UTILITY OF CATALYTIC MODELS IN THE ESTIMATION OF INCIDENCE AND PREVALENCE OF MALARIA IN A HYPERENDEMIC SITUATION

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Abstract. Simple catalytic models were used for estimating the true incidence of malaria in hyperendemic villages of Koraput District in Orissa State where *Plasmodium falciparum* is predominant. The hill top villages recorded a slide positive rate of 45.68. The daily rate of inoculation among infants was estimated to be 0.00781. The inoculation rate was so high that the recovery from one infection was compensated by the subsequent infection and hence the prevalence continued to increase with age. The model adequately represents the observed data for infants but could not be used for estimating the true prevalence in the adult population without incorporating other factors like immunity and superinfection.

INTRODUCTION

Decision and implementation of control measures for any infectious disease requires prior knowledge about the intensity of transmission and seriousness of the problem in that area. Incidence and prevalence are considered to be the basic parameters to assess the situation.

In malaria, incidence rate calculated for hyperendemic areas by the conventional method of fever surveillance tends to be overstimated because the fever due to malaria cannot be separated from other fevers due to presence of large number of asymptomatic carriers (Jambulingam *et al*, 1990). Therefore, there is a need to estimate the true prevalence by indirect methods. Since infants are assumed to be the susceptibles the incidence rate in infants is supposed to reflect the inoculation rate. Therefore, it is possible to estimate intensity of transmission (inoculation rate) indirectly from the incidence rate in infants by using mathematical models (Ross, 1911; Pull and Grab, 1974; Verma *et al*, 1980). This paper attempts to estimate true prevalence of malaria in the Koraput District of Orissa State, a hyperendemic area where the transmission is perennial (Rajagopalan *et al*, 1989).

MATERIALS AND METHODS

Data base

Hill top villates of Borigumma PHC of Koraput District were selected for this study. Fever and malaria parasites in a cohort of 27 infants were monitored at fortnightly intervals from June'89 to May'90. Though attempts were made to follow all children longitudinally, it was not possible for a few cases due to migration. To obtain the prevalence of malaria in the community, cross sectional surveys were carried out. Blood samples were collected once in a fortnight from fever as well as normal persons and examined for malaria parasite. The entomological data for this area published by Parida *et al* (1991) were considered for estimating entomological inoculation rate which was compared with the inoculation rate obtained from parasitologic data.

The model

The simple catalytic model developed by Muench (1959) was used to estimate the parasite inoculation rate using the rate of acquisition of infection. Pull and Grab (1974) and Verma *et al* (1980) used this model in malaria for the evaluation of inoculation rate and the risk of infection in infants. As per this model the acquisition of infection in the new born infants was described by

$$y = 1 - \exp(-ht) \quad \ldots\ldots\ldots(1)$$

where y is the age cumulated incidence rate and t is the time period (age of the infants in days) and h' is the daily rate of inoculation per susceptible infant in the population. The model parameters were estimated by using the method of maximum likelihood (Draper and Smith, 1981). In this model, it is assumed that the infants are exposed to a constant

rate of infection throughout the period.

It is assumed that at the initial stage (when $t = 0$) the number of positive cases is 0 ($y = 0$). It is also possible that infants once found positive may become negative in some of the subsequent blood examinations due to recovery of parasite. This can be expressed in the model

$$y = hk/(h+r)^* \{1 - \exp [- (h+r)^*t]\} \ldots\ldots(2)$$

where y is the prevalence of infection, t is the time in days, k is the proportion of infected infants actually detected and r is the daily recovery rate.

RESULTS

The monthly observed parasite incidence rate and the cumulative age incidence rate for 1,000 new born infants were calculated from the observed data and are given in Table 1. The observed incidence rate was fitted to the model (1) and inoculation rate was estimated by solving the non-linear equation using the method of Draper and Smith (1981). The daily inoculation rate h' upon the infant population was estimated from the model as 0.00781, which suggests that approximately 78 infants are getting a fresh malarial infection everyday for every 10,000 new born infants. The significance test carried out for the observed and estimated values ($p > 0.05$) clearly shows that the inoculation rate (0.00781) gives the best fit to the data.

Fig 1 shows the observed and expected values of the cumulated age prevalence of malaria infection in infants during the study period. The prevalence for other age classes was estimated using model (2)

Table 1

Agewise cumulative incidence of malaria calculated for 1,000 infants.

Age (in months)	Observed monthly incedence	No. of susceptide infants	New malaria cases in the cohort cumulated	Cumulated age-specific incidence rate (%)	
				Observed	Expected
0		1,000			
	12.5		125	12.50	14.67
1		875			
	10.0		213	21.25	27.2
2		788			
	20.0		370	37.00	37.88
3		630			
	23.5		518	51.82	46.99
4		482			
	50.0		759	75.91	54.77
5		241			
	15.0		795	79.53	61.41
6		205			
	9.5		815	81.48	67.07
7		185			
	5.6		825	82.50	71.91
8		175			
	27.8		874	87.36	76.03
9		126			
	0.0		874	87.36	79.55
10		126			
	5.6		881	88.07	82.55
11		119			
	6.7		889	88.86	85.11
12		111			

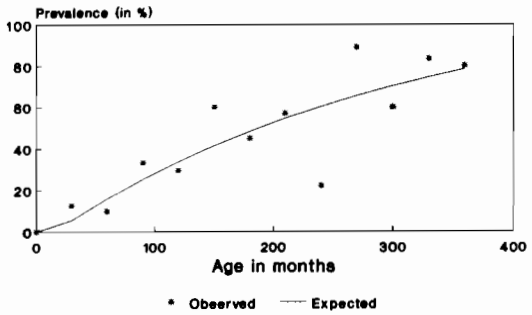

Fig 1–Prevalence of malaria among infants.

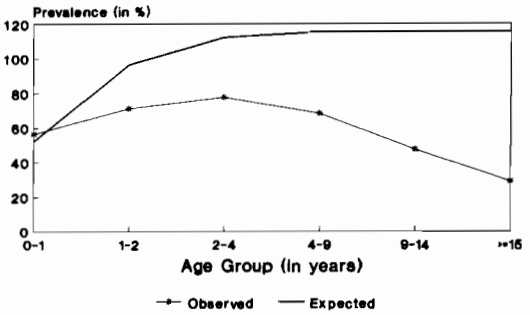

Fig 2–Agewise prevalence of malaria.

and the theoretical values were obtained from the model:

$$Y = 1.15^* [1 - \exp(-0.0033^*t)]^* 100$$

Using the estimated inoculation rate, the recovery rate r and k the proportion of parasite positive cases actually detected from the survey were estimated as -0.00451 and 0.49 respectively by solving the non-linear equation using the method of Draper and Smith (1981). The negative value obtained for r suggests that there is not possibility of recovery of cases from infection during the observation period. The prevalence and incidence both continued to rise with age in infants because the recovery rate in infants was negligible compared to the inoculation rate.

The inoculation rate h', was also calculated from the data on entomological variables using the equation:

$$h' = ma^*s \quad .....(3)$$

where ma is the biting rate and s is the proportion of mosquitos with sporozoites in their salivary glands. The entomological inoculation rate calculated based on the values given by Parida *et al* (1991) was found to be 0.0135 which is much higher than the inoculation rate estimated from the infant incidence rate. The proportion of anophelines with sporozoites in their glands that are actually infective b was 0.58 (calculated from the equation $h = b * h'$) which indicates that 58% of the infective bites resulted in infection.

Prevalence rates for various age groups of the population were estimated using the equation (2) assuming the inoculation and recovery rates obtained from the infant population is true for the entire population. Fig 2 compares the observed and expected agewise prevalence of malaria for the whole population. Though the observed and the expected values for less than one year age group coincides, the estimated prevalence was higher in other age groups and the difference between the estimated and observed prevalence continued to increase with age.

DISCUSSION

The model provides a means to estimate the inoculation and the recovery rates of infection among infants in this area. The inoculation rate h' obtained for this area (0.00781) is slightly lower than the one obtained by Pull and Grab (1974) for the Kenyan population (0.0084). However, the overall prevalence of malaria among infants was higher in this area (49.8%) than in the Kenyan population (46.0%). This could be due to the zero recovery rate obtained for this area. The higher value of inoculation rate obtained from the entomological data (0.0135) compared to the one obtained from parasitological data suggests that either all infective mosquitos are not successful in establishing the infections or due to super infection resulted in the lower infection rate in the human population.

The small discrepancy between the observed and estimated prevalence among infants may be due to the role of maternal immunity which gives protection to infants against infection and less exposure to mosquito bites. The prevalence rate estimated for different age classes using the model (2) is significantly higher than the observed rate. The difference between these two increases as the age increases. This could be either due to acquired immunity which affect the establishment of the

parasite or partly due to the treatment of positive during this period.

Since, this model does not include the immunological factors and the concept of super-infection which plays a vital role in malaria epidemiology, this model as such cannot be applied to estimate the prevalence of infection in the adult population.

ACKNOWLEDGEMENTS

The authors are grateful to the field staff at Koraput field station for their help in collecting this data. Mr S Subramanian and Mr P Vanamail are also acknowledged for their suggestions and the critical review of this manuscript. Finally, we thank our Director, Dr V Dhanda for his encouragement throughout the study.

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