Innovative ways of measuring TB transmission: prospects and challenges

Gabriel Chamie MD, MPH
Assistant Professor of Medicine
HIV/AIDS Division, San Francisco General Hospital
University of California, San Francisco (UCSF)
Ventilation & TB Transmission

• Ventilation & TB Transmission
  – 6-12 Air Changes per Hour (ACH) recommended for TB isolation & procedure rooms
  – Based on models of particle clearance rates
    • 1 ACH clears 67% of contaminants in an hour
    • 7 ACH clears 99.9% of contaminants in an hour

• Evidence supporting ventilation for TB prevention?
  – Limited, largely from hospitals/clinical settings
Household TB Transmission

- Homes of active pulmonary TB cases are high risk environments for TB transmission

<table>
<thead>
<tr>
<th>Exposure</th>
<th>N</th>
<th>Number Infected</th>
<th>Infected (%)</th>
<th>Risk Difference</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contacts</td>
<td>1918</td>
<td>1369</td>
<td>71.4</td>
<td>47.4</td>
<td>44.3, 50.6</td>
</tr>
<tr>
<td>Controls</td>
<td>1179</td>
<td>282</td>
<td>23.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- HIV-infected household contacts and children at particularly high risk of TB

The freshAIR pilot study

• Study Objectives
  – To describe the physical and social characteristics of TB patients’ homes in Kampala, Uganda
  – To develop and test the feasibility of a simple in-home measurement of ventilation using a carbon dioxide (CO$_2$) tracer gas decay technique
  – To determine if household ventilation is associated with TB in household contacts
  – To measure the impact of low-cost interventions on household ventilation
The freshAIR pilot study

- **Study population**: Pulmonary TB cases and their household contacts living in homes within 20 km of central Kampala
  - All index patients diagnosed with pulmonary TB at the National Tuberculosis and Leprosy Programme
  - All households identified from an existing prospective cohort: UCSF Family-based HIV Voluntary Counseling and Testing for patients at risk of study (PI: Dr. Charlebois)
- **Household Survey**
  - Individual questionnaire
  - Group questionnaire
  - Floor plan/map of home

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Household Structure Survey Variables/Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>House</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Square footage</td>
</tr>
<tr>
<td></td>
<td>Rooms per home</td>
</tr>
<tr>
<td></td>
<td>Persons per home</td>
</tr>
<tr>
<td></td>
<td>Number of windows &amp; doors</td>
</tr>
<tr>
<td></td>
<td>Square footage of windows &amp; doors</td>
</tr>
<tr>
<td><strong>TB Index Patient</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demographic information</td>
</tr>
<tr>
<td></td>
<td>HIV status</td>
</tr>
<tr>
<td></td>
<td>Time spent in home per day</td>
</tr>
<tr>
<td></td>
<td>Years living in the home</td>
</tr>
<tr>
<td><strong>Household contacts</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demographic information</td>
</tr>
<tr>
<td></td>
<td>HIV status</td>
</tr>
</tbody>
</table>
Measuring Household Ventilation

- CO2 tracer gas method for measuring air changes per hour (ACH)
  - Modification of a method used in Canadian hospitals for measuring ACH (Menzies, et al. AJRCCM, 1995)
  - Change in LogCO2 over time estimates ACH
Ventilation Measurement Schematic

CO₂ monitor

BASELINE

CO₂

400

3000

1000
In-home CO2 Decay Curves

Air Changes per Hour (ACH) = \( \frac{\ln(CO2[\text{peak}]) - \ln(CO2[t])}{t} \)

\( t \) = time for CO2 to return to baseline or at the end of measurement
In-home CO2 Decay Curves

IndexID=1464

CR: Communal Room

ACH: Air Change Hourly Rate

6 ACH

11 ACH
FreshAIR Results

Household Characteristics

• 61 homes enrolled in Kampala
• Median # residents: 5 people (IQR: 4-6)/home
• Median # of rooms: 1 room (IQR: 1-3)/home
• 58/61 homes (95%) reported closing all windows and doors at night
Results: Household Residents

- Index Cases (N=61)
  - Median age: 30 years
  - 48/61 (77%) AFB smear+
  - 24/61 (39%) HIV-infected

- Household contacts (N=205)
  - Median age: 15 years
  - HIV-infected
    - 9/205 (4.4%) of all contacts (adults + children)
    - 8/83 (9.6%) adult contacts
Household TB Transmission

• 12/61 homes (20%) reported co-prevalent TB in household contacts in the past 2 years
  – 5/64 (8%) available adult contacts reported a TB diagnosis (all tested HIV negative)
  – 8/61 homes (13%) reported a child contact (≤ 17 years) had been diagnosed with TB

• In 11/12 homes with co-prevalent TB, the index case was HIV negative and AFB smear+
Household Ventilation

N=94 rooms

Median 14 ACH (IQR: 10-18)
Ventilation Levels in other settings

- Recommended for hospital settings: 6-12 ACH
- Peruvian hospitals (Escombe, PlosMed, 2007)
- Guatemalan kitchens: 16 ACH (Cowlin, Smith, unpublished data)
Ventilation & TB Transmission

Median: 15 vs. 12 ACH
p=0.24
Ventilation & TB Transmission

Index Case = HIV-uninfected and AFB Smear+ (n=30)

Median: 17 vs. 12 ACH
p=0.03
Interventions to Increase Ventilation

• Opening a window
  – Average change in ventilation increase by 7 ACH

• Challenges
  – 5/61 homes did not have windows
  – 11/61 homes had no significant change in ventilation with opening a window
  – Concerns re: open windows
    • Security (64%)
    • Mosquitos/Malaria (36%)
Summary

• Median five residents and one room per home
• 95% of homes closed windows/doors at night
• 20% homes reporting co-prevalent TB
• Overall, median ventilation rate of 14 ACH
• In homes at high risk for TB transmission, ventilation rates significantly lower in homes reporting TB in a contact (12 vs. 17, p=0.03)
• Opening a window: mean increase of 7 ACH
Conclusions

• Homes in Uganda are crowded with few windows and doors
• CO2 diffusion method a low-cost, practical way to measure ventilation in homes
• Lower ventilation levels associated with increased household transmission of TB
• Simple and low-cost interventions (opening a window) can increase household ventilation
Acknowledgements

- The FreshAIR study participants
- Edwin Charlebois
- Diane Havlir
- Bonnie Wandera
- Annie Luetkemeyer
- Roy Mugerwa
- Bulya Nakalema
- Kirk Smith
- MU-UCSF Research Collaboration