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A Bayesian Approach to Compare the Statewise Dengue Death Counts in India

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ABSTRACT

Background: The Estimation of the true disease burden of dengue is a challenge, considering its varied epidemiology and dynamics of transmission. The true disease burden cannot be understood from ordinary count data on the number of deaths or number of infected cases.

Aim & Objectives: To compare the Indian states by the true disease burden due to dengue in the year 2010 by ranking with respect to their performance to deal with dengue death.

Methods: To compare the states by count data for observed deaths, the Bayesian approach is used. The source of data is the National Dengue Control Report published by National Vector Borne Disease Control Programme of 2009 and 2010 till the month of August. The statewise comparison of death due to dengue has been performed with all necessary computation done in the statistical software R.

Results: Certain states like Delhi, Gujarat and Andhra Pradesh had very high incidence of dengue cases. But the mortality per unit exposure due to dengue is less in Delhi in contrast to other state in the country.

Conclusion: This statewise dengue death comparison can be helpful to authorize the state specific dengue control programme, as several issues which are not clear from count data can surface from such analysis.

Keywords: Bayesian estimation, Dengue, Public health, Shrinkage Estimator

Introduction

Dengue Virus (DV) is an enveloped, single-stranded, positive RNA virus and a member of the family Flaviviridae, genus flavivirus. There are four antigenically related but distinct serologic subtypes; DV-1, DV-2, DV-3 and DV-4[1]. Generally, infection with one serotype confers future protective immunity against that particular serotype but not against others [2]. Dengue infection (DI) is amongst the most emerging viral diseases transmitted by mosquitoes to humans, in terms of both illness and death [3]. Past few decades has turned this disease into a serious public health problem, especially in the tropical and subtropical countries [4]. An estimated 50-100 million cases of Dengue Fever (DF) and about 250,000–500,000 cases of Dengue Hemorrhagic Fever (DHF) occur every year [5]. As per the report of World Health organization [6], it is estimated that 50 million dengue infections occur every year with 500000 requiring hospitalization; 2.5% of those affected may die. These figures are likely to be underestimated as the numbers reported are influenced by different surveillance and reporting systems as well as varying interpretations of case definitions and the presence of missed and silent infections [7].

Dengue in India

Dengue virus was first isolated in India in 1945 [8]. All four virus types circulate and cause epidemics, but only occasional cases of dengue hemorrhagic fever/dengue shock syndrome (DHF/DSS) have been reported in India[9]. Delhi had its largest outbreak of DHF/DSS from August through November in 1996. During that year a total of 8,900 cases were reported, with a death rate of 4.2% [10]. As dengue is a mosquito borne viral fever with potential to turn out to be fatal so the disease has emerged to be a threat to the public health system in the country.

The status of public health across the country is being put to strain because of annual dengue infection and several other diseases those results from poor living conditions. Dengue is sweeping across Delhi, Haryana, Uttar Pradesh and Rajasthan and chikungunya through Karnataka, Maharashtra, Andhra Pradesh, Kerala, Madhya Pradesh and Gujarat and an outbreak of malaria in Mumbai in 2006. Poor sanitary conditions, water logging, accumulation of stagnant water bodies during the monsoons turn out to be perfect breeding grounds for mosquitoes. Mosquitoes breed in stagnant water pools and rotting garbage – unfortunately an all-too-familiar situation during and after the monsoons in towns and cities where civic services are over burdened. Several studies have shown that the out break/ incidence of dengue cases increases in India in the month of October i.e. at the fag end of the monsoon season [11, 12]. In the year 2003, India had experienced one of the wettest monsoons in 25 years, which led to a spate of mosquito growth creating an alarming situation of mosquito borne diseases in many states[12]. Both the public health authorities and the public themselves, are not aware about the special cleanliness drives that the surroundings are to be put to during or after the monsoon in order to restrict the breeding of mosquitoes. As per the estimates of the Ministry of Health and Family Welfare, in 2008, India recorded 12419 cases of Dengue, up from 5534 case in 2007. Delhi alone recorded 1307 cases of Dengue in 2008, up from 548 in 2007. Four Indian states, Punjab, Haryana, West Bengal, and Gujarat, have been the worst hit by Dengue, with Punjab reporting 4349 cases, and Haryana, West Bengal and Gujarat reporting 1137, 1050 and 1023 cases respectively.

Fighting Dengue Out: Some Indian Issues

Considering the huge population of India, the proportion of people infected by dengue would not be significant and the fatalities due to dengue negligible. But a relatively small number of fatalities and low incidence of dengue infection should not be a cause for contentment. Such viruses and diseases should not surface at all and even if they do, public health authorities should be in a position to avert the loss of lives. To do that it is important to understand the burden of dengue to which the different states of India are subjected. However, estimating the true disease burden of dengue in the country like India is a challenge task considering its varied epidemiology and dynamics of transmission. India has a highly complex and colorful social mosaic. The topographical difference, hot and humid living conditions at places, difference in the share of average annual rainfall, disparity in the share of resources, unplanned urbanization and several other factors may be held responsible for the unsuccessful attempts in the uprooting diseases like malaria, dengue etc. from the country. It is necessary that the issues of public health be studied at the different regional level, going down to each individual states and if possible to the level of districts, at which the implementation of several government policies including those related to public health initiates. However, to understand the extent and pace to which the different public health policies are to be implemented at the different states it is necessary to estimate the actual burden of the corresponding health problem, with dengue being no exception.

Considering the continual return of dengue in the country and the need of estimating the true burden of disease at the different states of the country provides the backdrop of such a study. This works intent to quantify, the burden of dengue, in the different states of the country. The study can help the corresponding public health authorities of the states to adjust their programs, leading to eradication of dengue from India.

Review of Literature

The dengue disease and viruses is a great problem in the Indian subcontinent for at least the past 50 years [13, 14, 15]. Since last twenty years the epidemiology of dengue has dramatically changed. It has been reported many times in Indian subcontinent [16, 17, 18]. Thus, other sources of information are needed to help determine the probable underlying causes and to detect proper dengue cases. Delhi, a city in North India, has experienced seven outbreaks of dengue virus infection since 1967 with the last reported in 2003 [19, 20, 21]. Ekta et al [23] have compared the serological and virological profiles of the confirmed dengue cases reported to All India Institute of Medical Sciences (AIIMS) in these three years i.e.2003, 2004, and 2005. However, Jha et al.[11,21] have concluded that the major deaths in rural India take place at home, without prior attention by any qualified healthcare worker, so most causes are not medically certified.

Material and Methods

The data required for the study is based on the National Dengue Control Report published by National Vector Borne Disease Control Programme (NVBDCP) of 2009 and 2010 till the month of August. The report provides state wise total blood slides examinations, dengue cases and death in each year. The state wise comparison of death due to dengue is performed by comparing the mortality rate per unit exposure rate. The estimate of which for each of the states is obtained through a Bayesian analysis. It is practical to assume the true rates are similar in size that generates the dependency between the parameter. To deal with such problem it is good practice to call a hyper-parameter to reduce the dependency between parameters. The whole process produces the system of a hierarchical prior guiding us to use hierarchical Bayesian approach. All the relevant calculations are performed in the statistical software R[1].

The main goal of this work is the comparison by the mortality rates due to dengue for 23 Indian states. Each state has a true mortality rate λ_i, and the objective is to compare estimate of 23 rates $\lambda_1, ..., \lambda_{23}$. It is logical to assume a priori that the true rates are similar in size. However, it can be affected due the dependence between parameters. The particular information about one state's true mortality rate can influences the idea about other states. Suppose we are interested in

[1] The Software can be freely downloaded from http://cran.r-project.org/

simultaneously estimating the true mortality rates $\{\lambda_i\}$ for all states. The simple procedure is the compare the individual mortality rates by

$$\frac{y_1}{e_1} = ,,, = \frac{y_{23}}{e_{23}} \quad \ldots (1)$$

However, the individual mortality rates can be poor due the presence of small exposure states.

In Table 1, it has been shown that some states did not experienced any death and the individual mortality rate $y_i/e_i = 0$ would likely to be underestimate or overestimate due to the presence of low or high amount of exposure or cases. So it is important to combine the individual estimates in some way to obtain improved estimates. Suppose we can assume that the true mortality rates are equal across states; that is, $\lambda_1 = \ldots = \lambda_{23}$.

Under this "equal-means" Poisson model, the estimate of the mortality rate for the i^{th} hospital would be the pooled estimate

$$\frac{\sum_{j=1}^{23} y_j}{\sum_{j=1}^{23} e_j} \quad \ldots (2)$$

But this pooled estimate is based on the assumption that the true mortality rate is the same across the states. This estimate shrinks or moves the individual estimate y_i/e_i toward the pooled estimate $\Sigma y_j/\Sigma e_j$ where the parameter $0 < \lambda < 1$ determines the size of the shrinkage. The shrinkage estimate is a natural byproduct of the application of an exchangeable prior model on the true mortality rates [26].

The total number of exposed person due to dengue has been denoted by e. The estimate of mortality rate per unit of exposure rate assumed by λ. It has been assumed that the death count Y follow Poisson distribution with mean $e\lambda$. The standard estimate of λ is, $\hat{\lambda} = y/e$.

The comparison due to death rate among the states in 2010, has been performed by the prior information of mortality rate generated by reports of 2009 death counts. In the annual state report many state's death count is zero or nearer to zero and many states are having higher number of death counts. The prior information about death has been obtained from 10 randomly selected states as a representative of dengue endemic and epidemic area.

Here, Z_i represents the number of deaths in the i^{th} state and O_i represents the number of people exposure due to Dengue in the year 2009. It is assumed that Z_i will follow Poisson distribution of mean $\underline{\lambda}$. Initially λ assigns as a standard non-informative prior by, $P(\lambda) = \lambda^{-1}$ and the distribution for λ, given the form of 23 states becomes $P(\lambda) \propto \lambda^{-1} exp(-\beta\lambda)$, $\lambda > 0$. The gamma (α, β) prior for λ has been use by

$\alpha = \sum_{i=1}^{23} Z_i$ and $\beta = \sum_{i=1}^{23} O_i$

In 2009 data, $\sum_{i=1}^{23} Z_i = 96$ and $\beta = \sum_{i=1}^{23} O_i = 15535$. We assign, gamma prior for λ with parameters (96, 15535). The observed number of deaths due to the dengue is denoted by y and it is supposed that for the particular state with exposure of e the distribution will be Poisson($e\lambda$).

In the prior model λ assigned with gamma (α, β) and the posterior distribution becomes in the form of gamma($\alpha + y$, $\beta + e$) The predictive density of y is,

$$f(y) = \frac{f(y \mid \lambda) g(\lambda)}{g(\lambda \mid y)} \quad \ldots (3)$$

for $f(y|\lambda) \sim$ Poisson($e\lambda$). In the sampling $g(\lambda)$, $g(\lambda|y)$ is the prior and posterior density of λ.

In the first step, the death rate λ_i assumed to be generate from gamma (α, α/μ) distribution with the mean μ and μ^2/α.

$$G(\lambda \mid \alpha, \mu) = \frac{(\alpha / \mu)^{\alpha} \lambda^{\alpha - 1} \exp(-\alpha\lambda / \mu)}{\Gamma(\alpha)}, \ \alpha, \lambda > 0 \quad \ldots (4)$$

In the second step, μ and α are assumed to be independent and μ is in gamma prior by gamma (a ,b) and α has a density function of $g(\alpha) = \frac{V}{(\alpha + v_0)^2}$, $\alpha > 0$.

V is the median value of α. The simulate value obtained from fixed α = 5, 20, 80 and 400 given in the figure 1. To see the line of concentration of prior distribution between two rates λ_1, λ_2 we use the figure 1.

It can be conclude that as α parameter value increases α_1 and α_2 are concentrated along the line $\lambda_1 = \lambda_2$. As α tends to infinity rate λ_i's will concentrated in the same line by $\lambda_1 = \lambda_2 = \cdots = \lambda_{23}$

The posterior distribution of λ_i is gamma ($y_i + \alpha$, $e_i + \alpha/\mu$). The posterior mean of λ_i can be express by

$$E(\lambda_i \mid y, \alpha, \mu) = \frac{y_i + \alpha}{e_i + \alpha / \mu} \quad \ldots (5)$$

The shrinkage estimator B_i can be useful in place of λ_i to know the true posterior mean.

The shrinkage estimator can be replaced in equation (1) by,

$$E(\lambda_i \mid y, \alpha, \mu) = \frac{y_i + \alpha}{e_i + \alpha / \mu} = (1 - B_i)\frac{y_i}{e_i} + B_i \mu \quad \ldots (6)$$

where $B_i = \frac{\alpha}{\alpha + e_i}$. This estimator is useful to improving the estimation by reducing the mean squared error towards zero. Shrinkage is implicit in Bayesian inference. The use of shrinkage estimators in the context of regression analysis has been discussed by Copas (1983) in presences of large number of explanatory variables.

The number of deaths in one year for dengue has been reported for each of the 23 states. Let y_i and e_i is the number of deaths and exposure for the i^{th} state. We assumed that the number of deaths y_i follows a Poisson distribution with mean $e_i\lambda_i$ and the objective is to estimate the mortality rate per unit exposure $e_i\lambda_i$. The fraction y_i/e_i is the number of deaths per unit exposure and can be viewed as an estimate of the death rate for the i^{th} state. We plot the ratios y_i/e_i against the logarithms of the exposures $log(e_i)$ for all states where each point is labeled by the number of observed deaths y_i. The estimated rates are highly variable, especially for programs with small exposures. The states experiencing no deaths (a plotting label of 0) also are primarily associated with small exposures. Suppose we are interested in simultaneously estimating the true mortality rates λ_i for all states. One option is to simply estimate the true rates by the individual death rates $y_1/e_1, \cdots, y_{23}/e_{23}$.

Unfortunately, these individual rates can be poor estimates, especially for the states with small exposures. We saw that some of these states did not experience any deaths and the individual death rate $y_i/e_i = 0$ would likely underestimate the states' true risk of mortality. Also it is found that the rates for the states with small exposures have high variability.

Since the individual death rates are not reliable estimates of the actual situation, so it seems desirable to combine the individual estimates in some way to obtain improved estimates.

Suppose we assume that the true mortality rates are equal across states; that is, $\lambda_1 = \cdot\cdot\cdot = \lambda_{23}$. Under this "equal-means" Poisson model, the estimate of the mortality rate for the i^{th} state would be the pooled estimate $\sum_{i=1}^{23} y_i / \sum_{i=1}^{23} e_i$.

But this pooled estimate is based on the strong assumption that the true mortality rate is the same across states. This is questionable since one would expect some variation in the true rates. We have discussed two possible estimates for the mortality rate of the i^{th} states: the individual estimate y_i/e_i and the pooled estimate $\sum_{i=1}^{23} y_i / \sum_{i=1}^{23} e_i$.

A third likelihood is the cooperate estimate,

$$(1-\gamma)\frac{y_i}{e_i} + \gamma\frac{\sum_{i=1}^{23} y_i}{\sum_{i=1}^{23} e_i} \qquad \dots (7)$$

This estimate shrinks or moves the individual estimate y_i/e_i toward the pooled estimate $\sum_{i=1}^{23} y_i / \sum_{i=1}^{23} e_i$, where the parameter $0 < \gamma < 1$ determines the size of the shrinkage. We use the posterior mean B_i as a representation of the i^{th} state shrinkage. In figure 2, the plot of B_i against the logarithmic of exposure has been presented. For the state with small dengue death the shrinkage size is close to 50%.

Discussion

In India, maximum dengue cases are recorded in Delhi (Table 1). The national capital, Delhi is one of the highest exposed dengue states but with no fatal cases. It indicates that the health service availability in Delhi is excellent but the drainage system, sanitation and hygiene awareness of the citizens needs improvement. Similarly, in the other states inhabited by ethnic tribes mainly in the forest ecosystems, meso to hyper-endemic conditions of dengue exist with the preponderance of dengue to the extent of 90% or even more. During August 2009 to July, 2010 of resurgence of dengue, certain states in India like Kerala, Karnataka, Gujrat and Maharastha are found to have high incidence of dengue infection. Kerala, Haryana and Maharastha performed worst due to high amount of dengue deaths. Among all the states Bihar, Nagaland and Jammu and Kashmir performed best recording zero number of death and lowest number of dengue cases. However, when the true burden of dengue is considered via the posterior expectation of λ the ranking of the states showed several changes as evident from Table 1.

It is interesting to note that Haryana, one of the richest states in India, and with moderate number of dengue cases has a high mortality rate due to dengue and is worst compared to the other states. This may be attributed to some chance causes occurring in a particular year or may be due to some hidden reasons. But this definitely calls for serious concern in subsequent years.

However, the data available with NVBDCP are mostly based on hospital records and as reported by different surveillance programs. Sometimes cases of dengue fever may not be correctly detected. Shekatkar et al. [23] while writing about Leptospirosis comments that- "leptospirosis is easily mistaken for other febrile illnesses including influenza, dengue fever, meningitis, or hepatitis. Therefore, rapid and appropriate laboratory diagnostic tests are needed to aid clinical case identification and to facilitate the implementation of rapid outbreak investigations for optimal treatment and patient management." Thus, testing, diagnosing, relieving symptoms, and expecting a cure treatment are important for the contemporary health care service [24].

Poor economic condition and deplorable conditions of living of the people in the country is a hindrance in the control of Dengue in spite of several efforts from the government and NGOs. Misconceptions and wrong beliefs are common, which increases the gap between knowledge and practice in the public [25], ultimately leading to diseases that can be otherwise controlled by public awareness.

Conclusion

The statewise ranking based on dengue status can be computed in each year based on its status report presented by NVBDCP. This statewise dengue death comparison can be helpful in providing necessary guidelines for planning the course of action for the state specific dengue control programme. The public health facility to prevent the dengue and the health service facility to stop the dengue fatal are played important role to rank the states. In future these two factors are needed to control to deal with dengue cases and deaths.

Conflict of interest: None declared.

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Table 1: Dengue Status with respect to best state in the year 2010

State	Dengue cases	Death	$P(\lambda_{beststate} < \lambda_i) \times 10^6$	Rank
Andhra Pradesh	317	0	1.6863319	3
Bihar	0	0	5.3346581	17
Chhattisgarh	1	0	5.5411376	18
Delhi	3297	5	1.6795871	2
Goa	126	0	2.6944029	5
Gujrat	1273	0	0.6299257	1
Haryana	272	6	15.6366125	23
Karnataka	1696	5	3.2487718	6
Kerala	2274	15	6.4650672	20
Maharastha	788	6	7.0990745	21
Rajasthan	133	3	12.9985604	22
Tamilnadu	834	4	4.842342	11
Westbengal	259	1	4.299373	9
Pondichery	38	0	3.889819	8
Uttarpradesh	16	0	4.8926024	12
Punjab	299	0	1.799535	4
Madhya Pradesh	64	0	3.5842963	7
J &K	0	0	5.6821002	19
Nagaland	0	0	5.1840042	15
Chattisgarh	1	0	4.9962645	14
Orissa	19	0	4.9018798	13
A &N Island	25	0	4.6641704	10
Manipur	4	0	5.3152487	16