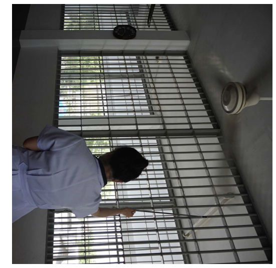
Jun 25, 2024

Assessment of tuberculosis transmission probability in three Thai prisons based on five dynamic models



DOI
dx.doi.org/10.17504/protocols.io.6qpvr868zlmk/v1

Nithinan Mahawan[1], Thanapoom Rattananupong[1], Puchong Sri-Uam[2], Wiroj Jiamjarasrangsi[1]

[1]Faculty of Medicine, Chulalongkorn University; [2]Center for Safety, Health and Environment of Chulalongkorn University

Wiroj Jiamjarasrangsi: Corresponding author;

Nithinan Mahawan
Faculty of Medicine, Chulalongkorn University

OPEN ACCESS

DOI: dx.doi.org/10.17504/protocols.io.6qpvr868zlmk/v1

Protocol Citation: Nithinan Mahawan, Thanapoom Rattananupong, Puchong Sri-Uam, Wiroj Jiamjarasrangsi 2024. Assessment of tuberculosis transmission probability in three Thai prisons based on five dynamic models. **protocols.io** https://dx.doi.org/10.17504/protocols.io.6qpvr868zlmk/v1

Protocol status: Working
We use this protocol and it's working

Created: May 05, 2024

Last Modified: June 25, 2024

Protocol Integer ID: 99258

Keywords: the probability of tuberculosis transmission, five dynamic models, the impact of model parameters, Prisons

Funders Acknowledgement:
The 90th Anniversary of Chulalongkorn University Fund
Grant ID: no. 035, 1/2021
the FY2021 Thesis Grant for Doctoral Degree Study of the National Research Council of Thailand
Grant ID: N41D640002, 2021

Abstract

This study aimed to assess and compare the probability of tuberculosis (TB) transmission based on five dynamic models: the Wells–Riley equation, two Rudnick & Milton-proposed models based on air changes per hour (ACH) and liters per second per person (L/s/p), the model proposed by Issarow *et al*, and the Applied Susceptible-Exposed-Infected-Recovered (SEIR) TB transmission model. The study also aimed to determine the impact of model parameters on such probabilities in three Thai prisons.

The results revealed that the median (Quartiles 1 and 3) of TB transmission probability among these cells was 0.052 (0.017, 0.180). Compared with the pioneered Wells–Riley's model, the remaining models projected discrepant TB transmission probability from less to more commensurate to the degree of model modification from the pioneered model as follows: Rudnick & Milton (ACH), Issarow *et al.*, and Rudnick & Milton (L/s/p), and the applied SEIR models. The ventilation rate and the number of infectious TB patients in each cell or zone had the greatest impact on the estimated TB transmission probability in most models. All stakeholders must urgently address these influential parameters to reduce TB transmission in prisons.

Attachments

PDF
assessment-of-tuberc...
4.6MB

Guidelines

1. The literature review.
2. A walk through survey to assess the suitability of prisons.

Materials

1. The absolute ventilation rate, always used as a surrogate for exhaled air, was assessed by steady-state carbon dioxide (CO_2) in parts per million using the Kimo HQ210 with SCOH 112 probe (Sauermann Industries, ZA Bernard Moulinet, Montpon, France).
2. ACH (Q; ACH), as a rule of thumb, is classically used as a metric for assessing infection control risk. It is the total air volume in a room or space that is completely removed and replaced in an hour. In this method, the wind speed (meters/second) in each cell was measured at the location of the opening facing prevailing winds using a hot wire thermo-anemometer and datalogger (Model SDL350, Extech Instruments, Waltham, MA).

Before start

1. The literature review comprises the following topics
   1.1 The incidence and prevalence of tuberculosis in prisons globally and specifically in Thailand.
   1.2 Evidence indicating that tuberculosis in prisons may serve as a reservoir for tuberculosis in the general population.
   1.3 Humanitarian issues concerning prisoners related to tuberculosis or overall health problems.
   1.4 Factors associated with the transmission of tuberculosis/drug-resistant tuberculosis in prisons
   1.5 Current dynamic models of tuberculosis transmission in prisons, including (1) the Wells-Riley equation (2) Rudnick & Milton-proposed (air change per hour: ACH) model (3) Rudnick & Milton-proposed (litre/second/person: l/s/p) model (4) the Applied Susceptible-Exposed-Infected-Recovered (SEIR) tuberculosis transmission model and (5) Issarow *et al* model.
2. Contact the academic department of the Department of Corrections for a walk through survey to assess the suitability of three sample prisons for research study (June, 2019).
(1) Cell architectural and environmental characteristics. (2) The number of TB infections.

Research ethics

1 The study received ethical approval from the Ethical Review Board of Chulalongkorn University Faculty of Medicine, with reference number 610/63.

2 Contact the academic department of the Department of Corrections to gained permission from the Department of Corrections at the Ministry of Justice before being conducted.

3 Present all the details of the research study to the relevant stakeholders of all three sample prisons, ensuring they are informed and given the opportunity to inquire about any concerns. Additionally, the superintendent of each correctional facility reviewed the “Information Sheet for Participants” and signed the “Submission Agreement for Volunteers” before initiating the study. No personal information was collected during the study that could identify inmates; thus, individual inmate consent was not required.

Data Collection

4 Our research team receives training on regulations, rules, and protocols for conducting research in each of the sample prisons and adheres strictly to them.

5 The inmate teams were trained by the principal investigator (NM) and a coinvestigator (PS, who is also an industrial hygienist) for collecting the CO_2 concentrations in the morning after at least 13 hours of lockup time using the Kimo HQ210 with SCOH 112 probe (Sauermann Industries, ZA BernardMoulinet, Montpon, France) within and outside each cell (985 cells in the winter; October 2020 to January 2021). These data use for calculating Germ-free ventilationrate, Q in liters/second/person (See S1 Table of PONE-D-24-02877R1 data Folder for more detail).

6 The wind speed (meters/second) in each cell was measured at the location of the opening facing prevailing winds using a hot wire thermo-anemometer and datalogger (Model SDL350, Extech Instruments,Waltham, MA). The credibility of the data was cooperatively ensured by the principal investigator (NM) and a coinvestigator (PS)(985 cells in the winter). These data use for calculating Germ-free ventilationrate, *Q* in air changes per hour (See S1 Table of PONE-D-24-02877R1 data Folder for more detail).

7 Working with HCW and Prison Health Volunteer for collecting the number of tuberculosis-infected patients in each cell and zone, which served as an indication of the prevalence at both the cell and zonal levels. These data were considered secondary data, comprising documents and computer databases sourced from the respective zonal and central administrative and medical facilities within the prisons. We cross-checked the data obtained from central administrative and medical facilities with the data from each zone to ensure consistency for all

PTB cases. The data was recorded as a percentage for a period of 6 months, from July to December 2020, for Prisons A and B, and from October 2020 to March 2021 for Prison C.

8 Five inmates from each zone were recruited and trained by the principal investigator (NM) and a coinvestigator (PS) to survey the architectural and environmental characteristics of each cell within the zone. The researchers verified the collected data against the prison blueprints and randomly measured the dimensions of the cells themselves.

9 However, since March 2021, there has been a COVID-19 outbreak in Thai prisons, leading to measures that prohibit outsiders from entering without valid reasons. This has prevented researchers from collecting data continuously according to the planned schedule. Once the COVID-19 situation in the sample prisons improved, the prisons relaxed their measures, allowing researchers to enter under strict adherence to the prison's protocols. Consequently, the researchers resumed collecting the data including (1) the architectural and environmental characteristics of each cell such as room volume, opening facing prevailing winds, opening into the building, and number of cells per courtyard; and (2) the demographic and health status composition of inmates, including the number of total and susceptible inmates per cell, residence time per day, and inmate turnover and (3) treatment effectiveness parameters, including period of infectiousness, number of recovered patients, and TB-related, natural, and other mortality rates (secondary data). These variables and parameters were collected or obtained as shown in S1 & S2 Table of the manuscript [Assessment of tuberculosis transmission probability in three Thai prisons based on five dynamic models PONE-D-24-02877R1]

10 Review literature related to the model parameters additionally

Statistical analysis

11 To calculated the estimated TB transmission probability within cells using five dynamic models (See excel data Folder)

12 Agreement among the TB transmission probabilityestimated using the different dynamic models was then assessed via Spearman's rank correlation (r). The detailed pattern of agreement or difference was further investigated using Bland–Altman plots representing absolute and percent differences.

13 To investigate theinfluence of model parameters on TB transmission probability, two procedures were used separately for each TB transmission prediction model. First, cells were categorized into four subgroups based on the quartile of predicted TB transmission probability. Furthermore, subgroups of model parameters were then compared using the Wilcoxon rank–sum (Mann–Whitney) test since the cell-specific probabilities of TB transmission were non-normally distributed. Second, the magnitude and pattern of change in

the predicted TB transmission probability along each model's parameter categories were investigated using a multiple linear regression incorporating all model parameters simultaneously for a specific prediction model. The adjusted
beta (i.e., the magnitude of change in the predicted TB transmission probability) and its 95% confidence
intervals were estimated. All statistical analyses were performed using Stata software, Version 13.0 (StataCorp. 2013, Stata Statistical Software: Release 13, College Station, TX: StataCorp LP).

Results and Conclusion

14 This study showed that the variant models projected different values of TB transmission probability. Althoughthe probability values differed, three models, i.e., the Wells–Riley model and the two Rudnick & Milton-proposed models, estimated similar patterns of TB transmission probability. Using the pioneered Wells–Riley's model as the reference, the remaining models projected discrepant TB transmission probability from less to more commensurate to the degree of model modification from the pioneered model as follows: Rudnick & Milton (ACH), Issarow *et al.* and Rudnick & Milton (L/s/p), and the applied SEIR models. In terms of risk factors, our study identified two parameters that significantly contribute to ongoing TB transmission risk in all models: low ventilation rates and a high number of existing TB inmates in the cell or zone. All stakeholders must urgently address these issues to reduce TB transmission in prisons. Furthermore, since these five models produced varying estimates of TB transmission probabilities, further studies are required to determine their relative validity in accurately
predicting TB incidence in prison settings.

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