Cost-effectiveness of Alternative Case Finding Strategies for Prisons with High Prevalence of MDR-TB

Multi-drug resistant TB worldwide

Distribution of proportion of MDR-TB among new cases, 1994-2009. WHO 2010
TB in the former Soviet Union (FSU)

- After the fall of the Soviet Union, TB incidence rose sharply in the newly formed countries taking its place.
- The proportion of MDR-TB among new and retreatment cases has also seen a stark increase.

Figure from Stuckler et al. 2008
TB and incarcerated populations

- Prisons concentrate TB, acting as an “epidemiologic pump”
- In 1999-2002 there were an estimated 1.4 Million people in custody in the FSU (Walmsley 2003)
- From 1991 – 2002, incarceration rate could account for ~3/5 of increased TB incidence ($\beta = 0.34$)
- Incarceration rate also had a significant impact on MDR-TB prevalence (Stuckler et al. 2008)

Figure from Stuckler et al. 2008
Research question

- As efforts to improve TB control extend to include comprehensive treatment of MDR-TB, what is the **optimal case finding strategy** for prisons with a high proportion of MDR cases?

- The WHO’s Tuberculosis Control in Prisons (2000) recommends:
  - Radiographic screening on entry to prison
  - Ongoing case finding among inmates through:
    - Self-referral
    - Annual radiographic screening
    - Symptom questionnaires

- The WHO’s strategy emphasizes confirmation of cases through direct smear-microscopy
### Case finding strategies in our model

<table>
<thead>
<tr>
<th></th>
<th>Upon entry</th>
<th>Screening step</th>
<th>Confirmation/Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>MMR</td>
<td>Self-referral</td>
<td>MMR/smear</td>
</tr>
<tr>
<td>S2 (status quo in)</td>
<td>MMR</td>
<td>MMR annually</td>
<td>smear</td>
</tr>
<tr>
<td>S3</td>
<td>MMR</td>
<td>Symptom screening annually</td>
<td>MMR/smear</td>
</tr>
<tr>
<td>S4</td>
<td>MMR</td>
<td>Symptom screening annually</td>
<td>MMR/smear/culture</td>
</tr>
<tr>
<td>S5</td>
<td>MMR</td>
<td>MMR/Symptom screening annually</td>
<td>Smear</td>
</tr>
<tr>
<td>S6</td>
<td>MMR</td>
<td>MMR/Symptom screening annually</td>
<td>Smear/culture</td>
</tr>
<tr>
<td>S7</td>
<td>MMR</td>
<td>Symptom screening annually</td>
<td>Smear/PCR</td>
</tr>
<tr>
<td>S8</td>
<td>MMR</td>
<td>MMR/Symptom screening annually</td>
<td>Smear/PCR</td>
</tr>
</tbody>
</table>
Model of TB disease progression, screening and treatment

Latent DS-slow

Susceptible

Latent MDR-slow

Latent DS-fast

Active DS (Sm-)

Active DS (Sm+)

Active MDR (sm-)

Active MDR (Sm+)

Recovered DS

Treatment Failure/Chronic Dz

Recovered MDR
Model of TB disease progression, screening and treatment

DS-TB

Latent DS-slow

Susceptible

Latent DS-fast

Active DS (Sm-)

Active DS (Sm+)

Active DS (sm-, Tx)

Active DS (sm+, Tx)

Recovered DS

Treatment Failure/Chronic Dz

Latent MDR-slow

Latent MDR-fast

Active MDR (sm-)

Active MDR (sm+)

Active MDR (sm-, Tx)

Active MDR (sm+, Tx)

Recovered MDR

MDR-TB

\[d\]

\[\gamma_1\]

\[\gamma_2\]

\[\lambda\]

\[\lambda_m\]

\[\lambda_d\]

\[\phi\]

\[\phi_n\]

\[\phi_p\]

\[\mu\]

\[\sigma\]

\[\pi_d\]

\[\pi_m\]

\[\tau_d\]

\[\tau_m\]

\[\gamma\]

\[\delta\]

\[\alpha\]

\[\beta\]

\[\gamma\]

\[\delta\]

\[\alpha\]

\[\beta\]
Model of TB disease progression, screening and treatment

**Latent DS-slow**

**Susceptible**

**Latent DS-fast**

**Active DS (Sm-)**

**Active DS (Sm+)**

**Active MDR (sm-)**

**Active MDR (sm+)**

**Recovered DS**

**Recovered MDR**

**Treatment Failure/Chronic Dz**

Active disease

Variables and parameters include:

- $\lambda_d$, $\lambda_m$
- $q$, $1-q$
- $\gamma_1$, $\gamma_2$
- $\rho$
- $\mu$
- $\varphi_n$, $\varphi_p$
- $\sigma$
- $\pi_d$, $\pi_m$
- $\tau_d$, $\tau_m$
- $n$, $p$
- $\%$
- $z_1$, $z_2$, $z_3$
Model of TB disease progression, screening and treatment

Latent DS-slow

Susceptible

Latent DS-fast

Latent MDR-slow

Latent MDR-fast

Active DS (Sm-), Tx

Active DS (sm-), Tx

Active MDR (sm-), Tx

Active MDR (sm+), Tx

Recovered DS

Active DS (sm+), Tx

Active MDR (sm+), Tx

Recovered MDR

Treatment Failure/Chronic Dz

Smear-positive

z_1 + v_λ_d

z_2 + v_λ_m

π_d

π_m

τ_d

τ_m

φ_p

φ_p

q

1-q

ν_λ_d

ν_λ_m

γ_1

γ_2

1-ρ

ρ

1-q

1-q

1-ρ

1-ρ

μ

μ

σ

σ
Susceptible
Latent
DS-slow
Latent
MDR-slow
Latent
DS-fast
Latent
MDR-fast
Active DS
(Sm-)
Active DS
(Sm+)
Active MDR
(sm-)
Active MDR
(sm+)
Active DS
(sm-), Tx
Active DS
(sm+), Tx
Active MDR
(sm-), Tx
Active MDR
(sm+), Tx
Recovered DS
Treatment Failure/
Chronic Dz
Recovered MDR
Treated
and isolated*

*Note: smear-negative cases on treatment are assumed not to be infectious
Cost Overview

- Two primary categories of costs: screening costs and treatment costs
  - Direct cost analysis performed as part of a TB prevalence study in prisons of Tajikistan

<table>
<thead>
<tr>
<th>Screening Method</th>
<th>Cost of Screening (per test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass miniature radiography</td>
<td>$2.34</td>
</tr>
<tr>
<td>Symptom screening</td>
<td>$1.02</td>
</tr>
<tr>
<td>Sputum smear</td>
<td>$1.21</td>
</tr>
<tr>
<td>Sputum culture</td>
<td>$19.03</td>
</tr>
<tr>
<td>PCR</td>
<td>$19.56</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug sensitive TB (smear-negative)</td>
<td>$303.44</td>
</tr>
<tr>
<td>Drug sensitive TB (smear-positive)</td>
<td>$387.65</td>
</tr>
<tr>
<td>Multi-drug resistant TB</td>
<td>$7,741.29</td>
</tr>
</tbody>
</table>
**Major Assumptions**

- TB is categorized as DS or MDR
- Constant prison population
- Equal probability of release from any health state
- Upon release, people have a normal life expectancy of a 20-25y/o in Tajikistan
- No one enters the prison with hx of TB or in the fast progression category
- No over tx
- Gaps in literature for MDR-TB were assumed to be comparable to DS-TB values
- Infective fitness of MDR-TB = infective fitness of DS-TB
$1,286/\text{QALY}$

$2,659/\text{QALY}$

$-786/\text{QALY}$
Conclusions

- Strategies including symptom screening were cost-saving and more effective compared to strategies based on MMR alone.

- The addition of PCR to the confirmatory step is cost-effective relative to the per capita GDP of former Soviet countries (ICER = $2,659/QALY).

- The relative cost-effectiveness of alternative strategies is driven by prevalence of MDR-TB.
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Bibliography


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