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Performance of five dynamic models in predicting tuberculosis incidence in three prisons in Thailand

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Abstract

This study examined the ability of the following five dynamic models for predicting pulmonary tuberculosis (PTB) incidence in a prison setting. This 1-year prospective cohort study employed 985 cells from three Thai prisons. The results show that a 1% increase in baseline TB transmission probability was associated with a 3%–7% increase in future PTB incidence rate, depending on the dynamic model. The Wells–Riley model exhibited the best performance in terms of both internal and external validity.

Attachments

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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).

Exposure assessment

1 Baseline risk assessment of TB transmission was conducted for each cell based on each of the five dynamic models: the classic Wells–Riley equation, Rudnick & Milton's, and Issarow et al.'s modified Wells–Riley equations, and the applied SEIR model. The detailed procedure has been described previously "Assessment of tuberculosis transmission probability in three Thai prisons based on five dynamic models" [Mahawan N, Rattananupong T, Sri-Uam P, Jiamjarasrangsi W. Assessment of tuberculosis transmission probability in three Thai prisons based on five dynamic models. PLoS One. 2024 Jul 19;19(7):e0305264. https://doi.org/0.1371/journal.pone.0305264 PMID: 39028741; PMCID: PMC11259261.].

Outcome assessment

2 The outcome of interest was PTB occurrence. The diagnostic procedure adhered to accepted clinical practice and included a physical examination, chest radiograph, sputum acid-fast bacilli smear, and nucleic acid amplification testing using the XpertÒ MTB/RIF assay (Cepheid, Sunnyvale, USA) [22]. The incidence of PTB outcome was regarded as a repeated outcome. The data sources used for determining this outcome included documents and computer databases of the central administrative and medical facilities in the prisons, while information regarding the cell location of the PTB inmateswas determined by surveys and interviews with zonal staff and inmates who were prison health volunteers. The data included the number of TB-infected patients in each cell and zone, which represented the incidence at the cell and zonal levels. The magnitude of PTB was reflected by the number of PTB cases per cell and the incidence rate (IR) of PTB, which was calculated as the number of new PTB cases divided by the person-years of observation and reported as the number of new PTB cases per 1,000 person-years.

Statistical analysis

3 A four-step procedure, which encompassed model specification tests, in-sample model fitting, internal validation, and external validation, was implemented to evaluate the performance of five dynamic models. The first three steps were performed using prison B data (referred to as in-sample, n=652), and the final step was conducted with prison A and C data (referred to as out-of-sample, n=333). The outcome variable was the number of PTB cases, while the predictors were the TB transmission probabilities estimated by the five dynamic models.

Results and Conclusions

4 As determined by a standard procedure for evaluatingthe performance of the five dynamic models in predicting future PTB incidence in prison settings, our study demonstrated that the classic Wells–Riley model exhibited the best performance both in the internal and external

validations. Given its requirement for fewer parameters, the Wells–Riley model is therefore recommended as the most appropriate dynamic model, especially for large-scale investigations. However, all the assessed dynamic models still exhibited poor fit in their ability to explain the variation of future PTB incidence in the analytical models. Consequently, additional research is required to confirm our findings and to acquire more detailed information that can be used as input to enhance the performance of these dynamic models.

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