

\[
\frac{\$1350}{\text{.98}}
\]
Cost-Effectiveness

FIBRESONIC

$895/QALY

PAXIL

$1378/QALY

Usual Care

Effectiveness (QALYs)

.90     .92     .94     .96     .98     1.0

Cost-Utility Results

Paroxetine

$16,100 / QALY

Most C/E
Incremental Cost Effectiveness

ICER = \frac{\Delta \text{Cost}}{\Delta \text{Effect}}

Another Example

Question

How do you know if $275,000 per QALY is “too much”? 

Anyone who tells you there is an easy answer to this is mistaken!

Question

Why are we using QALYs, anyway?
### “League Table”

<table>
<thead>
<tr>
<th>COST DESCRIPTION</th>
<th>$ / OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>“PPI Test” in acid reflux</td>
<td>$10,160</td>
</tr>
<tr>
<td>Screening for Barrett’s esophagus</td>
<td>$10,440</td>
</tr>
<tr>
<td>Screening for celiac sprue in IBS</td>
<td>$11,000</td>
</tr>
<tr>
<td>Angioplasty in acute MI</td>
<td>$13,100</td>
</tr>
<tr>
<td>CMV prophylaxis in AIDS</td>
<td>$22,000</td>
</tr>
<tr>
<td>Screening for varices in cirrhosis</td>
<td>$175,833</td>
</tr>
<tr>
<td><strong>Celebrex for chronic arthritis</strong></td>
<td><strong>$275,000</strong></td>
</tr>
<tr>
<td>Intravenous PPI therapy for ulcer bleed</td>
<td>$708,735</td>
</tr>
</tbody>
</table>

**References:**
- PPI Test: Ofman et al. APT 2002
- Sprue: Spiegel et al. Gastroenterol 2004
- Angioplasty: Lieu et al. JACC 1997

### Another Example

<table>
<thead>
<tr>
<th>Effectiveness (QALYs)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.90</td>
<td>800</td>
</tr>
<tr>
<td>.92</td>
<td>800</td>
</tr>
<tr>
<td>.94</td>
<td>800</td>
</tr>
<tr>
<td>.96</td>
<td>1200</td>
</tr>
<tr>
<td>.98</td>
<td>1200</td>
</tr>
<tr>
<td>1.0</td>
<td>1200</td>
</tr>
</tbody>
</table>

- **Strategy A**: “Dominated”
- **Strategy B**: “Dominant”
Another Competing Choice Example

Effectiveness (QALYs)

Cost ($)

Effectiveness

Most effective, but no bargain

“Diminishing Return” Curve is Steep

Elbow of curve is sweet spot – closest to RLQ

Doing Us

- Do Nothing
- BB
- sEGD-->BB
- EGD-->BB
- sEGD-->EBL
- EGD-->EBL

1750
1625
1500
1500
1750
1625
1500
2000
.90 .92 .94 .96 .98 1.0

Another Competing Choice Example

Example

Doing Nothing is Usually Cheap

"Diminishing Return" Curve is Steep

Most effective, but no bargain

Elbow of curve is sweet spot – closest to RLQ
Handling Uncertainty

- Precise probability estimates may not be valid
- Cost estimates may vary between different settings
- Solution: Sensitivity Analysis

One-Way Sensitivity Analysis: Cost of Paroxetine

Cost of Paroxetine ($) vs. Cost / Effectiveness

- Usual Care
- Paroxetine

Usual Care: $2.00
Another Example

Effectiveness (QALYs)

Cost ($)

ASA alone
ASA+PPI
Clop alone
Clop+PPI
ASA+Clop
ASA+Clop+PPI

ICER $195,725

ICER $240,662
Sensitivity analysis on PPI cost

Cost ($) vs Effectiveness (QALYs)

- ASA alone
- ASA+PPI
- Clop alone
- Clop+PPI
- ASA+Clop
- ASA+Clop+PPI

PPI $3.50 per tab

ASA alone
ASA+PPI
Clop alone
Clop+PPI
ASA+Clop
ASA+Clop+PPI

PPI $2.40 per tab

ASA alone
ASA+PPI
Clop alone
Clop+PPI
ASA+Clop
ASA+Clop+PPI

Effectiveness (QALYs)

Cost ($)
Sensitivity analysis on PPI cost

Monte Carlo Analysis: Paroxetine vs Usual Care
CEAs Don’t Tell the Whole Story

Limitations of CEAs:

– Difficult to interpret ICERs – sometimes more academic than practical
– Does not account for underlying prevalence of disease
– Less useful when effectiveness is similar in competing strategies
– Does not address budget impact

Focusing on Effectiveness: Screening for Varices in Cirrhosis

0.4 days of life is:

→ 9.6 hours
→ 40,000 heart beats
→ 6900 breaths of air
Importance of Considering Budget Impact

1 Endoscopy = 30 Bicycle Helmets for Kids

Importance of Considering Budget Impact

1 Endoscopy = 100 Flu Vaccinations
Importance of Considering Budget Impact

1 Endoscopy = 300 Bottles of Aspirin

Budget Impact Question:

In a managed care population, what is the per-member per-month (PMPM) cost of paying for endoscopic screening with EGD versus using empiric medical therapy alone?
## Budget Impact Results

<table>
<thead>
<tr>
<th>Strategy</th>
<th>1-Year Cost per Cirrhotic</th>
<th>PMPM</th>
<th>IPMPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Screening</td>
<td>$3,824</td>
<td>$1.59</td>
<td>--</td>
</tr>
<tr>
<td>Screening</td>
<td>$4,432</td>
<td>$1.85</td>
<td>$0.26</td>
</tr>
</tbody>
</table>

* Assuming 0.5% prevalence of cirrhosis in MCO of 1,000,000 covered lives

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## PMPM League Table

<table>
<thead>
<tr>
<th>Intervention</th>
<th>PMPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tegaserod for irritable bowel syndrome</td>
<td>$0.01</td>
</tr>
<tr>
<td>Sildenafil for erectile dysfunction</td>
<td>$0.18</td>
</tr>
<tr>
<td>Screening for varices in cirrhosis</td>
<td>$0.26</td>
</tr>
<tr>
<td>Intravenous PPI therapy for ulcer bleeding</td>
<td>$2.68</td>
</tr>
<tr>
<td>Rifaximin for hepatic encephalopathy</td>
<td>$3.41</td>
</tr>
</tbody>
</table>

Cook et al. J Man Care Pharm 2005;11:674
Huang et al. Aliment Pharm Ther 2007;27:1147
If we assume that a hypothetical MCO has 1,000,000 covered lives, and that the prevalence of IBS is 10%, then:

**PMPM\text{SSRI} = \frac{\left(\frac{1350}{12\text{ months}}\right) \times (1,000,000 \times 0.1)}{1,000,000} = $11.25**

**PMPM\text{Usual} = \frac{\left(\frac{850}{12\text{ months}}\right) \times (1,000,000 \times 0.1)}{1,000,000} = $7.08**

**IPMPM = $11.25 - $7.08 = $4.17**
# BIM Spreadsheet

## IBS Budget Impact Model

<table>
<thead>
<tr>
<th></th>
<th>1-Yr Cost (per patient)</th>
<th>PPPM</th>
<th>IPPPM</th>
<th>PMPM</th>
<th>IPMPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual Care</td>
<td>$850</td>
<td>$70.83</td>
<td>~</td>
<td>$7.08</td>
<td>~</td>
</tr>
<tr>
<td>SSRI</td>
<td>$1,350</td>
<td>$112.50</td>
<td>$41.67</td>
<td>$11.25</td>
<td>$4.17</td>
</tr>
</tbody>
</table>

>> KEY VARIABLES CONTROL PANEL <<

- Covered Lives in MCO (dropdown menu): 1,000,000
- Percent with IBS (dropdown menu): 10.00%
- Total IBS (total lives x prop with HE): 100,000

## Changing IBS Prevalence

![Graph showing the change in PMPM with varying IBS prevalence](image)

- SSRI
- Usual

<table>
<thead>
<tr>
<th>Prevalence of IBS</th>
<th>PMPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>$0</td>
</tr>
<tr>
<td>5%</td>
<td>$2.08</td>
</tr>
<tr>
<td>10%</td>
<td>$4.17</td>
</tr>
<tr>
<td>15%</td>
<td>$8.34</td>
</tr>
<tr>
<td>20%</td>
<td>$12</td>
</tr>
</tbody>
</table>
Take Home Points

• Most health economic analyses are based on underlying decision model

• Good models must be comprehensive in competitors and scope

• We use QALYs as an “exchange currency” to compare strategies across medicine

• Interpret ICERs with league table

• CEAs don’t account for prevalence, but BIMs do