Malaria Prevalence in Arunachal Pradesh—A Northeastern State of India

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Abstract. Malaria is endemic in Arunachal Pradesh, India. To understand seasonal prevalence and malaria transmission, a retrospective surveillance study was conducted from 1995 to 2012. *Plasmodium vivax* caused 80.8% and *P. falciparum* caused 17.7% of total malaria cases. It was observed that prevalence rates of *P. vivax* declined significantly ($P < 0.001$) from 1995 to 2012 but that *P. falciparum* remained constant during the study period ($P = 0.57$). The decrease in the prevalence of *P. vivax* cases may be because of effective implementation of vector and disease management programs. It is noted that there was a significant correlation between the number of *P. falciparum* malaria cases and rainfall ($P < 0.06$). These findings help us to understand the patterns of malaria epidemiology in Arunachal Pradesh and show that *P. falciparum* is circulating constantly and requires more effective control measures to combat it.

INTRODUCTION

Malaria is one of the leading infectious diseases, and it is endemic in 104 tropical and subtropical countries of the world.¹ According to the World Health Organization (WHO; 2013), 207 million malaria cases and 627,000 malaria deaths were reported globally. Most of these cases (80%) are being reported from the African region followed by the southeast Asia region (13%) and the eastern Mediterranean region (6%); 90% of deaths caused by malaria were in the African region, 7% of deaths caused by malaria were in the southeast Asian region, and 3% of deaths caused by malaria were in the eastern Mediterranean region. Globally, about 3.4 billion people are at risk of malaria, of which 2.2 billion people are at low risk (< 1 case reported per 1,000 people) and 1.2 billion people are at high risk (> 1 case per 1,000 people) living mostly in Africa (47%) and southeast Asia (37%).²

According to the WHO malaria report, of 11 countries in the southeast Asia region, 10 countries are endemic for malaria, meaning that 1.6 billion people are at some risk and 1 billion people are at high risk. Around 2.5 million malaria cases are reported annually from southeast Asia, in which India alone contributes 52% of the total number of cases.² India is the most populous country in which malaria incidence is common, and 95% of the population is at risk of infection.^{3,4} Malaria transmission rates vary with reference to geographic regions between urban and rural zones of India, where rural malaria accounts for > 90 –95% of cases and urban malaria accounts for < 5 –10% of cases.^{5,6} The number of reported cases in India decreased from 2 million in 2000 to 1.1 million in 2011, whereas the number of slides examined increased from 87 million to 109 million.⁷ According to WHO estimates, malaria causes about 15,000 deaths (5,000 children and 10,000 adults) each year in India.³ According to the National Vector Borne Disease Control Program (NVBDCP), 1.06 million cases were reported in 2012, and 50.01% were caused by *Plasmodium falciparum*.⁸

Malaria is a major public health concern in the northeastern states of India, such as Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, and it

continues to deter the equitable socioeconomic development of the region.⁹ Deaths of epidemic proportions are reported every year from different parts of the northeast region (which accounts for 10% of confirmed malaria cases and 13–14% of all malaria-related deaths), mostly caused by the infection of *P. falciparum*, which is the predominant parasite species.^{10,11} It is estimated that *P. falciparum* accounts for more than 60% of malarial infections, and others are caused by infection with *P. vivax*.

Multiple mosquito vectors, like *Anopheles minimus*, *An. dirus* (species D; recently revised taxonomically as *An. baimaii*), *An. fluviatilis*, *An. philippinensis*, *An. nivipes*, *An. annularis*, *An. culicifacies*, and *An. maculatus*, play a vital role in this region for malaria transmission.^{12–16} These species have adapted to the ecological condition of Arunachal Pradesh and are considered to be the major vectors for *P. falciparum* and *P. vivax* malaria transmission.^{12–14} Information on the breeding habitats of malaria vector species and its relationship with malaria cases in the forest and fringed areas of the northeast region is very limited. According to the report by the WHO,² the state of Arunachal Pradesh is considered as highly endemic for malaria. However, there are limited reports available on the disease transmission dynamics of malaria in Arunachal Pradesh. This is the first epidemiological study to describe spatial mapping of malaria-endemic zones and detail the malaria situation throughout the year. To understand the malaria situation in all of the districts of Arunachal Pradesh, the data were analyzed retrospectively from 1995 to 2012. The output of this study will certainly help in understanding the disease spectrum and infection dynamics, which may be useful in control strategies.

METHODS

Study area. Arunachal Pradesh (26°30' N and 97°30' E) is geographically the largest state (83,743 km²) in the northeast part of India, and it is nestled in the foothills of the Himalayas. The climate of the state varies with elevation (i.e., areas that are at a very high elevation in the upper Himalayas have tundra climate). The areas below the upper Himalayas are the middle Himalayan belt, where people experience temperate climate. Areas of the sub-Himalayan region are at sea level and generally experience humid, subtropical climate with hot summer and mild winter. Arunachal Pradesh receives heavy rainfall of 2,000–4,100 mm annually (most between May and September).

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Collection of data. Arunachal Pradesh comprises 15 districts with 91 primary health centers (PHCs) and 28 community health centers (CHCs) that have a facility for diagnosis and treatment of malaria. Each center collects data on malaria from all sources, which is pooled monthly/annually. These pooled epidemiological datasets of malarial cases in Arunachal Pradesh for the years 1995–2012 were obtained from the Directorate of Health Services, Government of Arunachal Pradesh. The data included total population of the district and parasitological survey details, such as number of blood samples collected (BSCs), number of BSCs that tested positive for either *P. vivax* and *P. falciparum* infection, and dichlorodiphenyltrichloroethane (DDT) spray information.

Parasitological survey. Parasitological survey is a routine process done by government health officials to estimate the disease prevalence and parasitic load in the community by examining the blood smears from the respondents. To assess malaria prevalence among 15 districts, the blood samples were collected using the random convenience sample method from selected inhabitants, and both healthy and sick participants were included in this study. The malaria parasite species were screened from peripheral blood obtained by the finger prick method. The collected thick and thin blood smears were used for species identification. These slides were stained with Jaswant Singh Bhattacharya (JSB) stain, examined under microscope, and recorded individually.¹⁷

Calculation of the annual parasite index. Annual parasite index (API) was calculated as the number of malaria-positive patients per 1,000 inhabitants at each of the study sites:

$$\text{API} = (\text{number of positive slides} / \text{total population}) \times 1,000.$$

Calculation of the annual *P. vivax* index. Annual *P. vivax* index (AVI) was calculated as the number of *P. vivax* malaria-positive patients per 1,000 inhabitants at each of the study sites.

$$\text{AVI} = (\text{number of } P. \text{ vivax} - \text{positive slides} / \text{total population}) \times 1,000.$$

Disease control interventions. To suppress the malaria prevalence, vector control interventions were implemented by spraying two rounds of indoor residual spray (143,888 kg DDT [50% water-dispersible powder (W.P.)]). This spraying was conducted annually in the villages where a high prevalence of malaria cases had been reported. The first round of DDT spray is usually conducted from April to June, and the second round of DDT spray is usually conducted from July to August each year. Apart from this spraying, the Government of India and State Government of Arunachal Pradesh have implemented impregnated bed nets in endemic areas as a barrier to human–mosquito contact. In addition to these efforts, many health education camps and awareness programs are conducted by the government and non-governmental organizations routinely. Training programs for health officials are also conducted periodically for strengthening healthcare services, particularly in high-risk zones. The major obstacles to controlling the malarial prevalence in Arunachal Pradesh are mainly caused by the varying altitudes (50–7,000 m) traversed throughout by a number of rivers and rivulets, and the majority of areas is covered with dense forest and forest fringes. Himalayan foothill villages share international borders with

Bhutan, China, and Myanmar. Other than these factors, availability of various mosquito species, parasitic load in the community, low socioeconomic conditions, and suitable ecoclimatic conditions together contribute to the malarial burden in these areas. Lots of attention has been paid by the government to suppression of the disease by implementing various control measures, but malaria continues to be uninterrupted, contributing to high morbidity and mortality in Arunachal Pradesh.

Global position system data. The coordinates (longitude, latitude, and altitude) of all PHCs and CHCs of Arunachal Pradesh were recorded on site using Garmin handheld global position system (GPS) receivers (GARMIN [ASIA] Corp., Taipei, Taiwan). GPS data were downloaded from the handheld GPS receiver for Geographical Information System (GIS) mapping. MapSource software was used to download maps data, points of interest (POIs), waypoints, tracks, and routes from the GPS unit. Arc GIS 9.2 software was used for GIS mapping of the API in Arunachal Pradesh. The average APIs from 1995 to 2012 were divided into five categories: (0, 1–10, 11–25, 26–50, and > 51) and mapped using GIS.

Meteorological data. Meteorological data on rainfall were obtained from the Indian Meteorological Department, Government of India, Pune, India.

Ethics statement. The study received ethical approval from the Indian Institute of Chemical Technology Ethical Committee affiliated with the Ministry of Science and Technology, Government of India. We declare that the data on epidemiology were collected from Directorate of Health Services, Government of Arunachal Pradesh based on records at the PHCs/CHCs in Arunachal Pradesh and analyzed anonymously; here, no particular patient by name was involved.

Statistical analysis. Statistical analysis was done with SPSS, version 15.0 statistical software. To compare the malaria parasite prevalence between different categories, a χ^2 test was used. Similarly, correlation analysis was performed on the data to check the statistical dependence of the climatic factors with malaria cases. The level of significance was considered at $P < 0.05$.

RESULTS

Malaria prevalence in Arunachal Pradesh from 1995 to 2012. Although malaria disease transmission rate is high throughout the year in Arunachal Pradesh, it was served that there was significant decrease in the overall disease rate in the past two decades. It was also noticed that only two major *Plasmodium* species (*P. vivax* and *P. falciparum*) were encountered in this region, and they cause the maximum malaria infection in all of the districts of Arunachal Pradesh. During this study period, 0.67 million malaria cases were reported, of which 0.54 million (80.8%) cases had *P. vivax* infection, 0.1 million (17.7%) cases had *P. falciparum* infection, and 10,372 (1.5%) cases had mixed infections (both *P. vivax* and *P. falciparum* species).

The disease surveillance and screening of blood samples for malaria significantly decreased from 1995 to 2012 ($P < 0.01$). However, through analyzing the annual slide positive rate (SPR), it was noticed that a high number of positive cases was observed (17%) in 1995, which decreased to 6% in 2012 ($P < 0.55$) (Figure 1). Similarly, the population of Arunachal Pradesh has increased from 0.8 million in 1995 to 1.3 million in 2012. Among the positive cases, two types of pathogens

FIGURE 1. The slide positive rate and annual parasite index gradually declined in Arunachal Pradesh from 1995 to 2012.

were reported (*P. vivax* and *P. falciparum*) followed by mixed infection of both parasite species. While comparing these two malaria parasites from the collected samples, it was observed that the number of positive cases caused by *P. vivax* infection was predominantly more than the number of cases caused by *P. falciparum* malaria. The number of cases with infection caused by *P. vivax* was found to decrease gradually from 1995 to 2012 ($P < 0.001$), whereas the number of cases of infection caused by *P. falciparum* was found to be constant ($P = 0.57$). The mixed infections were found to be very low and constituted less than 2% of total annual cases. Similarly, API

decreased significantly ($P < 0.001$) from 59 per 1,000 inhabitants in 1995 to 6 per 1,000 inhabitants in 2012 (Figure 1).

It was noticed that all the districts of Arunachal Pradesh are endemic for malaria with *P. vivax* and *P. falciparum* species. However, the intensity of occurrence was not constant within the districts during the period of study. While analyzing the number of malaria cases caused by *P. vivax* and *P. falciparum* among the districts, it was noticed that higher numbers of *P. vivax* cases were reported in most of the districts compared with *P. falciparum* cases. Similarly, comparing *P. falciparum* and *P. vivax* cases with total

FIGURE 2. *P. vivax* and *P. falciparum* malaria cases in relation to rainfall by year in Arunachal Pradesh, India.

FIGURE 3. Distribution of malaria cases by month in Arunachal Pradesh, India from 2006 to 2012.

rainfall, it was found that rainfall did not influence the number of *P. vivax* cases ($P < 0.96$) but that rainfall has some correlation to the number of *P. falciparum* cases ($P < 0.06$) (Figure 2).

Seasonal prevalence of malaria in Arunachal Pradesh from 2006 to 2012. There was an apparent fluctuation in the malarial trend observed in Arunachal Pradesh. The data by month show that the malaria transmission occurs throughout the

year. Malaria cases start increasing in April and peak during the monsoon period (i.e., June and July). They gradually decline from August onward (Figure 3). The malaria data reveal that, during the post-monsoon season, the *Plasmodium* parasites steadily increase from the month of September and are at their peak in October. The prevalence of malaria then showed a sharp decline in the months of November and December for all years (Figure 3).

FIGURE 4. Spatial map showing the average annual parasite index of malaria cases in Arunachal Pradesh, India from 1995 to 2012.

Spatial distribution of malaria endemicity. The spatial distribution of API of malaria has been done from 1995 to 2012. Because the malaria prevalence varied largely among the districts (ranging from 0 to 91 per 1,000 persons), the spatial map of malaria endemicity was classified into five different endemicity groups: group A represents the non-endemic zone (no cases), group B represents the low endemic zone (< 10 cases/1,000 population), group C represents the moderate risk zone (11–25 cases/1,000 population), group D represents the high endemic zone (26–50 cases/1,000 population), and group E represents very the high-risk zone for malaria (> 50 cases/1,000 population) (Figure 4).

DISCUSSION

The physiography of Arunachal Pradesh is very distinct from the rest of the country but quite similar to neighboring countries, like Myanmar and Thailand.⁹ Malaria cases reported in Arunachal Pradesh were mainly caused by infection with *P. vivax* and *P. falciparum*.¹³ Persistence of malaria in this region may be caused by lack of awareness and low socioeconomic status among the populace, difficult terrain to reach, lack of proper healthcare services, and ideal climatic conditions for mosquito breeding.¹⁸ Because of these prevailing factors, it is very difficult to monitor malaria dynamics in the northeast region.¹⁹ To understand the pattern of disease transmission and the reasons for the high numbers of malarial cases, a detailed epidemiological study was conducted in Arunachal Pradesh from 1995 to 2012. This malaria prevalence survey provides the baseline parasitological information for the population living in endemic districts of Arunachal Pradesh.

During the study period (1995–2012), it was noticed that high number of cases were reported from Changlang, Lohit, Upper Dibang Valley, East Siang, West Siang, and Papum Pare compared with other districts in Arunachal Pradesh. Malarial cases were more often caused by *P. vivax* (80.8%) than *P. falciparum* (17.7%). While analyzing the AVI over these years, it was noticed that the *P. vivax* cases had significantly decreased from 51 cases per 1,000 persons in 1995 to 4 cases per 1,000 persons in 2012 ($P < 0.001$). Similarly, *P. falciparum* cases varied between the years, but the intensity of parasite was found to be persistent during the study period.

Malaria cases examined at hospitals from Asian and Pacific areas are mostly caused by infection with *P. vivax*. In our study, the highest number of malaria cases recorded was caused by infection with *P. vivax*. However, from this study, it was noticed that the number of *P. vivax* malaria cases decreased significantly from 1997 to 2012, which might be because of the effective implementation of malaria and vector control programs by the Government of India: the Modified Action Plan for Malaria Control implemented in 1995, the Enhanced Malaria Control Project (EMCP) in 1997, the National Anti-Malaria Program in 1999, the Intensified Malaria Control Project in 2005, and introduction of long-lasting insecticide-treated nets (LLINs) and revised national drug policy in 2010.²⁰ It was also reported that there were 100% cure rates of *P. vivax* malaria treated with chloroquine in different regions of India.²¹ With chloroquine, there was a significant reduction of *P. vivax* prevalence, but there was no change in the number of cases on *P. falciparum* malaria. This result clearly shows the non-effectiveness of the chemotherapy

introduced in the study area for the control of *P. falciparum* cases. There is also a possibility that the predominance of *P. vivax* infection postulated a faster acquisition of immunity compared with that of *P. falciparum*.²²

Malaria is widespread in tropical and subtropical areas, and mortality is associated mainly with *P. falciparum* infection. The Government of India is primarily targeting control of the infection, because this parasite is reported to frequently develop resistance to the effective drugs compared with *P. vivax* malaria. In our study, we also found that *P. falciparum* malaria transmission was persistent throughout the study period; however, their numbers were highest from May to September. The rise in *P. falciparum* malaria in these months may be because of the increase in the biting rates of *An. minimus*, *An. dirus* (recently revised taxonomically as *An. baimaii*), *An. philippinensis*, *An. nivipes*, *An. annularis*, *An. Culicifacies*, and *An. maculates*.^{12–16} Earlier studies reported that *An. minimus* and *An. dirus* act as potential *P. falciparum* malaria vectors in the northeast region.²³ The seasonal abundance pattern of these vectors in different habitats was significantly higher in monsoon season than that of pre-monsoon and post-monsoon seasons.¹³ Higher numbers of *P. falciparum* malaria in these regions may be because of the presence of many breeding habitats throughout the year with favorable temperatures that lead to constant risk of malaria infection. The occurrence of *P. falciparum* infection shows the increase of drug resistance of the parasite as well as the insecticidal resistance of transmitting vectors.^{24,25} The persistence of *P. falciparum* infection with low prevalence is thought to be a strong indicator for emergence of drug-resistant strains.^{26,27} The other possibility for *P. falciparum* cases is higher vector densities with high parity rate, vector resistance to insecticides, and parasitic load in the community. Similarly, migration of people across the borders, poor intercountry-coordinated vector control interventions,^{28,29} deforestation, and expansion of agriculture land encourage vector abundance and disease transmission.¹⁶

An earlier study suggested that there is a high correlation between various climatic factors and the distribution of malaria. Most of the studies were undertaken in Africa, Europe, Asia, South America, and Australia, and very little is known about the impact of climate variation on malaria in temperate regions, like India. Most of the studies were focused on meteorological aspects, like the effect of temperature on malaria and rainfall.^{30,31} In this study, the malaria cases were correlated with rainfall, which was found to be significantly correlated with the number of *P. falciparum* cases. Earlier reports also suggested that the malaria pattern in Arunachal Pradesh is perennial and seasonally regulated: high transmission occurs during the monsoon period, and low transmission occurs in the post-monsoon period.^{10,32} In our study, parasite density rose soon after the start of the rainy season in May and reached its peak in July, because the rains provide good breeding sites for mosquito vectors. It was also confirmed that higher numbers of cases of malaria are caused by *P. vivax* and *P. falciparum*, and the number of cases mostly depends on the type of climatic factors³⁰ and may also be because of other associated factors, like mosquito abundance, population movements,³³ and drug resistance.³⁴ Hence, this study provides a better understanding of the malarial scenario in Arunachal Pradesh and will help health officials suppress the disease transmission in a schematic way.

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