Background

In May 2008, an outbreak of TB began in a homeless shelter in British Columbia, Canada. The index case, diagnosed with AFB4+ pulmonary TB, used the shelter for 12 nights, seeding a large first wave of both active cases and latent TB infections (LTBI). By December 2013, the outbreak had grown to include 52 active cases, with 2,310 community members identified as potentially exposed and subsequently investigated with tuberculin skin testing (TST). By combining a unique dataset of the shelter client roll calls and bed locations with a TST screening database, we were able to examine the influence of exposure distance and duration from the index case on other shelter clients’ risk of TB infection.

Methods

Bed map and roll call data: Each night, incoming shelter clients are assigned a numbered bunk; the bed number and client name are recorded on paper roll calls. As part of the outbreak investigation, the shelter provided the public health unit with the roll calls for the 12 nights the index case used the shelter, along with a scaled map of the numbered bed locations as the shelter was configured in early 2008. From these data, we identified individuals exposed to the index case at the shelter, their sleeping distance from the index case, and the number of nights spent in the shelter with the index case.

Client TB status definitions: We cross-referenced individuals exposed to the index case using a TST screening database and assigned shelter clients to one of three outcomes: “infected” (having a diagnosis of active TB or a positive TST result with no prior history of TB disease and no prior positive TST), “uninfected” (at least one negative TST test two or more months after exposure to the index case), and “unknown” (clients who were not screened, or received a TST but did not have it read, or had a prior positive TST, or had prior TB infection, or had BCG vaccination that precluded definitively linking their positive TST to the index case).

Distance and Exposure Variables: For each client, we calculated the total time exposed to the index case (T) as the cumulative, non-consecutive, number of days that a client slept in the shelter when the index case was present. We also calculated each client’s sleeping distance from the index case’s bed (D) under three different scenarios: Dsum – the sum of the nightly sleeping distances from the index; Dmin – minimum distance from the index; Davg – distance to exposure time ratio. We also normalized Dsum by T to create a combined measure, DT – the distance-to-exposure time ratio.

Statistical Methods: Odds ratios were calculated using a univariate logistic regression with the response variable infection status (Infected/Uninfected) and predictor variables (considered individually) T, Dsum, Dmin, Davg, and D. All predictors were treated as continuous, unless otherwise indicated. All tests for significance were two-sided and were considered significant if p < 0.05. Clients with unknown TB status were not included in the analysis. A threshold was established using recursive partitioning with a maximum tree depth of one using R v 3.0.2 and the package party v 4.1. The recursive partitioning took as input a continuous variable, such as exposure or proximity, and established a threshold that optimally separated infected and uninfected clients.

Results & Discussion

Distribution of shelter clients’ TB screening results. A total of 161 clients were exposed to the index case during their stay in the shelter. The index case had two visits: the first for seven nights over an 11-night window and the second four months later for five nights over a 10-night window. Of all clients, a total of 58 were screened, and 3 had previously known TB infections.

Conclusions

Assessing the impact of distance & exposure variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1.78 (1.35 - 2.34)</td>
<td>0.02</td>
</tr>
<tr>
<td>Dsum</td>
<td>1.01 (1.00 - 1.02)</td>
<td>0.04</td>
</tr>
<tr>
<td>Dmin</td>
<td>0.95 (0.93 - 0.98)</td>
<td>0.21</td>
</tr>
<tr>
<td>Davg</td>
<td>0.95 (0.93 - 0.98)</td>
<td>0.21</td>
</tr>
</tbody>
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Sensitivity Analysis of Exposure Time Ratio. We varied the total number of cases that could have had a pre-existing latent infection to explore whether baseline LTBI rates affected our finding. Exposure time was found to be significant under up to ~5 pre-existing infections.

Visualizing the cumulative exposure threshold. Using data mining methods, we found that five days’ exposure optimally separated infected (all active and latent) from non-infected clients. Clients are plotted according to their cumulative exposure time T and their distance-to-exposure time ratio DT. The dotted line indicates the maximally separating exposure threshold determined using machine learning that best separates infected and uninfected clients.

Table time exposed to the index case was an important determinant of TB status, but sleeping proximity to the index case was not.

Clients that were exposed to the index case for 5 days or greater had a higher odds of being infected with TB.

The small sample size and incomplete medical history of our study necessitates a follow-up to verify our conclusions.

Our approach may be helpful to other shelter environments with similar data constraints.

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