Review Article

DENGUE IN INDIA: TEMPORAL AND SPATIAL EXPANSION IN LAST TWO DECADES

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ABSTRACT

Background: Dengue has become a major public health issue across the globe particularly in tropical and subtropical regions. The global prevalence of dengue has grown exponentially and it is endemic in 129 countries of Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific regions of

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World Health Organization (WHO). In SEAR, except Democratic Peoples' Republic of Korea, all 10 countries including India are endemic for dengue. All states/Union Territories in the country (except Ladakh and Lakshadweep) have reported cases and deaths due to dengue. The present paper describes the status of dengue in India, its geographical spread in last few decades, changing epidemiology over the years, associated complications and present and the future challenges. It also provides insight of dengue control programme in India and how the surveillance system has strengthened.

Material and Method: The data on dengue for two decades (2000-2009 and 2010-2019) available at National Vector Borne Disease Control Programme under Ministry of Health and Family Welfare, Government of India has been used in this paper. To find out the correlation between population movement and dengue, the data regarding domestic tourism was obtained and analyzed. The data was entered, processed and analyzed by using MS Excel 2010. In present study, Statistical Package for Social Sciences for Windows (version 24.0; SPSS, Inc., Chicago, IL) was used to perform Statistical analyses.

Results and Discussion: During last two decades, significant geographical spread of dengue has been observed in India with repeated outbreaks and an 11 fold increase in the number of cases. The number of states and Union Territories (UTs) reporting cases increased from 8 (7 states and one UT) in 2000 to 35 (28 states and 7 Union Territories) at present. Ladakh was bifurcated from Jammu and Kashmir on 31st October 2019, therefore, Ladakh is not mentioned separately. The data used for this paper is upto December 2019 only. The Union Territories of Daman & Diu and Dadra & Nagar Haveli which were merged on 26th January 2020 are considered as two different UTs in this paper. A paradigm shift in dengue transmission from urban to rural settings has been observed which is not uniform due to ecological diversity. Transmission dynamics of dengue is correlated with vector density which remains

highest during monsoon and post-monsoon and it has been observed that maximum cases are also reported in this period. Also, there is a gradual shift of peak transmission from September to October from 2012 onwards. A distinct correlation between the numbers of cases and level of urbanization has been observed. There has been a significant correlation between numbers of domestic tourists and trend of dengue cases during last two decades. Though the incidence of dengue has increased, however, the case fatality rate in India has declined from 3.3% in 1996 and 0.4% in 2010 to 0.1% in 2019. Early diagnosis and timely referral played a pivotal role in bringing down the case fatality rate (CFR).

Conclusion: Dengue is a manifestation arising from the process of increasing vector density and adaptation to human habitation, as well as human-life style transformation, unplanned developmental activities compounded by climate change. Though there is a pronounced temporal and spatial heterogeneity in disease burden, a need for effective implementation of interventions and rationalization of programme resources is crucial, otherwise it will be difficult to halt the exponential temporal and spatial growth in number of dengue cases.

Keywords: dengue, epidemic, factors, transmission, dynamics, India

INTRODUCTION

Dengue is enlisted by World Health Organization (WHO) as one of ten threats to global health in 2019 and it has emerged as one of the major public health concerns with rapidly evolving epidemiology throughout tropical and subtropical regions.[1] The full global burden of the disease is still not known, however, the patterns are alarming for both human health and the economy. The number of cases reported increased from 2.2 million in 2010 to over 4.2 million in 2019 which was also the highest number ever reported.[2] The global prevalence of dengue has substantially increased in last few decades.[3] The disease is now endemic in 129 countries of Africa, Americas, Eastern Mediterranean, South-East Asia and Western

Pacific regions.[4] The Americas, South-East Asia and Western Pacific regions are the most seriously affected.

Approximately 1.8 billion (more than 70%) of the population at risk for dengue worldwide lives in member states of the WHO South-East Asia Region (SEAR) and Western Pacific Region, which also bear nearly 75% of the current global dengue disease burden. The true numbers are probably far more, since severe underreporting and mis-classification of dengue cases have been documented by the countries.[5] In SEAR, except Democratic Peoples' Republic of Korea, all 10 countries including India are endemic for dengue. India contributed 6% cases during 2009 to total dengue cases of SEAR which has been increased gradually from 10% during 2011 to 44% in 2017 and 33.5% in 2018.

In India, the occurrence of dengue fever was reported during 1956 from Vellore district in Tamil Nadu for the first time.[6] The first DHF outbreak was reported from Calcutta (present Kolkata), West Bengal in 1963. Since then, all states/Union Territories in the country (except Ladakh and Lakshadweep) have reported cases and deaths due to dengue. Repeated outbreaks of dengue were reported from many parts of country including newer areas.[7-9] This spread is attributable to many underlying factors resulting in expanding distribution of its mosquito vector (*Aedes* spp.) as well as geographic distribution of the virus. With its diverse climatic conditions and landscape, the Indian subcontinent is endemic for dengue and continues to experience outbreaks varying in spatial epidemiology and serotype.[10]

Since severe form of dengue is life threatening, laboratory confirmation is important for management of cases. Till 2006 there was limited diagnostic facility in the country. In order to establish an accurate picture of the epidemiology and to enable laboratory confirmation of diagnosis for comparison of data across the country, Government of India had established a network of laboratories in India in consultation with respective state governments during 2007 with 110 Sentinel Surveillance Hospitals (SSHs) equipped with laboratory support in the affected states. It was essential to agree on common principles and procedures for laboratory work and all the laboratories were linked into a coherent network so that data generation, compilation and feedback to all concerned was an active, continuous and sustained system under NVBDCP. To ensure uniformity in diagnosis, National Institute of Virology (NIV), Pune was entrusted for production and supply of the

IgM capture ELISA (MAC-ELISA) test kits to the laboratories under this network. In 2010, ELISA based NS1 was introduced under the programme for early diagnosis. These SSHs are linked with Apex Referral Laboratories (ARLs) having advanced diagnostic facilities. Total 695 SSHs with 16 ARLs are providing diagnostic facility throughout the country as on 2020.

Dengue virus (DENV) has four serotypes, i.e., DENV-1, DENV-2, DENV-3, and DENV-4. All of them can cause dengue fever. An episode of dengue fever may be due to the infection with a single or multiple serotypes. The ARLs are involved in identification of serotype in circulation in respective areas. In India, all 4 serotypes have been isolated.

The present paper describes the status of dengue in India, its geographical spread in last few decades, changing epidemiology over the years, associated complications, present and future challenges. The paper also provides insight of dengue control programme in India and how the surveillance system has evolved and strengthened.

MATERIAL AND METHODS

Data collection:

In India, the National Vector Borne Disease Control Programme (NVBDCP) under Ministry of Health and Family Welfare, Government of India deals with dengue in the country. At national level, reports of dengue positive cases and deaths submitted by the states are compiled and analyzed which are used for monitoring the disease trend, identify the outbreak including causes, to take corresponding preventive and responsive measures, planning, budget allocation and policy making.[11,12]

The identified laboratories (SSHs and ARLs) submit their reports with line-list to the states. In addition to the reports from SSHs, health facilities in private and public sector also submit their reports to states. All these reports are compiled and analyzed at the state level for age, gender and locality (urban and rural). After compilation and segregation, data is submitted to the Directorate of NVBDCP and is used for monitoring, providing technical guidance, framing strategies and policies.

The available data on dengue incidence for last 20 years were segregated into two decades, i.e., 2000-2009 and 2010-2019 for comparison of the temporal and spatial distribution, morbidity trend and transmission pattern in these two decades. For the purpose of comparing the endemicity based on incidence of dengue per 1000 population, the states were divided in three categories, *viz.*, High burden, Moderate burden and Low burden.[13] Available data on domestic tourism was obtained and analyzed to find out correlation between population movement and dengue.[14]

Data analysis:

Data were entered, processed and analyzed by using MS Excel 2010. Statistical Package for Social Sciences for Windows (version 24.0; SPSS, Inc., Chicago, IL) was used to perform Statistical analyses in this study.

RESULTS AND DISCUSSION

Historically, the first epidemic of clinical dengue-like illness from India was recorded in Madras (present Chennai) in 1780.[15] Dengue virus isolation in India dates back to 1945, during World War II.[16] First epidemic of dengue fever was reported from Chennai in 1956 and subsequently from Calcutta (present Kolkata) in 1963.[17] Thereafter, dengue outbreaks were reported from various parts of country from time to time. In 1991, total 6233 cases were reported from the states of Goa, Mizoram, Orissa (present Odisha) and Tamil Nadu. [17,18] Thereafter, major upsurge in dengue cases was reported in 1993 (11115 cases) and 1996 (16517 cases) in 20th century.

In 21st century, a major increase in number of cases was reported during 2003, 2010, 2012, 2013 and an exponential increase from 2015 onwards. Repeated outbreaks of dengue were reported from the states of Andhra Pradesh, Delhi, Goa, Haryana, Gujarat, Karnataka, Kerala, Maharashtra, Rajasthan, Uttar Pradesh, Puducherry, Punjab, Tamil Nadu and West Bengal in the country during this period. Till date, the highest number of dengue cases reported from the country was during 2017. Annual morbidity trend for dengue during 2000-2019 is depicted in the Fig. 1.

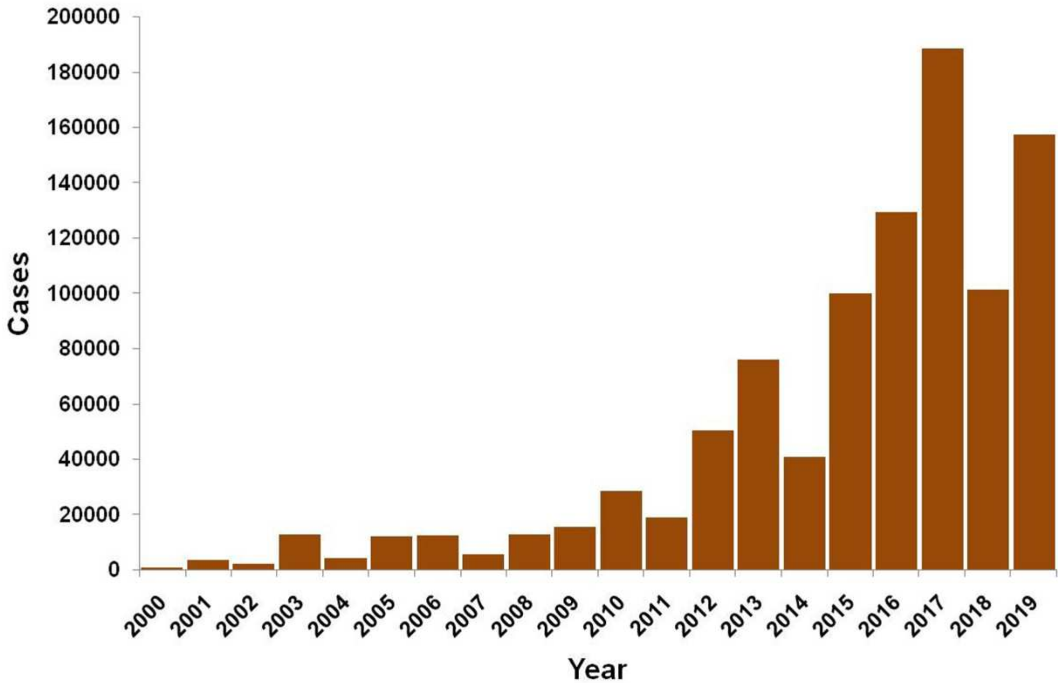

Fig. 1. Dengue morbidity trend in India during 2000-2019.

During the last two decades, significant geographical spread of dengue has been observed with an increase in number of reported cases. The number of states/UTs reporting dengue cases increased from 8 in 2000 to 35 at present. Newer areas are reporting outbreaks every year including a few from high altitudes (Bilaspur in Himachal Pradesh, Nainital, Dehradun in Uttarakhand from foothills of Himalayas). The geographical expansion of dengue in India in last two decades from 2000 to 2019 is depicted in the Fig. 2.

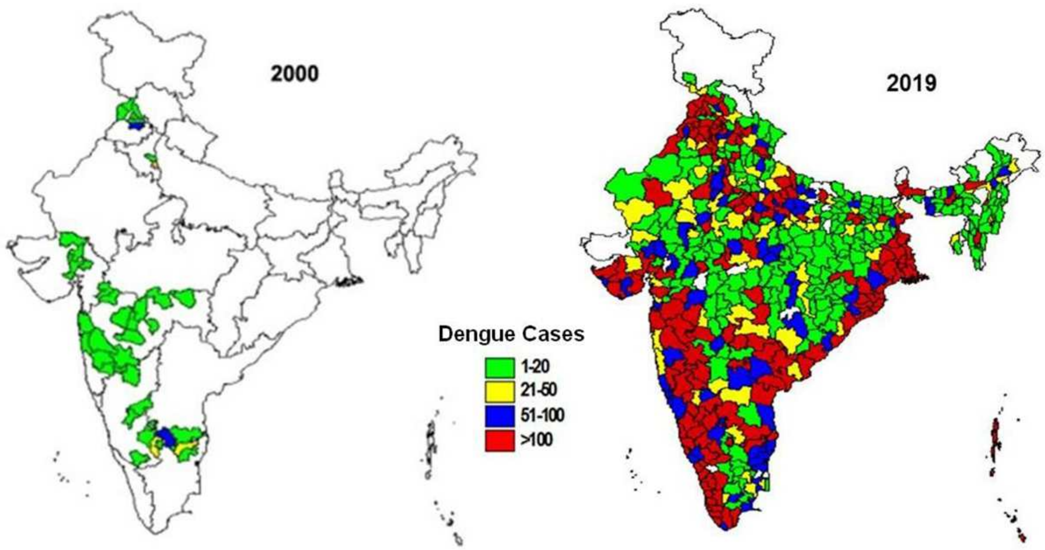

Fig. 2. Geographical spread of Dengue over the last two decades in India.

During the recent decade (2011-2019), there has been an 11 fold increase in the number of dengue cases as compared to the previous decade (2000-2009) in the country; however, it is not uniform. Out of 35 states/UTs, 10 did not report any case in the previous decade; 18 showed <100 fold increase; 3 showed 101-500 fold increase and rest 4 showed >500 fold increase. Even the states/UTs where reported dengue cases were ranging from 0-100 in 2000-2009 have shown an exponential increase in the number of cases in the recent decade, i.e., Assam from nil case in previous decade reported 18525 cases in the recent decade, 2010-2019. Similarly, in Bihar cases increased from 7 to 17337 cases (2477 fold), in Odisha from 5 to 41609 cases (8322 fold) and in Dadra and Nagar Haveli from 1 to 10464 cases (10464 fold) (Source: NVBDCP unpublished data). In the high burden states/UTs, though there is substantial increase in the number of cases, however, the increase is ranging between 6% and 12%.[12]

The proportional change in dengue cases per thousand population across the entire country between 2000-2009 and 2010-2019 was 9.2. There was a significant variation in the proportional change across different states, ranging from 8.3 among high burden states and 33.5 in moderate burden states to 176.8 in low burden states. Though 86.7% of cases were contributed by high burden states, the decadal proportional change among the low burden states is alarming. Thus, it can be a cause for concern if dengue scenario shifts in the country during coming years.[13]

Based on the transmission dynamics WHO has also grouped India in 2011 with Group 'A' Countries in SEAR where dengue is a major public health problem, leading cause of hospitalization and death among children, hyperendemicity in urban centres, spreading to rural areas and multiple virus serotypes circulating.[19]

As per recent publications regarding age-wise distribution of dengue, it has been observed that dengue presents fresh challenges in older adults.[20,21] Several studies in early 1980s reported a higher association of severe dengue and hospitalization rates with older age groups in Southeast Asia and Latin America. The age of the reported dengue cases has steadily increased in Singapore over the last four decades. The proportion of cases below 15 years of age decreased linearly from 30% in 1977 to 7% in 2011. Whereas, in the same time period, the incidence of dengue among the age group over 54 years has been steadily increased from zero to approximately 19%. In India, different age groups of both the genders are affected, however, the age-wise distribution of cases reveals maximum cases amongst age group 16 to 45 years. This possibly indicates extra-domiciliary transmission and one of the reasons for emphasizing workplace intervention under the national programme.

As per the recent data, there is a paradigm shift in dengue transmission with rapidly increasing cases from the rural areas. However, the shift is not uniform across the states due to ecological diversity.

Dengue is driven by complex interactions among vector, host and virus that are further influenced by climatic factors.[22] The meteorological variables, though have varying effects on dengue incidence, exhibit associations which coincide with the plausible biological pathways. Risks were particularly higher in meteorological events with moderate rain and conducive temperature.[23-25] Many studies have reported changing spatial patterns in dengue transmission. Reasons for such changes are related to several factors, ranging from globalization of travel and trade, which favours the propagation of pathogens and vectors, to climatic changes or modified human behaviour.[26,27]

Seasonal trend of the disease occurrence indicates that climate is an important driving force for dengue incidence. Transmission dynamics of dengue is correlated with vector density during monsoon and post-monsoon due to abundance of vector breeding in rain-fed containers.[28] Most parts of the country receive rainfall in the monsoon period (July to September), and it has been observed that majority of the dengue cases are also occurring during this period. The Indian summer monsoon typically lasts from June-September with large areas of western and central India receiving more than 90% of their total annual precipitation during the period, and southern and northwestern India receiving 50%-75% of their total annual rainfall.[29]

Rainfall and temperature are important climatic factors in vector abundance and disease transmission dynamics.[30] Precipitation is an important factor necessary for creation and maintenance of breeding sites and thus has a strong influence on vector distribution. Warm temperature and high humidity increase longevity of the adult mosquitoes and shorten the incubation period of the virus within the vector and its blood-feeding intervals, thus leading to faster viral replication and increased intensity of transmission.[31] The association between dengue and climate change varies across geographical locations and socio-environmental strata.[32] Similar observations about the correlation were also reported between dengue incidence and climatic variability with a strong positive correlation between temperature, humidity and incidence.[33]

Quarterly analyses of the data for last two decades (2000 to 2009 and 2010-2019) at national level reveals that in 2000-2009, during September to November, 65.6% of the total cases were reported, followed by 19.2% during June to August and lowest numbers of cases (4.1%) were reported during the months of March, April and May. Almost similar trend was observed in the recent decade of 2010 to 2019. Total 68% of the cases were reported during September to November, 17.7% during June to August and lowest numbers of cases i.e., 4.1% were reported during the months of March, April and May. Though the disease has a seasonal pattern with the peak of transmission after monsoon (as depicted in the Fig. 3 and 4), the seasonality and transmission pattern was not clear till the recent years. Data from last decade reveals peak of transmission in September, with a small peak in July (2003 and 2005) and sharp decline of cases from October and further reduced in November. From 2008-09, transmission continued beyond October. Gradually the peak of transmission shifted from September to October from 2012 onwards till

2018. In 2019, the peak has further shifted to November with the expansion of transmission window. The pattern of transmission and the shifting of trend are shown in Fig. 3 and 4.

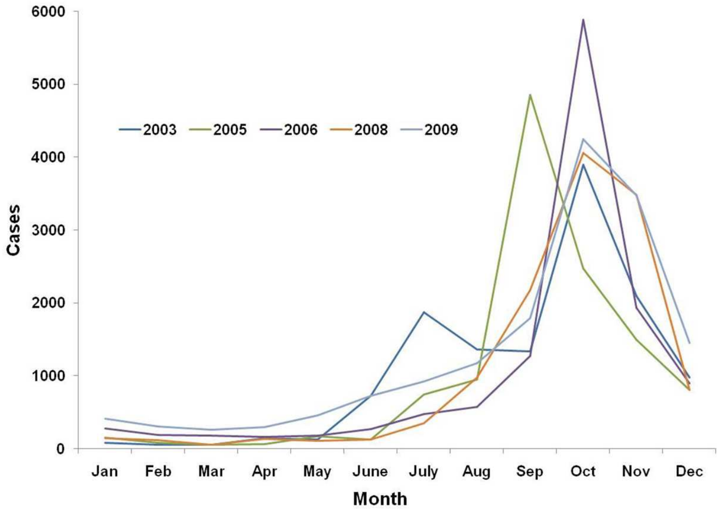

Fig. 3. Dengue trend during 2003-2009.

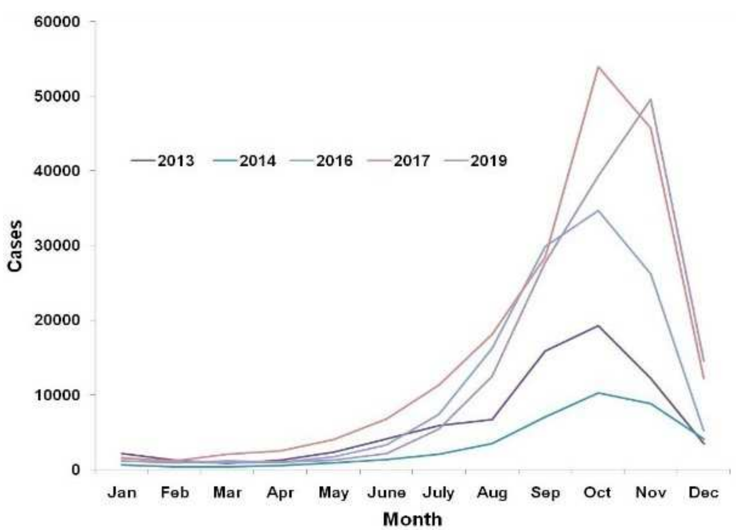

Fig. 4. Dengue trend during 2010-2019.

The gradual shift of peak transmission observed from September to October from 2012 onwards may be due to interactions of multiple factors associated with dengue ranging from urbanization, population movement, socio-economic transition and more importantly climate change. Owing to climate change, there may be 3.5 billion people worldwide who will face the risk of dengue infection during the 2085 as cautioned by Intergovernmental Panel on Climate Change.[34]

Epidemiology of dengue is an intricate phenomenon of many factors importantly rapid and unplanned urbanization, population growth, growth in industrial sector, developmental projects, construction activities, economic, social and agricultural reforms in rural areas, change in land use etc. Due to which uncontrollable and unpredictable propagation of vector has become a critical challenge for public health in both urban and rural settings. In recent years, automobile industry has developed tremendously booming the transportation system which is also responsible for spread of virus and vector into newer geographical areas earlier free of dengue. The increased population movement for education, business, tourism, pilgrimage or displacement due to natural calamities, leads to excellent conditions for multiplication and propagation of vectors which make the control activities more challenging.[8,9,35]

There are predictions that if the global trend for population growth, globalization and urbanization continues, frequency, magnitude and severity of dengue may increase many fold.[35] In India, a distinct correlation between the numbers of dengue cases and level of urbanization has been observed during the study period which may scale up in coming years.[13] The impact of population expansion and urbanization in Southeast Asia on dengue transmission had been well documented by studies carried out in Bangkok.[36]

Increasing use of non-biodegradable consumerism in recent decade is also considered as one of the reasons for increased incidence of dengue since improper solid waste management act as breeding habitats for vector species (particularly *Aedes aegypti*).[19] The quantities of solid wastes generated in urban areas on daily basis are quite enormous. The correlation between use of plastic and *Aedes* breeding is evident from the survey data of Central Cross Checking Organization of NVBDCP which revealed that the percentage of plastic containers found positive for *Aedes* breeding was 7.0% during 2007 and increased to 35.7% during 2017 (*Source:* NVBDCP unpublished data).

Population movement is a major risk factor for geographical spread of disease and introduction of newer serotypes in the population.[37] Many countries of dengue-endemic regions are also popular tourist destinations and thus the rise in international travel to these regions contributes significantly in the global spread of the disease.[38]

India also has many popular tourist destinations in its endemic states. Travelers are at a significant risk of acquiring the disease and also contribute to the disease spread in non-endemic regions.[39] There has been a consistent increase in the tourism in India in the last two decades. The number of domestic tourists has increased from 220.11 million in 2000 to 1854.93 million in 2018.[14]

Dengue-infected travellers returning home from endemic areas can place the local population at risk of disease as the vector already exists in most of the states. In such dengue free areas, incidence of dengue may be missed in the beginning because of under-diagnosis and lack of suspicion. These focal outbreaks spread to larger areas and reach near peak transmission before they are recognized and confirmed as dengue. Such outbreaks were reported from Sikkim in 2004, Moreh, Chandel district (Manipur) in 2007, Korea (Chhattisgarh) in 2012 and Pasighat, East Siang (Arunachal Pradesh) in 2015 (*Source:* NVBDCP).

Though the incidence of dengue has increased, however, the case fatality rate (CFR- deaths per 100 cases) in India has declined from 3.3% in 1996 to 0.4% in 2010, to 0.25% in 2013.[40] As per National target, dengue CFR has to be sustained at <1% at national level. After the introduction of first National Guidelines for dengue case management and repeated trainings, CFR was brought down to <1% during 2008 (0.6%). But it increased in 2011 (0.9%), when Orissa (now Odisha) reported its' first dengue outbreak with 1816 cases and 33 deaths. Punjab and Maharashtra also reported 33 and 25 deaths respectively in 2011. The reports submitted by states reveal that more deaths are reported due to association with comorbid illness like Diabetes, Hypertension, Hepatitis, Coronary Artery Disease, Chronic Kidney Disease etc. making the case management more challenging.[41]

CFR was further reduced after updation of the National Guidelines for dengue case management in 2014. It was sustained at 0.2% during 2015-2018 and brought down to 0.1% in 2019. Early diagnosis and timely referral also played a pivotal role in bringing down the CFR. The case fatality rate for dengue in India has steadily declined during 1996-2019 ($R^2 = 0.825$) which is depicted in Fig. 5.

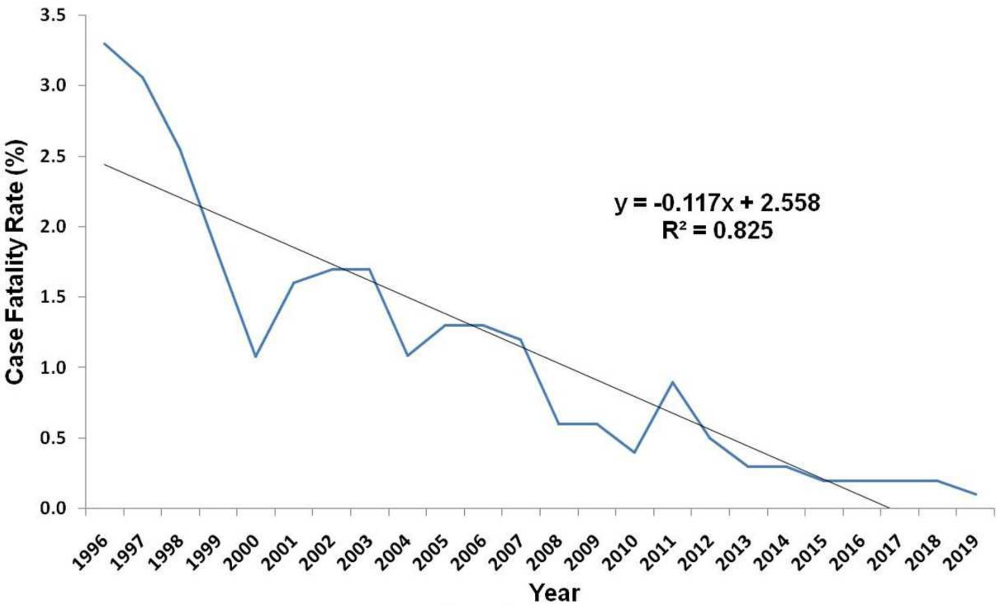

Fig. 5. Dengue case fatality rate in India during 1996-2019.

CONCLUSION

Transmission pattern of dengue through rapid epidemiological progression till the last decade has now been stabilized in India. The transmission window has been widened during recent decade as compared to the previous. The peak of dengue transmission is also shifting towards November from October in the recent decade from irregular peak of previous decade. In the southern and western states, dengue was perennial, whereas, contrary to that in the northern states, seasonal pattern with maximum cases were reported to be occurring during monsoon and post-monsoon period. However, the present pattern in shift of transmission is clearly evident that dengue can not be considered as a seasonal disease.

The network of Sentinel Surveillance Hospitals with laboratory facility was established for free diagnosis of dengue and proactive surveillance in endemic areas in 2007. Surveillance and response approaches provide high predictive certainty of any outbreak. The most commonly used indication of an impending dengue outbreak is the appearance of early cases in an area. After introduction of NS1

Antigen test in 2010, this network is playing crucial role in detection of any upsurge at its inception and alarms public health authorities to culminate before it spreads further.

Along with epidemiological observations, climate forecasts can be used potentially for prediction of disease occurrence and will allow opportunities to minimize its transmission. It is, however, highly unlikely that accurate predictions of an outbreak can be made solely on the basis of environmental observations and climatic forecasts. Nonetheless, it can possibly be used as a basis for issuing an alert, which in turn can trigger intensive surveillance efforts for the area under reference. If surveillance data confirms presence of the pathogen or an increase in vector density, it should be considered as a warning. Though there is pronounced temporal and spatial heterogeneity in disease burden of high, medium and low burden states; a need for effective implementation of interventions and rationalization of resources is crucial in the programme perspective, to halt the exponential growth in number of dengue cases in time and space.

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Authors contribution: KB and AK conceived and designed the study. KB and HS analyzed the data. KB, AK, NA and HS prepared the manuscript. KB finalized the manuscript. All authors read and approved the final manuscript.

Conflict of interest: Authors have none to declare.

REFERENCES

1. World Health Organization. Ten threats to global health in 2019. Accessed on November 17, 2020. Available from: https://www.who.int/news-room/feature-stories/ten-threats-to-global-health-in2019.

2. World Health Organization. Dengue and severe dengue. 2020. Accessed on November 17, 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue,

3. World Health Organization. Global strategy for dengue prevention and control - 2012-2020: WHO Geneva. 2012. Accessed on November 16, 2020. Available from: https://www.who.int/denguecontrol/9789241504034/en/.

4. Pan American Health Organization (PAHO). Dengue prevention and control during COVID-19 pandemic. 2020. Accessed on November 17, 2020. Available from: https://www.paho.org/en/documents/dengue-prevention-and-control-during-covid-19-pandemic.

5. World Health Organization. Prevention and Control of dengue and Dengue Haemorrhagic Fever comprehensive guidelines WHO Regional Publications SEARO No. 29, New Delhi. 1999. Accessed on November 13, 2020. Available from:

https://apps.who.int/iris/bitstream/handle/10665/204894/B4751.pdf?sequence=1&isAllowed=y.

6. Abdul Kader MS, Kandaswamy P, Appavoo NC, Anuradha. Outbreak and control of dengue in a village of Dharmapuri, Tamil Nadu. J Commun Dis. 1997;29:69-72.

7. Ilkal MA, Dhanda V, Hassan MM, *et al*. Entomological investigations during outbreaks of dengue fever in certain villages in Maharashtra state. Indian J Med Res. 1991; 93:174-8.

8. Baruah K, Kumar A, MeenaVR.Entomological investigations for DF/DHF in Alwar district, Rajasthan, India. Dengue Bulletin. 2004; 28: 213-5.

9. Baruah K, Singh IK, Agrawal CM, Dhillon GPS. An outbreak of dengue in Moreh: a small rural town in Chandel District, Manipur near Indo-Myanmar border Dengue Bulletin. 2008; 32: 219-21.

10. Raheel U, Faheem M, Riaz MN, *et al*. Dengue fever in the Indian Subcontinent: an overview. J Infect Dev Ctries. 2011; 5:239-47.

11. National Vector Borne Disease Control Programme. Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India.Long Term Action Plan for Prevention and control of dengue and Chikungunya.2007. Accessed on November 26, 2020. Available from: https://nvbdcp.gov.in/Doc/long_term_Action_Plan.pdf.

12. National Vector Borne Disease Control Programme, Directorate of Health Services, Ministry of Health & Family Welfare, Government of India.Mid Term Plan for prevention and control of dengue and Chikungunya. 2011. Accessed on November 26, 2020.Available from: https://nvbdcp.gov.in/WriteReadData/l892s/Mid-Term-Plan-dengue-Chikungunya-%202011-13.pdf.

13. Baruah K, Katewa A, Singh G, Dhingra N. Epidemiological stratification of dengue in India and strategic challenges. Dengue Bulletin. 2020; 41:149-165.

14. Number of domestic tourist visits in India from 2000 to 2018. Accessed on November 16, 2020. Available from: https://www.statista.com/statistics/207012/number-of-domestic-tourist-visits-in-india-since-2000.
15. Gupta N, Srivastava S, Jain A, Chaturvedi UC. Dengue in India. Indian J Med Res. 2012; 136:373-90.
16. Sabin AB. Research on dengue during World War II. Am J Trop Med Hyg. 1952;1:30-50.
17. Baruah K,Dhariwal AC. Epidemiology of dengue, its prevention and control in India. JIMA. 2011; 109 (2):82-6.
18. Bandyopadhyay S, Jain DC, Datta KK. Reported incidence of dengue/DHF in India 1991–1995. Dengue Bulletin. 1996; 20:33-4.
19. World Health Organization. Comprehensive Guidelines for prevention and control of dengue and dengue Haemorrhagic fever – WHO, SEARO, Revised and expanded edition. 2011. Accessed on November 16, 2020. Available from:

    https://apps.who.int/iris/bitstream/handle/10665/204894/B4751.pdf?sequence=1&isAllowed=y.
20. Guzman MG, Kouri G, Bravo J, Valdes L, Vazquez S, Halstead SB. Effect of age on outcome of secondary dengue 2 infections. Int J Infect Dis. 2002; 6:118-24.
21. Garcia-Rivera EJ, Rigau-Perez JG. Dengue severity in the elderly in Puerto Rico. Pan American Journal of Public Health Rev PanamSalud Publica. 2003; 13:362-8.
22. Arunachalam N, Murty US, Kabilan L, *et al*. Studies on dengue in rural areas of Kurnool District, Andhra Pradesh, India. J Am Mosq Control Assoc. 2004; 20: 87–90.
23. Chakravarti A, Arora R, Luxemburger C. Fifty years of dengue in India. Trans R Soc Trop Med Hyg. 2012; 106: 273-82.
24. Fischer D, Thomas SM, Beierkuhnlein C. Temperature-derived potential for the establishment of phlebotomines and flies and visceral leishmaniasis in Germany. Geospatial Health 2010; 5: 59-69.
25. Iguchi JA, Seposo XT, Honda Y. Metrological factor affecting dengue incidence in Davao, Philippines. BMC Public Health. 2018; 18:629.
26. Pfeffer M, Dobler G. What comes after bluetongue—Europe as target for exotic arboviruses. Berl Munch Tierarztl Wochenschr. 2009; 12: 458-66.
27. Randolph SE, Rogers DJ. The arrival, establishment and spread of exotic diseases: patterns and predictions. Nat Rev Microbiol. 2010; 8: 361–71.
28. Chakravarti A, Kumaria R. Eco-epidemiological analysis of dengue infection during an outbreak of dengue fever, India. J Virol. 2005; 2:32, doi:10.1186/1743-422X-2-32.
29. Halpert MS, Bell GD. Climate Assessment for 1996. Climate Prediction Center, NCEP/NWS/NOAA, Washington, D.C. Accessed on November 6, 2020. Available from: https://www.cpc.ncep. noaa.gov/products/assessments/assess_96/toc.html.

30. Hii YL , Zhu H, Ng N, Ng LC, Rocklöv J. Forecast of Dengue Incidence Using Temperature and Rainfall. PLOS Neglected Tropical Diseases. 2012; 6(11): e1908; https://doi.org/10.1371/journal.pntd.0001908
31. Tseng WC, Chen CC, Chang CC, Chu YH. Estimating the economic impacts of climate change on infectious diseases: a case study on dengue fever in Taiwan. Climatic Change. 2009; 92: 123–40.
32. Arcari P, Tapper N, Pfueller S. Regional variability in relationships between climate and dengue/DHF in Indonesia. Singapore. J Trop Geo. 2007; 28: 251-72.
33. Sharmin S, Glass K, Viennet E, Harley D. Interaction of mean temperature and daily fluctuation influences dengue incidence in Dhaka, Bangladesh. PLoS Neglected Tropical Diseases. 2015; doi:10.1371/journal.pntd.0003901.
34. Parry M, Canziani O, Palutikof J, van der Linden P, Hanson C. Climate Change 2007: Impacts, Adaptation and Vulnerability World Meteorological Organization and the United Nations Environment Programme. 2007; 47.
35. Wilder-Smith A, Gubler DJ. Geographic expansion of dengue: the impact of international travel. Med Clin North Am. 2008; 92:1377-90.
36. Cummings DA, Irizarry RA, Huang NE, *et al*. Travelling waves in the occurrence of dengue haemorrhagic fever in Thailand. Nature. 2004; 427:344-7.
37. Gubler DJ. Dengue, Urbanization and Globalization: The Unholy Trinity of the 21st Century. Trop. Med. and Health. 2011; 39 (4): 3-11; doi:10.2149/tmh.2011-S05.
38. World Health Organization. Dengue: Guidelines for Diagnosis, Treatment, Prevention and Control New ed. A joint publication of the World Health Organization (WHO) and the Special Programme for Research and Training in Tropical Diseases (TDR). Geneva, Switzerland. 2009; ISBN: 9789241547871.
39. Wilder-Smith A, Schwartz E. Dengue in travelers. N Engl J Med. 2005; 353: 924-32.
40. World Health Organization. Fact sheets on vector-borne diseases in India. 2014. Accessed on November 17, 2020. Available from: https://www.who.int/docs/default-source/searo/india/health-topic-pdf/vbd-fact-sheets.pdf?sfvrsn=c1908b04_2.
41. National Vector Borne Diseases Control Programme, Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India. National Guidelines for Clinical management of Dengue Fever.2014. Accessed on November 26, 2020. Available from: https://nvbdcp.gov.in/WriteReadData/l892s/Dengue-National-Guidelines-2014.pdf.

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