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Mapping of Pneumonia Disease in Malaysia Using Poisson-Gamma Model

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Abstract

Bayesian models have been used as one of the estimation techniques for smoothing relative risks estimation for disease mapping. One of the most commonuses of Bayesian methodology in disease mapping is Poisson-gamma model. This paper begins with a brief introduction of pneumonia disease. Then followed by a review of methodology used in this paper that is Poisson-gamma model which used to estimate the values of relative risk.Then, the results will be shown into a map to show pneumonia risk areas. The risk areas can be shown clearlythrough disease map. Thus, the objective of this study is to estimate the value of relative risk for pneumonia based on Poisson-gamma model. Pulau Pinang, Perak, Selangor, Kuala Lumpur & Putrajaya, Sabah, Labuan and Sarawak are categorized as low-risk of pneumonia occurrence, while Terengganu and Negeri Sembilan categorized as high-risk areas.

Keywords: disease mapping; pneumonia; relative risk; Poisson-gamma model

1. Introduction

This paper demonstrates and discusses the used of the most common and earliest Bayesian method that is Poisson-gamma model in disease mapping.First, we explain about pneumonia. This is followed by description of Poisson-gamma model that was suggested by Lawson et al.[1].Pneumonia is an infection in one or both lungs which inflames the air sacs with pus or fluid.It can be causedby different type of organisms which include viruses, bacteria and fungi[2].However, the most common cause for someone to get pneumonia is caused by bacterial pneumonia known as Streptococcus pneumoniae and viruses. These viruses include the new virus which is now already became outbreak worldwide that is Coronavirus-2019 (COVID-19), which may trigger pneumonia and can become serious. Forchildren under 5 years old, the most well-known cause of pneumonia are viruses. Eventhough viral pneumonia usually is just minor, however it can become most terrible in some case[2].Both bacterial and viral pneumonia are contagious which mean that they can transmit the disease from a person to anothervia air when a person inhales airborne droplets from a sneeze or cough of an infected person. It also can be transfered to others through contact with objects or surfaces that are contaminated with bacteria or viruses.When someone is

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infected with pneumonia, it will show symptoms such as chest pain when cough or breathe, fever, chills, shortness of breath, and coughing that produce mucus[2]. The symptoms can be varied from minor to serious depend on factors such as age, type of organisms that causes the inflammation, and overallcondition of health. For mild symptom, it shows like a normal flu or cold, but it last longer.

The severity of pneumonia can range from mild to life-threatening. Infants and young children especially under-age of five, people aged 65 years and older, and people with weakened immune systems are the higher risk group and can become most serious for them if they are being infected with pneumonia[2]. Pneumonia has been recognized as top five diseases that causes of death globally with 2.6 million in 2017[3]. About 15% from these 2.6 million are deaths among children under-age of five. About 1 child dies of pneumonia every 39 seconds and this made it become number one killer among the leading infectious disease cause of death for children under-age of five[4].These 2.6 million of deaths concentrated in South Africa, South East Asia, and sub-Saharan Africa. Even though pneumonia is a preventable disease, but it kills more children than other infections. It also recognized as a common cause of death for elderly where in 2017, about 1.13 million of deaths are among adults aged over 65 years[3]. According toDepartment of Statistics Malaysia, pneumonia has been listed as top three diseases that cause death in Malaysia[5]. In 2019, 145,419 cases had been reported with 7,542 number of deaths[5]. Pneumonia also been reported as top three causes of death for children under-age of five.If this situation persists, it will affect the number of future populationsif it is not control where we will be facing ageing population as there are more people aged 70 years and older than there are children under-age of five in the future.

It is necessary to look into this problem as complication for those who infected with influenza and Corona Virus Disease 2019 (COVID-19) can lead someone to get pneumonia disease[5]. Both can contribute to the increase in the number of pneumonia cases. Pneumonia disease might become outbreak if it does not control as the number of pneumonia cases can be increase due to other diseases.

Current approach used in Malaysia to estimate the low and high-risk areas of pneumonia is by monitoring based on the reportedoverall number of cases in each state. However,this approach only showed general information without consider other important factors such as number of population and geographical areas.

One of the important tools in public health research is disease mapping where it can be help in controlling and alsoas the stopping strategies for a disease[6]. Disease mapping can be seen as a descriptive picture of pneumonia's burden in some geographical areas.Besides, it can help showing areas that need more attention from government especially in term of health supply and medical treatment.In this study, Empirical Bayes approach specifically Poisson-gamma model are used where this approach arehighly 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.

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2. Materials and Methods

In this study,the relative risk values are computed using WinBUGSsoftware. This software is a program created to implement Bayesian inference on statistical problem using computations of Markov Chain Monte Carlo (MCMC)[1].Findings of this study are presented in form of table and graph. A map of the pneumonia risk will be displayed to show the high-low risk areas depend on the values of relative risk which are estimated. ArcGIS software is used to produce the map.For the Poisson-gamma model,the prior parameters values, α and β are unknown and are assumed to have exponential prior distributions with values of hyperparameter 0.1[1]. The prior expected relative risks in this study using this model is equal to 1.

2.1 Poisson-gamma Model

One of the initial Bayesian methods is Poisson-gamma model that has been suggested by other researchers to be used to overcome the weakness of the Standardized Morbidity Ratio(SMR)method[1]. Poisson distribution is used as this is the fundamental model for count data. Here,$i=1,2,\ldots,M$ represent the study areas while$j=1,2,\ldots,T$represent the time period.Assumingthat the numberof new infections,y_{ij} followsthe Poisson distribution over a period of time, with mean and variance,$e_{ij}\theta_{ij}$. In this model, the expected number of new infectives is expressed as $e_{ij}$and the relative riskis expressed asθ_{ij}, hence:

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

The parameter of the relative risk has a gamma prior distribution withα and β parameters:

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

Based on this Poisson-gamma model, the expected posterior relative risk will be one of the outputs of the analysis.

2.2The Data Set

In this study, the data set wasgivenby the Department of Statistics and Ministry of Health in Malaysia. This Poisson-gamma model are implemented to pneumonia data from year 2010 until year 2019in form of the number of cases for 13 states in Malaysia that are Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan, Sabahand Sarawak and three federal territories that are Kuala Lumpur, Putrajaya, and Labuan. However, in this study, both territories and states are informed as states for simplicity. In this study, for Putrajaya state pneumonia data are included in the data for the states of Kuala Lumpur where it is written as Kuala Lumpur& Putrajaya.

3. Results

Figure 1 shows the estimatedresultsof the relative risk value for 15 states in Malaysia. From the graph, most statesshow the relative risk values more than one from year 2010 until 2019 which implies that the susceptible people in these states tendtogetpneumonia disease compared with people throughout thewhole population.The relative riskin this study isdefinedas the conditional probability that a person inside anareabecome infected with the disease divided by the conditional

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probability that a person in the whole population become infected with the disease. From the graph, Sabah and Sarawak has relative risk close to one for most epidemiology weeks, which means there is no significant difference in terms of the likelihood that the people in these states and within the whole population to contract with pneumonia disease. Conversely, for Selangor, Kuala Lumpur & Putrajaya and Pulau Pinang, these three states have relative risk value less than one for most epidemiology weeks which shows that people within thesestates are less probable to get pneumonia disease when compared to wholepopulation in Malaysia.

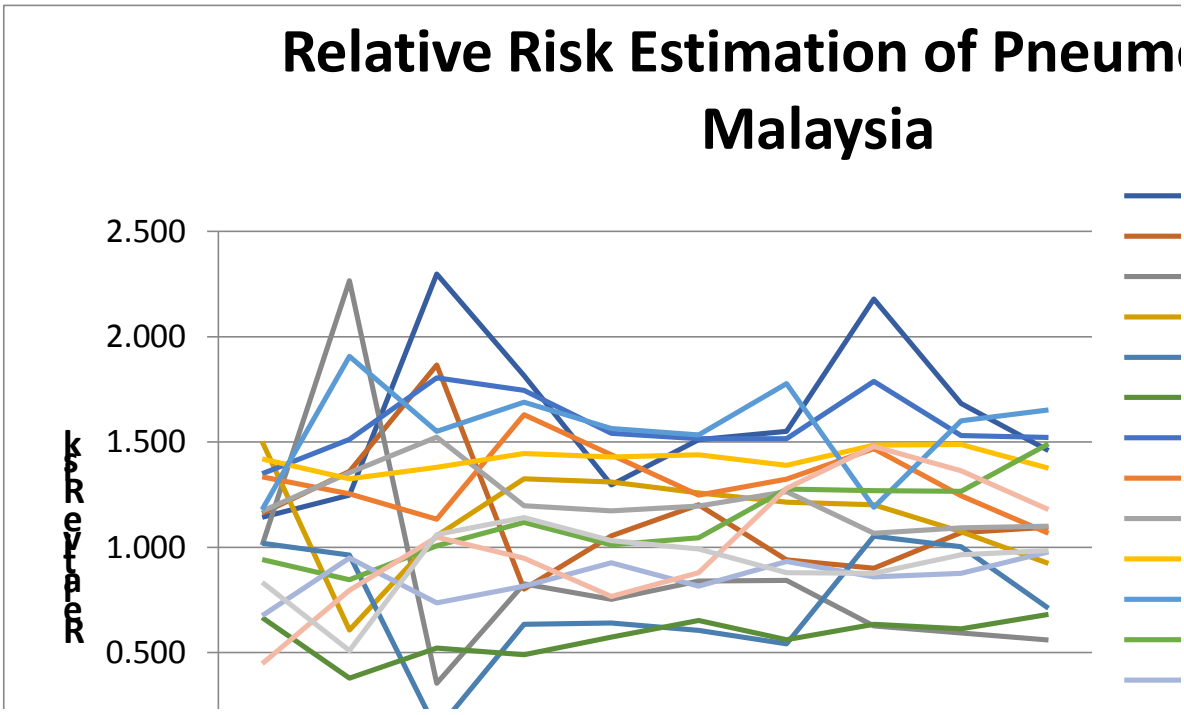

Fig. 1Plots of time series for the relative risk estimation using Poisson-gamma model for 15 states in Malaysia.

Numerical values for the relative risk are shown in Table 1 for year 2019. From Table 1, susceptible personsin the state of Terengganu has the highest risk of getting infected with pneumonia disease with 1.651 value of relative risk. In contrast withsusceptible persons in Pulau Pinangwhere it recognized to bethe lowest risk areawith value of 0.559.

States	Relative risk
Perlis	**1.458**
Kedah	**1.094**
Pulau Pinang	**0.559**
Perak	**0.922**
Kuala Lumpur & Putrajaya	**0.710**
Selangor	**0.682**
N. Sembilan	**1.521**

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Melaka	**1.066**
Johor	**1.099**
Pahang	**1.375**
Terengganu	**1.651**
Kelantan	**1.491**
Sabah	**0.978**
Labuan	**1.178**
Sarawak	**0.983**

Table 1. Estimation of Relative Risk forPneumonia for Year 2019

Figure 2 shows the choropleth pneumonia map that showhigh-low risk areas for the occurrence cases of pneumonia for 15 states of Malaysia for year 2019. Each state is allocated with one of five different levels of relative risk, starting from very low to very high risks with intervals of [0.0,0.5), [0.5, 1.0),[1.0,1.5), [1.5,2.0) and [2.0,∞). Here, very low risk is represented bythe brightestshade and for very high risk, it is represented by the darkest shade to differentiate the levels of relative risk.

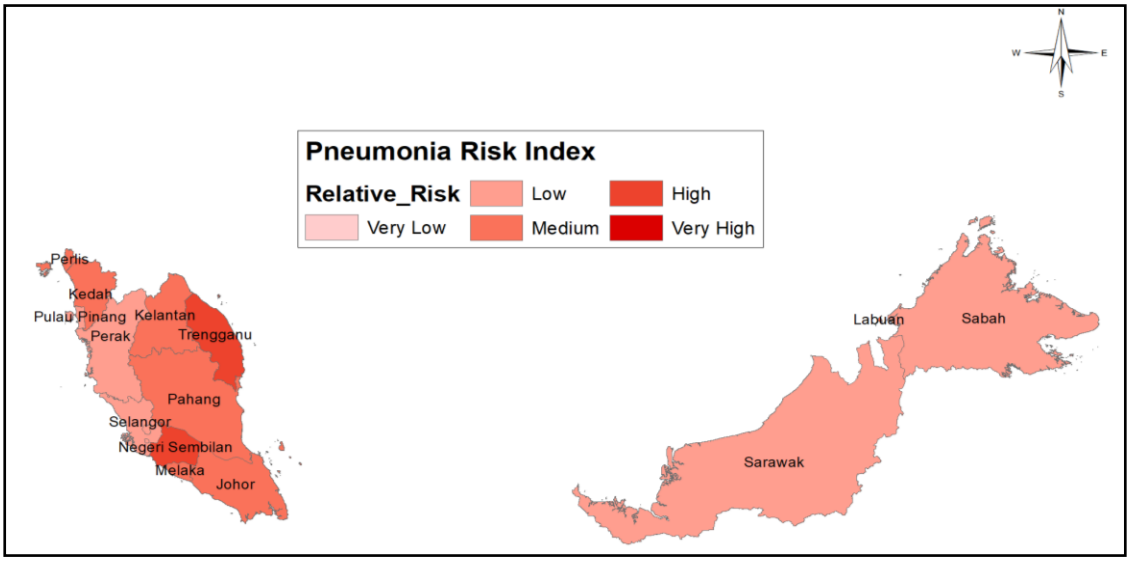

Fig. 2. Relative risk estimation map forpneumonia disease using Poisson-gamma modelfor year 2019

Figure 2 demonstratesthe map ofPoisson-gamma. From the map, the stateofNegeri Sembilan and Terengganu have high risk areas. Perlis, Kedah, Johor, Pahang and Kelantan have been identified as medium risk areas. The other statesare identified aslow risks.There is no state identified as very high risk and very low risk area.

4. Conclusion

It very important to estimate the values of relative risk in orderto monitor and control the spread of pneumonia, especially in Malaysia. In this study, Poisson-gamma model has been used to estimate the relative risk values, which this model is one of the initial approach of Bayesian in estimating the relative risk. The results for

this study are shown in form of graph, table and also map. From the map, it givesobvious picture of areas withhigh-low risks. To conclude, there is no state that has been identified as very high-risk and very low-risk area. Terengganu and Negeri Sembilan highest risk area while Pulau Pinang, Perak, Selangor, Kuala Lumpur& Putrajaya, Sabah, Labuan and Sarawak show the lowest risk areas of contracting pneumonia. Based on the study by Lawson et al., they demonstrated the use of Poisson-gamma model in their study and itis shown that a map issmootherwith less extreme values of the relative riskcompared when using SMR method[1].This Poisson-gamma model still has its own drawbacks where the covariate adjustment is difficult and there is no likely to deal with spatial correlation between risks in adjacent areas. Hence, this urges researchers to purpose other approachesto estimate therelative risk values.The map should be seen as atool which canhelp to inform and direct government strategy for monitoring and controlling pneumonia disease.

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