Research Journal of Applied Sciences 11 (9): 822-825, 2016
ISSN: 1815-932X

Tuberculosis Disease Mapping with Poisson-Gamma Model in Malaysia

Ijlal Mohd Diah, Nazrina Aziz and Nazihah Ahmad
Department of Mathematics and Statistics, School of Quantitative Sciences,
UUM College of Arts and Sciences, Universiti Utara Malaysia,
Kedah Darul Aman, 06010 Sintok, Malaysia

Abstract: TB case is a widespread disease which is one of several factors that cause millions of death worldwide. It can become epidemic and also pandemic if it is not controlled. In Malaysia, the numbers of TB cases reported keep on increasing from year to year. Disease mapping can show clear picture of the risk areas. Hence, it can be used as the prevention strategies and in controlling a disease. However to get an accurate disease map, it relies on the modelling used to estimate the relative risk. Relative risk estimation is important when studying disease mapping. Therefore, the aim of this study is to estimate relative risk for TB disease transmission using one of the earliest applications of Bayesian methodology in disease mapping that is Poisson-gamma model. This relative risk estimation is applied to TB data in Malaysia. Then this result will be displayed in a map to represent TB risk areas. Perlis, Kedah, N. Sembilan, Melaka, Pahang and Terengganu have low risk of TB occurrences while Pulau Pinang, Kuala Lumpur & Putrajaya, Sarawak and Sabah (including Labuan) show very high risk areas.

Key words: Disease mapping, tuberculosis, relative risk, poisson-gamma model, application

INTRODUCTION

This study demonstrates and discusses the used of the most common and the earliest application of Bayesian method in disease mapping that is Poisson-gamma model. First, we explain about Tuberculosis. This is followed by description of Poisson-gamma model which is based on model suggested by (Lawson *et al*., 2003). Tuberculosis or TB (short for tubercle bacillus) is a bacterial disease caused by Mycobacterium tuberculosis organism which these slow-growing bacteria grow well in the area of the body that has a lot of blood and oxygen (Bhowmik *et al*., 2009). TB was also called consumption, phthisis or phthisis pulmonalis in the past (Kumar *et al*., 2007). According to New Yark Department, it usually give effect to the lung (pulmonary TB or PTB) but also can affect any part of the body such as bones, kidneys, lymph nodes and brain as the infection can spread via blood from the lung which is called as Extrapulmonary Tuberculosis (EPT).

This type of disease can be transmitted from a person to another through air (Konstantinos, 2010; Kethireddy, 2010). Tiny droplets released into the air when people with active TB infection sneeze, cough or spit. Even though the droplets dry out quickly, the bacteria can still remain airborne in the air for hours. The infection of TB can either be active or latent. People with active TB infection are caused by actively duplicate tubercle bacilli. They easily spread the disease to others and show symptoms. While those who with latent infection have previously been infected but do not show any symptoms and are not contagious (Konstantinos, 2010).

According to WHO (2013) in 2012, 8.6 million people have been estimated to develop TB and lead to the death of 1.3 million people whereby 320,000 of them are HIV positive. Almost 1.1 million people which is about 13% people who had TB in 2012 were HIV-positive. About 75% of the cases take place in the African region. About 9 million people were infected with TB in 2013 including 1.1 million cases among people living with HIV. In 2013 the cases increased as 1.5 million fatalities caused by TB, including 360,000 among people who were HIV-positive. Globally in 2014, the number of TB cases that have been reported increased to 9.6 million people and it is estimated that 12% of them were HIV positive. The 58% of the TB cases take place in South-East Asia and Western Pacific regions. There were an estimated 1.5 million deaths from TB where 390,000 deaths among people who are HIV positive. TB ranks alongside HIV as a leading cause of death worldwide (WHO, 2013, 2015).

According to Director of the Institute of Respiratory Medicine and Senior Medical Consultant, Datuk Dr Abdul

Corresponding Author: Nazrina Aziz, Department of Mathematics and Statistics, School of Quantitative Sciences, UUM College of Arts and Sciences, Universiti Utara Malaysia, Kedah Darul Aman, 06010 Sintok, Malaysia

Razak Muttalif, TB is the second highest disease among infectious disease and it is a prime cause of death from infectious disease in Malaysia. Hence, there is still a long way to achieve Stop TB Partnership target. In Malaysia, traditional approach has been used to estimate the high-low risk areas by monitoring based on the total number of TB cases for each region that have been reported. This method only showed general information without considers the area of disease transmitted.

Disease mapping can be used in controlling and as the prevention strategies for a disease (Samat and Percy, 2012). Disease mapping can help to show a clear picture of the risk area. However, to get a good disease mapping, it relies on the accurate value of relative risk estimation. Relative risk estimation for disease mapping is still ongoing studies as it is an important issue that need to consider when investigate geographical distribution. Bayesians approach are highly recommended in the use of small area estimation as it smooth the relative risk and provides the measures of uncertainty associated with this relative risk estimation and the modeling can take into account the spatial autocorrelation. The approach to smoothing in Bayesian approach is by borrowing strength values from geographically referenced neighboring values. Poisson-gamma model is one of the earliest Bayesian approach used by many researchers (Lawson *et al*., 2003).

MATERIALS AND METHODS

Poisson-gamma model: Many researchers have investigated various methods for estimating the relative risk of a disease due to the shortcoming of the SMR as a relative risk estimator. One of it including the use of the initial examples of Bayesian methods that is the Poisson-gamma model (Lawson *et al*., 2003). Poisson distribution is used as this is the fundamental model for count data.

According to Samat and Ma'arof in this model, it is assumed that the numbers of new infectives y_{ij} follow a Poisson distribution within a given period of time with mean and variance $e_{ij}\theta_{ij}$. Here, i = 1, 2,..., M for study regions and j = 1, 2, ..., T refer to time period, e_{ij} is the expected number of new infective while θ_{ij} is the relative risk:

$$y_{ij}|e_{ij}, \theta_{ij} \sim \text{Poisson}(e_{ij}\theta_{ij}) \quad (1)$$

The relative risk parameter has a gamma prior distribution with parameters α and θ:

$$\theta_{ij} \sim \text{Gamma}(\alpha, \beta) \quad (2)$$

Based on this Poisson-gamma model, expected posterior relative risk will be included in the analysis. This risk is for all regions and for all time periods.

Experimental: In this study, WinBUGS software is used to compute the relative risk. WinBUGS software is a program designed to implement Bayesian inference on statistical problem using Markov chain Monte Carlo (MCMC) computations (Lawson *et al*., 2003) All of these results are presented in table and graph. Based on the relative risk outcomes, map of the TB risk is constructed. For the Poisson-gamma model, based on (Lawson *et al*., 2003), the prior parameter value that are α and β are unknown and are assumed to have exponential prior distributions with hyperparameter values of 0.1. The prior expected relative risks in this study using this model is equal to 1.

Data set used in this study was provided by Ministry of Health, the Institute for Medical Research and the Department of Statistics in Malaysia. This Poisson-gamma model are applied to TB data from year 2008 until year 2015 in the form of counts of cases within 14 states in Malaysia that are Perlis, Kedah, Penang, Perak, Federal Territory of Kuala Lumpur and Putrajaya, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan, Sabah (including Labuan) and Sarawak.

RESULTS AND DISCUSSION

The results of the relative risk estimation for all states of Malaysia are showed in Fig. 1. The graph displays that most states have relative risk below one from year 2008 until 2015. This is a necessary consequence of the positively skew distribution inherent of the positive valued relative risk. The relative risk in this analysis is defined to be the conditional probability that a person within a region contracts the disease divided by the conditional probability that a person in the population contracts the disease. In this analysis, a value for the relative risk is close to 1. Based on definition of the relative risk by Samat and Percy (2012), a relative risk is close to 1 is refer to no real difference between the conditional probability of a person within the specific region and the general population to contract with the disease. This means that there is no significant difference in terms of the likelihood that the people affected with TB disease in a region and within the whole population. Conversely, for a value of relative risk increase above 1, this indicates that people within the region are tending to suffer from this disease compared with people in the overall population in Malaysia. It can be seen clearly from the graph that the Federal of Kuala Lumpur and Putrajaya,

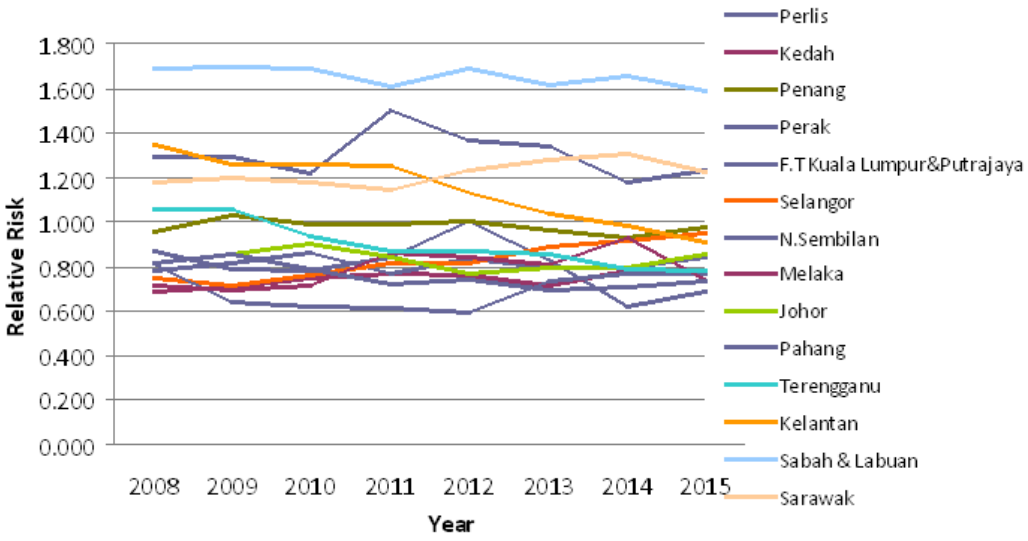

Fig. 1: Time series plots of the relative risk estimation based on the poisson-gamma model for different states in Malaysia

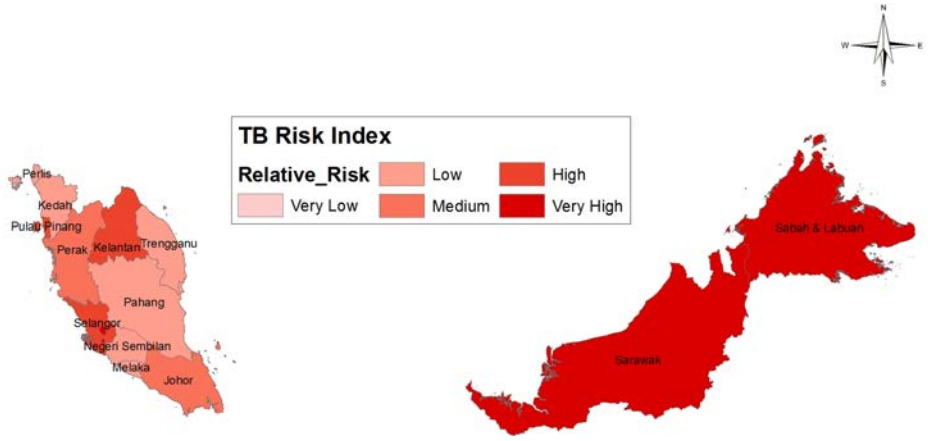

Fig. 2: Disease map of relative risk estimation based on Poisson-gamma model for year 2015

the states of Kelantan, Sarawak and Sabah (including Labuan) have relative risk >1 for most epidemiology years. If the value of relative risk is <1, it shows that there is a decrease in likelihood of getting the disease which means that the people within the region are less likely to endure from this disease compared with people in the population.

Table 1 shows the numerical values for the relative risk based on Poisson-gamma model for year 2015. From Table 1, it can be seen that Sabah & Labuan has the highest risk of contracting TB with corresponding value of relative risk approximately, 1.582 while Perlis has the lowest risk value of contracting TB with 0.686 when compared with people in the overall population.

In order to show a clear picture of the risk areas, choropleth map with single-hue progression colours is used to display and differentiate between high and low risk areas of TB cases occurrence for each state in Malaysia. Each state is assigned one of five different levels of relative risk which are very low, low, medium, high and very high risks with respective interval of $(-\infty, 0.67)$, $(0.67, 0.77)$, $(0.77, 0.90)$, $(0.90, 0.97)$ and $(0.97, \infty)$. The lightest shade represents the very low risk while the darkest shade represents the very high risk area for different levels of relative risk.

Figure 2 shows the Poisson-gamma map that the state of Pulau Pinang, Kuala Lumpur and Putrajaya, Sarawak and the state of Sabah and Labuan have very high risk

Table 1: Relative Risk Estimation of TB Disease for Year 2015

States	Relative risk
Perlis	0.686
Kedah	0.778
Pulau Pinang	0.972
Perak	0.844
Kuala Lumpur and Putrajaya	1.231
Selangor	0.950
N. Sembilan	0.766
Melaka	0.744
Johor	0.855
Pahang	0.729
Terengganu	0.778
Kelantan	0.905
Sabah (including Labuan)	1.582
Sarawak	1.229

areas. The states of Selangor and Kelantan are identified as high risk areas. Perak and Johor have been identified as medium risk areas. This is followed by low risks by other states.

CONCLUSION

It is necessary to estimate the relative risk in controlling spreading of TB. In this study, Poisson-gamma model has been used in order to find the relative risk estimation which this is the most common statistic method and one of the earliest applications of Bayesian used to estimate the relative risk. The results of the relative risk are present in graph, table and also map which this map give clear picture of high-low risk areas. In conclusion, Pulau Pinang, Kuala Lumpur and Putrajaya, Sarawak and the state of Sabah and Labuan have the highest risk area while Perlis, Kedah, N. Sembilan, Melaka, Pahang and Terengganu show the lowest risk areas of contracting TB. Samat and Percy (2012) demonstrates the use of Poisson-gamma model in his study which gives a smoother map with less extreme values for estimates the relative risk compared with using SMR. However, in this model, the adjustment of the covariate is difficult and there is no likely to deal with spatial correlation between risks in adjacent areas. Thus, this encourages many researchers for the purpose of alternative methods to estimate the relative risk. Samat and Precy suggested that this work can be extending by including relative risk estimation based on disease transmission model.

ACKNOWLEDGEMENT

The researchers would like to acknowledge Universiti Utara Malaysia for the financial support in respect of this study.

REFERENCES

Bhowmik, D., R.M. Chandira, B. Jayakar and K.P.S. Kumar, 2009. Recent trends of drug used treatment of tuberculosis. J. Chem. Pharmaceutical Res., 1: 113-133.

Kethireddy, S., 2010. Tuberculosis-a review of clinical features, differential diagnosis and treatments available. Int. J. Pharm. Technol., 2: 206-245.

Konstantinos, A., 2010. Diagnostic tests testing for tuberculosis. Aust. Prescr., 13: 12-18.

Kumar, V., R. Cotran and S. Robbins, 2007. Robbins Basic Pathology: With Veterinary Consult Access. WB Saunders, Philadelphia, PA.

Lawson, A.B., W.J. Browne and C.L.V. Rodeiro, 2003. Disease Mapping with WinBUGS and MlwiN. Vol. 11, John Wiley & Sons, New York, USA., ISBN:0-470-85604-1, Pages: 122.

Samat, N.A. and D.F. Percy, 2012. Dengue disease mapping in Malaysia based on stochastic SIR models in human populations. Proceedings of the 2012 International Conference on Statistics in Science, Business and Engineering (ICSSBE), September 10-12, 2012, IEEE, Greater Manchester, England, ISBN:978-1-4673-1581-4, pp: 1-5.

WHO., 2013. Global Tuberculosis Report 2013. World Health Organization, Geneva, Switzerland, ISBN:9789241564656, Pages: 289.

WHO., 2015. Global Tuberculosis Report 2015. World Health Organization, Geneva, Switzerland, ISBN:978-92-4-156505-9, Pages: 204.