Outline

- Obstructive sleep apnea (OSA) and insomnia cost-of-illness (COI)
- Utility of cost-of-illness studies
- What is cost-effectiveness analysis
- What do we know about cost-effectiveness of OSA and insomnia treatments?

OSA and Insomnia Cost/Burden-of-Illness ($Billions)

<table>
<thead>
<tr>
<th></th>
<th>Direct</th>
<th>Accidents</th>
<th>Absenteeism</th>
<th>Presenteeism</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSA</td>
<td>47-90</td>
<td>15-60</td>
<td>5-15</td>
<td>NE *</td>
<td>65-165</td>
</tr>
<tr>
<td>Insomnia Low</td>
<td>NE</td>
<td>NE</td>
<td>8.2</td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td>Insomnia High</td>
<td>39.5</td>
<td>32.3</td>
<td>11.8</td>
<td>63.0</td>
<td>146.6</td>
</tr>
</tbody>
</table>

NE = not estimated

References:
Apnea: Harvard Medical School Division of Sleep Medicine. The price of fatigue: the surprising economic costs of unmanaged sleep apnea
Insomnia (low): Estimates based on Sarsour, The association between insomnia severity and healthcare and productivity costs in a health plan sample
NOT SAYING ESTIMATES ARE INCORRECT!!!

But Hard to Know That They Are….

• Major reason is that patients often have multiple illnesses, all of which may be contributing to same outcomes
  – e.g., patients with insomnia, OSA, prior CVD, hypercholesterolemia, hypertension, diabetes, and obesity
• What causes what?

Cost/Burden-of-Illness ($Billions)

<table>
<thead>
<tr>
<th></th>
<th>Direct</th>
<th>Productivity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>176</td>
<td>69</td>
<td>245</td>
</tr>
<tr>
<td>CVD</td>
<td>193.1</td>
<td>123.5</td>
<td>316.6</td>
</tr>
<tr>
<td>Hypertension</td>
<td>45</td>
<td>3.6</td>
<td>48.6</td>
</tr>
<tr>
<td>Overweight / Obesity</td>
<td>147</td>
<td>3.4 – 6.4</td>
<td>150.4 – 153.4</td>
</tr>
</tbody>
</table>

• Has to be a lot of double counting here

References:
- Diabetes: ADA. Economic costs of Diabetes in the U.S. in 2012
- Overweight/obesity: CDC. Adult obesity causes and consequences.
Double Counting

- OSA and insomnia?
  - Some patients have both, but unclear how much researchers do to allocate their costs to one or the other condition
    - Many studies funded by makers of medical therapies
    - Who’s interested in a low number?
- OSA/insomnia, CVD, diabetes, obesity?
  - Some patients have all 5
- More generally, Bloom et al. have reported that sum of cost-of-illness of estimates of direct medical cost for 80 different diagnoses was 2 fold greater than annual US health expenditures

ADA and AHA Are Trying

- ADA and AHA are some of the only organizations to make efforts to avoid double counting, but....
- When there are multiple causes (technically referred to as joint costs) methods for assigning costs to particular causes are arbitrary
- Typically don’t have a gold standard for judging whether allocation methods are correct
  - Some costs may be truly joint and only avoided if all of the contributing factors are simultaneously eliminated

Implications of Double Counting

- Common to consider cost-of-illness estimates as measures of what can be avoided if we treat or cure a problem such as insomnia or OSA
- But if source of adverse outcomes is multifactorial, unclear how many adverse outcomes (and how much of their costs) can actually be avoided
  - e.g., if we successfully treat insomnia in a person who also is obese, has diabetes and high blood pressure, and has prior CVD, do we know how much cardiovascular disease – and its cost – we’ll actually avoid?
BUT EVEN IF THE COI ESTIMATES ARE CORRECT....

...They May Be Besides the Point!!!

- Investment decisions should depend on value, not magnitude of burden
- How much do we have to pay to avoid burden and how much burden do we avoid?
- Learn about these trade-offs by use of cost-effectiveness analysis, NOT cost-of-illness studies

COST-EFFECTIVENESS ANALYSIS
Cost-Effectiveness Analysis

• Estimates costs and outcomes of intervention
• Costs and outcomes expressed in different units
  – Costs usually measured in money terms; outcomes in some other units

Cost-Effectiveness A Relative Measure

• Cost-effectiveness is a relative measure; no program is "cost-effective" in abstract
  – Results meaningful in comparison with:
    • A predetermined standard
      – e.g., $50,000 - $100,000 per quality-adjusted year of life saved
    • Other accepted and rejected interventions (e.g., a league table)

Cost-Effectiveness Ratios

• Cost-effectiveness ratio, e.g., CPAP vs No CPAP:

\[
\frac{\text{Costs}_{\text{CPAP}} - \text{Costs}_{\text{NoCPAP}}}{\text{Effects}_{\text{CPAP}} - \text{Effects}_{\text{NoCPAP}}}
\]

• A ratio can exist for every pair of options
  – 1 option (case series), no ratios calculated
  – 2 options, 1 ratio
  – 3 options, 3 ratios (option 1 versus option 2, option 1 versus option 3, and option 2 versus option 3)
What Effectiveness Measure?

- Can calculate a ratio for any outcome
  - Cost per toe nail fungus day averted
- For cost-effectiveness ratios to be an informative, must know willingness to pay for outcome
  - In many jurisdictions – but not the US Congress – quality-adjusted life year (QALY) is recommended outcome of cost-effectiveness analysis

QALYS

- Economic outcome that combines preferences for both length of survival and quality into a single measure
- Help us decide how much to pay for therapies that:
  - Save fully functional lives/life years
  - VS
  - Save less than fully functional lives/life years
    - e.g., heart failure drug that extends survival, but extra time spent in NYHA class III
    - VS
  - Don’t save lives/life years but improve function
    - e.g., heart failure patients spend most of their remaining years in class I instead of class III
QALY Scores

- QALY or preference scores generally range between 0 (death) and 1 (perfect health)
  - E.g., health state with a preference score of 0.8 indicates that year in that state is worth 0.8 of year with perfect health
  - There can be states worse than death with preference scores less than 0

CEA Example: Pietzsch, et al., No CPAP vs CPAP

- Lifetime projected results:
<table>
<thead>
<tr>
<th>COST</th>
<th>QALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No CPAP, $217,000</td>
<td>10.81</td>
</tr>
<tr>
<td>CPAP, $244,000</td>
<td>12.49</td>
</tr>
<tr>
<td>Difference $27,000</td>
<td>1.68</td>
</tr>
</tbody>
</table>

- Cost-effectiveness “Table” incorporates these data plus the ratio of ΔC and ΔQ

CEA Example: Pietzsch, et al., No CPAP vs CPAP

- Cost-Effectiveness table, difference in cost

<table>
<thead>
<tr>
<th>C_{NoC}</th>
<th>C_{CPAP}</th>
<th>ΔC</th>
<th>Q_{NoC}</th>
<th>Q_{CPAP}</th>
<th>ΔQ</th>
<th>C/Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pietzsch 217k</td>
<td>244k</td>
<td>27k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WHAT DO WE KNOW ABOUT THE COST-EFFECTIVENESS OF OSA/INSOMNIA TREATMENTS?
IS CPAP COST-EFFECTIVE?

HAVE NEVER PERFORMED LONG-TERM COST-EFFECTIVENESS TRIALS, BUT ASSUMING CPAP DOES WHAT WE THINK IT DOES....

Markov: 5(10)-Year Cost and QALYs, Nothing vs CPAP

<table>
<thead>
<tr>
<th></th>
<th>C_CCPAP</th>
<th>△C</th>
<th>Q_CCPAP</th>
<th>△Q</th>
<th>C/Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar '03 (c)</td>
<td>55</td>
<td>2719</td>
<td>2664</td>
<td>3.39</td>
<td>3.73</td>
</tr>
<tr>
<td>Ayas ($)*</td>
<td>1659</td>
<td>4177</td>
<td>2518</td>
<td>1.47</td>
<td>2.22</td>
</tr>
<tr>
<td>Mar '06 (c)</td>
<td>-</td>
<td>-</td>
<td>6000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tan ($C)*</td>
<td>266</td>
<td>2983</td>
<td>2717</td>
<td>1.47</td>
<td>2.22</td>
</tr>
<tr>
<td>Sadatsafavi</td>
<td>4216</td>
<td>6401</td>
<td>2185</td>
<td>3.34</td>
<td>3.50</td>
</tr>
<tr>
<td>Pietzsch ($)</td>
<td>70k</td>
<td>80k</td>
<td>9500</td>
<td>5.67</td>
<td>6.26</td>
</tr>
</tbody>
</table>

All less than $50k/QALY
### Lifetime Cost and QALYs, Nothing vs CPAP

<table>
<thead>
<tr>
<th></th>
<th>C_N (€)</th>
<th>C_CPAP (€)</th>
<th>ΔC</th>
<th>Q_N (QALY)</th>
<th>Q_CPAP (QALY)</th>
<th>ΔQ</th>
<th>C/Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar (-)</td>
<td>591</td>
<td>7902</td>
<td>7311</td>
<td>12.90</td>
<td>14.38</td>
<td>1.48</td>
<td>4938</td>
</tr>
<tr>
<td>Guest (£)</td>
<td>10645</td>
<td>9672</td>
<td>-973</td>
<td>7.22</td>
<td>8.09</td>
<td>0.87</td>
<td>DOM</td>
</tr>
<tr>
<td>Weatherly (€)</td>
<td>8140</td>
<td>9301</td>
<td>1061</td>
<td>11.93</td>
<td>12.39</td>
<td>0.46</td>
<td>2524</td>
</tr>
<tr>
<td>Pietzsch ($)</td>
<td>217k</td>
<td>244k</td>
<td>27k</td>
<td>10.81</td>
<td>12.49</td>
<td>1.68</td>
<td>15,915</td>
</tr>
<tr>
<td>Tan ($)</td>
<td>62.4k</td>
<td>66.2k</td>
<td>3800</td>
<td>10.3</td>
<td>11.3</td>
<td>1</td>
<td>3900</td>
</tr>
</tbody>
</table>

*All less than $50k/QALY*

### IS HOME DIAGNOSIS AND CPAP TITRATION COST-EFFECTIVE COMPARED WITH IN-LAB DIAGNOSIS AND TITRATION?*

*P < 0.05; Dom: less expensive and same or better outcomes*

### In Lab vs Home Diagnosis/CPAP Titration

<table>
<thead>
<tr>
<th></th>
<th>C_Home ($)</th>
<th>C_Lab ($)</th>
<th>ΔC</th>
<th>Q_Home (QALY)</th>
<th>Q_Lab (QALY)</th>
<th>ΔQ</th>
<th>C/Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chervin ($)</td>
<td>3460</td>
<td>4210</td>
<td>750</td>
<td>3.955</td>
<td>4.019</td>
<td>0.064</td>
<td>11,719</td>
</tr>
<tr>
<td>Deutsch ($)</td>
<td>4096</td>
<td>4866</td>
<td>790</td>
<td>2.23</td>
<td>2.33</td>
<td>.1</td>
<td>7900</td>
</tr>
<tr>
<td>Kim ($)</td>
<td>1575</td>
<td>1840</td>
<td>264*</td>
<td>Equivalent</td>
<td>Dom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atwood ($)</td>
<td>4057</td>
<td>4621</td>
<td>564*</td>
<td>Equivalent</td>
<td>Dom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Newer studies indicate home testing cheaper and as effective; older studies indicated in-lab cost-effective*
WERE PRE-TEST PROBABILITIES SO HIGH THAT NO ONE SHOULD HAVE BEEN TESTED?
DO LOWER PRE-TEST PROBABILITIES CHANGE RECOMMENDATION?

Moro Home vs In-Lab Comparison

- When costs and effects modeled out to 5 years, no role for in-lab testing
- When costs and effects modeled out to 10 years, in-lab has role only if annual cost of untreated OSA > $2000 and pre-test probability between 10% and 60%


IS TELE-HOME FOLLOW-UP COST-EFFECTIVE?

Current evidence is equivocal
### Telemedicine OSA Follow-Up

<table>
<thead>
<tr>
<th></th>
<th>$C_{Tel}$</th>
<th>$C_{FTF}$</th>
<th>$\Delta C$</th>
<th>$Q_{Tel}$</th>
<th>$Q_{FTF}$</th>
<th>$\Delta Q$</th>
<th>$C/Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>164</td>
<td>180</td>
<td>16*</td>
<td>.011</td>
<td>.012</td>
<td>.001*</td>
<td>13.3k</td>
</tr>
<tr>
<td>Sleep</td>
<td>115</td>
<td>151</td>
<td>36†</td>
<td>.011</td>
<td>.012</td>
<td>.001*</td>
<td>30.3k</td>
</tr>
</tbody>
</table>

- * NS; † p = 0.05

- Telemedicine group experienced significantly lower travel time for therapy (8.6 vs 23.3 minutes) and time out of work (21.1 vs 55.0), but more nurse visits (24 vs 10)

### CBT FOR INSOMNIA

<table>
<thead>
<tr>
<th></th>
<th>$C_{NoC}$</th>
<th>$C_{CPAP}$</th>
<th>$\Delta C$</th>
<th>$Q_{NoC}$</th>
<th>$Q_{CPAP}$</th>
<th>$\Delta Q$</th>
<th>$C/Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonin</td>
<td>72</td>
<td>251</td>
<td>179</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.004</td>
</tr>
<tr>
<td>Morgan</td>
<td>142.6</td>
<td>272.4</td>
<td>130*</td>
<td>-.014</td>
<td>.024</td>
<td>.038</td>
<td>£3.4k</td>
</tr>
</tbody>
</table>
Summary

• There is a large literature on the cost-effectiveness of diagnosing and treating OSA and insomnia
  – Point estimates from this literature generally indicate that treatments for OSA and insomnia are cost-effective

• Little to none of literature based on randomized outcome studies of long-term effects of diagnosis and treatment

• Potential co-determination of outcomes and selection bias in long-term observational samples makes it difficult to estimate magnitude of treatment effects

• But MUST make decisions based on current knowledge base
  – Current estimates may be best we have!!!