


# What India can learn from globally successful malaria elimination programmes

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## ABSTRACT

India is targeting malaria elimination by 2030.

Understanding and adopting the strategies employed by countries that have successfully eliminated malaria can serve as a crucial thrust in this direction for a geographically diverse country like India. This analysis is based on extensive literature search on malaria elimination policies, strategies and programmes adopted by nine countries (China, El Salvador, Algeria, Argentina, Uzbekistan, Paraguay, Sri Lanka, Maldives and Armenia) which have attained malaria-free status over the past decade. The key points which India can learn from their journey are mandatory time-bound response in the form of case reporting and management, rapid vector control response, continuous epidemiological and entomological surveillance, elevated community participation, more training and capacity building, private sector involvement, use of quality diagnostics, cross-border collaborations, inclusion of prevention of re-establishment programmes into the elimination plans, higher investment in research, and uninterrupted funds for successful implementation of malaria elimination programmes. These learnings would help India and other South Asian countries steer their programmes by devising tailor-made strategies for their own regions.

## INTRODUCTION

The 2021 World Malaria Report (WMR) estimated 241 million cases with approximately 0.63 million malaria deaths from 85 malaria-endemic countries ([figure 1](#)). Most of the deaths were reported in children under 5 years of age (~77%) and majority were in African nations (~96%). By 2021, 40 countries have been certified by the World Health Organization (WHO) as malaria-free,<sup>1</sup> two (Malaysia and the Islamic Republic of Iran) have achieved zero indigenous case status, and Azerbaijan and Tajikistan have applied for certification.<sup>2</sup> The world's 11 highest malaria burden countries (India being one of them), accounting for 70% of global cases, have adopted the WHO's High Burden to

## SUMMARY BOX

- ⇒ By 2021, 40 countries have been certified by the WHO as malaria-free. There are 85 malaria-endemic countries, with an estimated 241 million cases in 2020.
- ⇒ India continues to show a sustained decline in overall malaria but faces several challenges in its malaria elimination journey.
- ⇒ An overview of malaria elimination strategies which were central to the success achieved by nine countries in the past decade is presented here. Some of these can be emulated by India and other South Asian countries to overcome the challenges in their elimination drive.
- ⇒ Barriers to smooth adoption of these strategies in the Indian programme have also been described.

High Impact initiative to formulate a country-led response for malaria elimination.<sup>3</sup>

India is slated for malaria elimination by 2030.<sup>4</sup> It contributed 83% of the estimated malaria cases and 82% of malaria deaths in South-East Asia Region (SEAR) in 2020, according to the 2021 WMR. *Plasmodium falciparum* and *P. vivax* are the major prevalent parasites in India. The country contributed 51% of the global *P. vivax* cases in 2016, when the country launched the National Framework for Malaria Elimination, outlining the goals, strategies, guidelines and time-bound targets to eliminate malaria in India by 2030.<sup>4</sup> Through concerted efforts, India has managed to sustain the decline in overall burden, with 186532 cases and 93 deaths reported in 2020 by India's national programme ([figure 2](#)). Malaria endemicity in India is heterogeneous, with the highest endemicity regions being tribal and forested areas of the country. Analysis of epidemiological data from 2000 to 2019 revealed that forested districts contributed ~32% of malaria cases and 42% of mortality due to malaria, while harbouring ~6.6% of the country's



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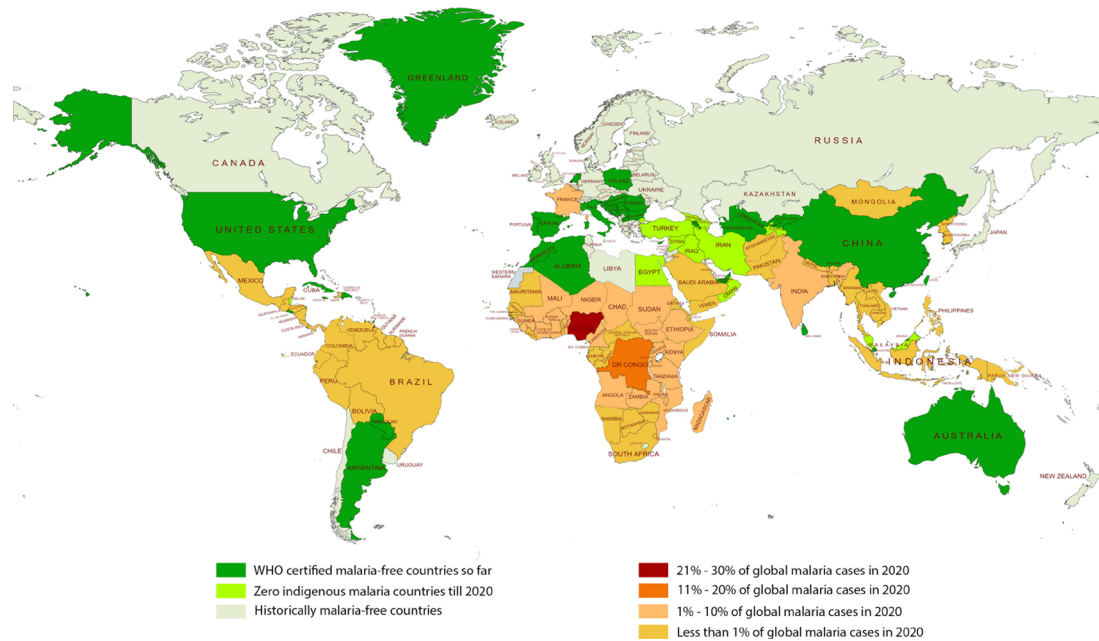
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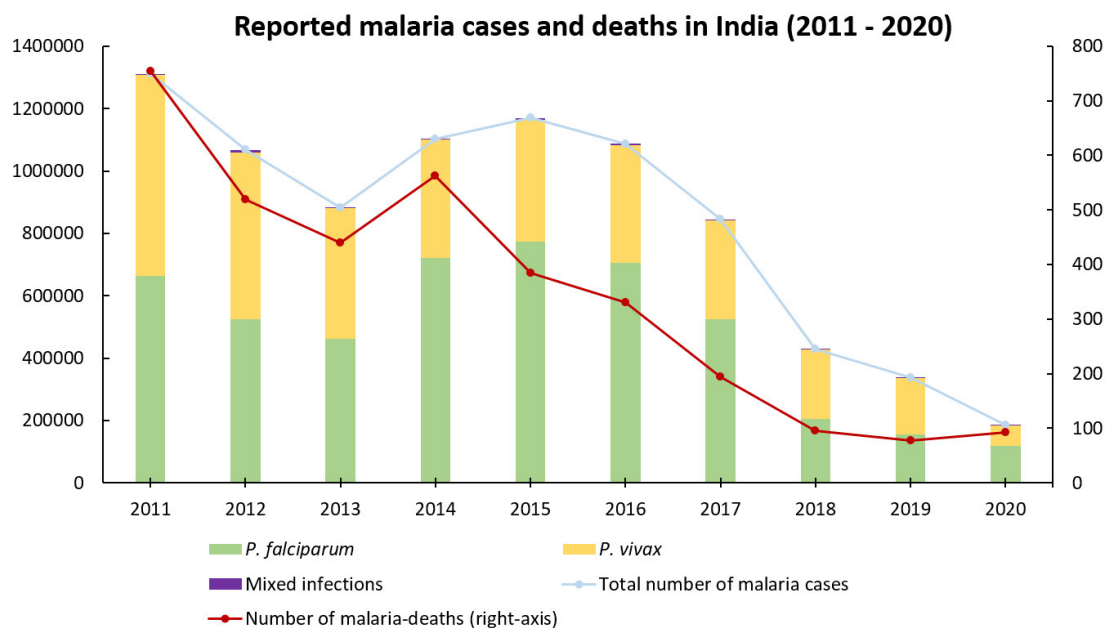


**Figure 1** World map depicting country-wise contribution of global malaria cases in 2020 and WHO-certified malaria-free countries so far.<sup>1 2</sup>

population.<sup>5</sup> The different topographies, climatic conditions and ecosystems support breeding and survival of *Anopheles* species. The major challenges towards malaria elimination in India are large population size, population movement across regions of different endemicities (the risk of parasite carriers moving from high endemic to low endemic areas), undetected asymptomatic and subpatent malaria cases, multiple vectors, threat of drug and insecticide resistance, shortage of skilled human resources, lack of reporting from the private sector, and unplanned expansion of urban and semi-urban areas. These factors

add to the complexity of malaria transmission and make malaria elimination challenging in India.

Several countries share the above challenges associated with malaria control and prevention but have successfully eliminated malaria. Here, we have selected nine countries as they have successfully eliminated malaria in the last decade (2011–2021). We chose these countries for the reason that in these 10 years the most impactful interventions, namely insecticide impregnated bed nets, rapid diagnostics and artemisinin-based drug therapy, were deployed and they made a major dent in the burden



**Figure 2** Reported number of malaria cases and deaths in India and species-wise break-up of cases in India in the last 10 years (2011–2020). Data source: Directorate of the National Centre for Vector Borne Diseases Control, Government of India, and WHO World Malaria Report 2021.<sup>2</sup>

of malaria in endemic countries.<sup>6</sup> Moreover, molecular surveillance of parasites and systematic periodic vector surveillance studies were established as the monitoring mechanisms during this decade itself. Additionally, some of these countries share a similar ecological and epidemiological scenario, such as the dominance of *P. vivax* cases in Sri Lanka and the southern part of India.

Therefore, we feel that studying these countries' practices and policies would be insightful for Indian malaria programme managers and malariologists. For example, the diverse mosquito species that caused malaria in Maldives and Uzbekistan and their elimination strategies for vector control could be additional lessons for India. Environmental engineering methods as adopted by Argentina could be helpful in tackling forest malaria in India. El Salvador had successful strategies for active surveillance of migrant populations searching for employment. In India, the migrant population is a threat for reintroducing malaria in states which have reached almost zero indigenous cases. The strategy of Algeria in combating *P. falciparum* and the involvement of non-governmental organisations (NGOs) and private sectors in Sri Lanka and Paraguay could be inspiring strategies for India to imbibe. It is essential to reach population groups even in the hard-to-reach and conflict-ridden areas to achieve elimination. In this regard, India could learn from Sri Lanka's elimination drive even during a civil war. If we consider China, its population size is similar to India. Also, its battle, like India, has been a long one but successful, and therefore these countries' strategies in eliminating malaria are a great learning lesson for us.

We also realise that it is difficult to emulate all the strategies and practices of the victorious countries due to diversity in the epidemiological and entomological picture and the different population scale in India. However, we believe that India can imbibe many of the best practices followed by these countries by closely studying the factors and influences behind the successful elimination of malaria, and if possible replicate them at the appropriate level in India. In this paper, we have analysed the strategies/policies used by these countries in their fight against malaria and have listed them in the following sections, which can serve as torchbearers for India.

## KEY STRATEGIES ADOPTED BY SOME SELECTED COUNTRIES

### China

In 2021, China, in the WHO Western Pacific Region (WHO WPR), was declared malaria-free after reporting the last indigenous malaria case in 2016<sup>7</sup>—this was a culmination of efforts of over ~70 years. *P. vivax* was the major parasite species of concern in China. At the time of transition of their programme from control to elimination in 2011, *P. vivax* malaria cases (2118 cases) were ~1.5 times of *P. falciparum* (1269 cases).<sup>8</sup> The policies and strategies which became the cornerstone of malaria elimination programme in China were the following: (1) In 1967, China launched a national effort called 'the 523 project',

which resulted in the discovery of the artemisinin group of highly effective antimalarial drugs, which are the most potent antimalarial drugs to date. (2) Within the control strategy of malaria, mass drug administration (MDA) was used on a large scale (1973–1983). (3) During the decline phase (1981–2000), the country implemented the strategy of environmental management as well as protective measures for exposed population {early distribution of insecticide impregnated bednets and indoor residual spray (IRS) for vector control}, and then a foci-based response (2000–2009) to reduce the high burden of malaria in different provinces by stratification based on transmission risk and incidence. Under this phase they also introduced the National Malaria Elimination Action Plan that combined surveillance and response with real-time reporting.<sup>9–11</sup> (4) During the malaria elimination phase (2011–2020), the country adopted local, tailor-made, pragmatic approaches with deployment of the '1-3-7' surveillance strategy, which meant prompt reporting of confirmed cases within a day to a web-based national case reporting system, further investigation within 3 days and genome sequencing to distinguish imported and indigenous cases, treatment within 3 days, and foci response and adopted reactive case detection (RACD) within 7 days to prevent further transmission.<sup>12</sup> Imported malaria was tackled by the '1-3-7' strategy and by the collaborative approaches of health professionals at the border, with polymerase chain reaction (PCR) as an additional diagnostic tool used by the reference laboratories at the counties. For prevention of re-establishment (POR), they restructured the 1-3-7 approach to 3-3-7, where the diagnosis of case is completed within 3 days, reconfirmation and epidemiological investigation are done within another 3 days, and foci investigation and response completion is done within 7 days after diagnosis. Additionally, China in 2017 initiated a subnational malaria elimination drive for individual provinces which was in tandem with the WHO 2017 Malaria Elimination Programme. They invested in building systems such as the National Institute of Parasitic Diseases and the Chinese Center for Disease Control and Prevention (China CDC), supported by capacity building and web-based reporting system at the grass-roots level. They also collaborated with the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM), which contributed to global malaria elimination efforts through collaborative projects which created an opportunity for mutual learning.<sup>12</sup>

### El Salvador

In 2021, El Salvador became the first country in the Central America of the WHO Region of the Americas (WHO AMR) to be certified as malaria-free. The last indigenous malaria case of *P. falciparum* in El Salvador was reported in 1995, while the last *P. vivax* cases were reported in 2016.<sup>13</sup> The key programmatic activities which possibly paved the way for elimination were the following: (1) geographical stratification using altitude and slide positivity rate data; (2) decentralisation

for diagnosis facilities and data reporting; (3) weekly reporting systems and analysis; (4) computerised malaria information system; (5) decision on MDA and IRS at the local and regional level; (6) mandatory reporting by the private sector and (7) outbreak response on detection of two or more cases.<sup>14</sup>

### Algeria

In 2019, Algeria, in the WHO African Region (AFR), was declared malaria-free by the WHO, with the last case of indigenous malaria reported in 2015. *P. falciparum* was the dominant parasite species. Geographical information system (GIS) mapping to identify imported cases of malaria, epidemiological surveys around each positive case and entomological surveillance to document the movement of mosquito vectors helped in curtailing imported malaria.<sup>15</sup>

### Argentina

Argentina, in the WHO AMR, was certified by the WHO as a malaria-free country in 2019. In this South American country, the last indigenous case was reported in 2010. The most prevalent parasites in the country were *P. falciparum* and *P. vivax*. The key elements were IRS including at border areas, collaboration between border countries, prompt IRS by brigades on diagnosis of a malaria case and surveillance within the 500 meter radius of the identified case. Management of estuaries as breeding sites via infrastructural development and reintroduction of vertical vegetation, removal of green algae, and IRS with dichloro-diphenyl-trichloroethane (DDT) were especially helpful.<sup>16</sup>

### Uzbekistan

Uzbekistan, in the WHO European Region (WHO EUR), was declared malaria-free in 2018. The last locally acquired malaria case in Uzbekistan was reported in 2010. Both *P. falciparum* and *P. vivax* infections were prevalent in the country. Private sector involvement, supervised treatment for *P. vivax* cases, MDA, larvivorous fish *Gambusia* for vector control, and annual surveys to identify and liquidate water bodies acting as mosquito breeding grounds helped the country achieve malaria-free status in 2018.<sup>17</sup>

### Paraguay

Paraguay, in the WHO AMR, was declared malaria-free by the WHO in 2018, with the last indigenous case reported in 2011.<sup>18</sup> *P. falciparum* was the major reported parasite. Reporting of cases within 24 hours of detection and timely treatment, investigation of outbreaks within 24 hours of a case, GIS and establishment of a behavioural change communications plan for at-risk populations were some of the key steps.

### Sri Lanka

Sri Lanka, which belongs to the WHO SEAR, was declared malaria-free in 2016, with the last case of indigenous *P. vivax* infection reported in 2012.<sup>19 20</sup> *P. vivax* and

*P. falciparum* were the most prevalent parasites. Some of the crucial steps taken were the following: (1) the '1, 2, 3 approach' that is confirmation within 24 hours (1 day) of malaria case by either a public or a private facility, investigation within 48 hours (2 days) and RACD within 72 hours (3 days); (2) close and periodic follow-up upto one year to tackle the resurgence of *P. vivax* cases in malaria camps and prevention of relapse due to lack of treatment compliance by directly observed primaquine (PQ) treatment was adopted<sup>20 21</sup>; (3) public-private partnerships; (4) mobile clinics and (5) stringent vigilance on imported malaria, which is key to POR of malaria in Sri Lanka.<sup>22 23</sup> Despite facing a civil war, Sri Lanka achieved the elimination of malaria. The realisation that malaria is deadly but can be prevented and cured, the motivation and cooperation of conflicting groups to work with the government to protect the populations, and the involvement of neutral organisations played crucial roles.<sup>24</sup>

### Maldives

Maldives became the first country within the WHO SEAR to eliminate malaria in 2015. The last case of indigenous *P. vivax* was reported in 1984, after which the reported cases were only from imported malaria. There are a total of 1200 islands in Maldives with large forested areas, out of which 198 are habitable. Important interventions which helped the country were the following: (1) hospital boat, called *Golden Ray*, which was equipped with medicines moved between the islands to treat patients (2) epidemiological and entomological surveys along with efforts to wipe out malaria vectors and (3) vigilance of imported malaria cases and vectors.<sup>25</sup>

### Armenia

Armenia, in the WHO EUR, attained malaria-free status in 2011. The country reported its last indigenous case in 2009. *P. vivax* was the dominant parasite species and *P. falciparum* was via imported malaria. Mandatory notification, hospitalisation (in no later than 1–3 days), treatment of asymptomatic cases by supervised treatment, prophylaxis among military personnel and follow-up of patients for a period of 3 years for monitoring relapses were important steps.<sup>26 27</sup>

## CURRENT CHALLENGES TO INDIA'S MALARIA ELIMINATION PROGRAMME

India has managed to sustain the decline in overall malaria burden, but some of the significant current challenges which make malaria intractable in India are the following:

1. Incomplete understanding of the actual burden of malaria as the private sector is not involved in data reporting, although it caters to the healthcare needs of a large section of the population in India.
2. Inaccessible and remote areas of India are malaria-endemic (with persistent malaria), and providing health services to these communities becomes extremely difficult especially during monsoon and post-

monsoon (transmission seasons) when these areas are cut off from the usual mode of communication and transportation.

3. Uncertain contribution of asymptomatic and low-density malaria infections to continued transmission of malaria.
4. Inadequate coverage and use of vector control products due to huge target population and time lag in replacements through a single channel of national control programme.
5. Cross-border malaria and internal migration.
6. Substantial burden of *P. vivax* malaria and weak mitigation policies and tools, such as missed diagnosis by the current methods, poor compliance to PQ's 2-week course and lack of monitoring of relapses.
7. Emergence of drug and insecticide resistance in India's neighbouring countries and border areas poses a threat of introduction of resistant parasites and vectors in the country.
8. Lack of skilled human resource in the national programme has been a long-standing challenge and more so with the integration of malaria programme with the general health services. Grass-root-level workers and healthcare staff are shared between several healthcare schemes and programmes and malaria may not be given the prioritisation it needs, more so when the target to report the last indigenous case is 2027 and elimination certification by 2030.

### LESSONS INDIA CAN LEARN IN ITS PROGRAMME TO ACCELERATE MALARIA ELIMINATION

The national strategies for malaria elimination in the nine countries were mainly based on WHO guidelines and included intensified surveillance, vector control programmes, early diagnosis, rigorous case investigations, free and prompt treatment of patients based on malaria cases, and follow-ups. The key strategies of the nine countries are summarised in [table 1](#).

India, in its national programme for malaria elimination, has all the major and essential elements well documented, and perhaps most of the steps are in the right direction to make malaria elimination possible. Additionally, certain strategies/policies/activities of the successful countries can be emulated in the following facets of the Indian elimination programme:

#### Strengthening of surveillance

1. Time-bound response by countries, such as the 1-3-7 strategy of China and the 1, 2, 3 strategy of Sri Lanka: a strong surveillance system was the most important pillar that played a crucial role in malaria elimination for most countries. The pivotal strategy, which could be adopted in our context, could be similar to those used in China and Sri Lanka. This will need to be supported by a strong web-based system that connects the public and private sectors at the level of healthcare to a central portal system. In India, at present, there is no

**Table 1** Countries certified as malaria-free by the WHO from 2011 to 2021 and their key elimination strategies

	Mandatory time-bound response	Case management	Vector control response	Continuous surveillance	Community participation	Training and capacity building	Private sector involvement	Quality diagnostics	Cross-border collaborations	POR programmes	Uninterrupted funds
China (2021)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
El Salvador (2021)		✓	✓	✓	✓	✓	✓	✓	✓		✓
Algeria (2019)		✓	✓	✓		✓			✓		
Argentina (2019)		✓	✓	✓	✓	✓		✓	✓		
Uzbekistan (2018)		✓	✓	✓	✓	✓	✓	✓	✓		
Paraguay (2018)		✓	✓	✓	✓		✓	✓	✓		✓
Sri Lanka (2016)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maldives (2015)		✓	✓	✓	✓	✓		✓	✓	✓	
Armenia (2011)		✓	✓	✓		✓		✓			✓
POR, prevention of re-establishment.											

time-bound strategy for mitigation of malaria cases on detection of a case. Hence, adopting some time frame would be useful in early management and thus in curtailing transmission.<sup>28</sup>

2. Modernisation of surveillance system, that is, digital near real-time surveillance and smart surveillance systems: in China, a smart web-based health information system called the Chinese information system for disease control and prevention used time-bound alert Short Message Service (SMS) for follow-up and control measures. El Salvador also used computerised management information system to overcome delays in manual reporting system.<sup>14 29</sup> Such strong real-time surveillance and data-based decision making at the local level were also applied in Uzbekistan and Maldives. Countries like China and El Salvador overcame barriers by integrating digital technology and mobile SMS systems in their malaria elimination programme. Although surveillance has been strengthened in the malaria elimination drive in India, it still needs to be more inclusive and comprehensive. Therefore, this is the right time for India to adopt smart digital tools for surveillance,<sup>30</sup> and discussions at the national malaria elimination programme have already begun in this direction. Following the same, the ICMR-National Institute of Malaria Research has developed a Malaria Dashboard that is ready for data reporting, collation, visualisation and research. Case-based and foci-based examinations are much required, particularly in low transmission areas to achieve elimination in India.<sup>31</sup> Hence, implementation of a robust surveillance system (digital methods such as electronic dashboards) is very important.<sup>30 32</sup> It is therefore an opportunity for India to revamp its surveillance strategies from the archaic paper-based and aggregated systems to near real-time, digital and technology-backed integrated systems.<sup>33</sup> Such changes may fasten the process of malaria elimination.
3. Annual Parasite Index (API)-based stratification: India has stratified the states and districts (unit of implementation) based on their API. The subnational plan for elimination, although adopted by India, is yet to be fully deployed to certify states as malaria-free as and when they achieve this status.
4. Focus on high transmission areas: India, in its national strategic plan, has focused on high-burden endemic regions. Regular process monitoring, innovative research and prompt translation in policy along with increased community mobilisation will play an important role in reducing malaria cases.
5. Involvement of the private sector in reporting of malaria case data: Sri Lanka, El Salvador and Paraguay have led by example and allowed active involvement of the private sector in the mainstream of malaria surveillance and management. In India, participation of the private sector is crucial because it provides 60%–70% of healthcare. The inclusion of this sector in India is in the nascent stages as there is no concrete roadmap

towards this aim. We have suggested ways to involve the private sector in our previous work.<sup>34</sup> Additionally, India could gain insights from the national programmes of Sri Lanka, El Salvador and Paraguay which have actively involved private providers. India has made malaria a notifiable disease in 31 states, but it is only an initial step towards tackling under-reporting and underestimation of malaria burden in the country. Rapid diagnostics as field diagnostics have been the cornerstone of early identification and thus timely management of cases. Over-the-counter availability of rapid diagnostic tests (RDTs) in the commercial sector can empower people to self-diagnosis and reporting to the healthcare system.<sup>34</sup>

### Use of molecular tools of diagnosis and national reference laboratories

Prompt and accurate diagnosis of malaria cases, including the hidden burden of asymptomatic and subpatent infections, is important as it will help in treatment and thus cessation of transmission. Adoption of molecular methods for diagnosis in the national programme would be a way forward. The WHO recommends microscopy as the gold standard and RDT as field diagnostics. Use of molecular tools like PCR and loop-mediated isothermal amplification for RACD, as adopted by China, was useful in the identification and resolution of all malaria cases. India suffers from considerable burden of low-density infections which escape detection by routine diagnostics.<sup>31</sup> The development of field-friendly, point-of-care/collection molecular tests could help bring out the burden and management of subpatent malaria.<sup>35</sup> District-level healthcare facilities have been empowered in terms of infrastructure and expertise owing to the COVID-19 pandemic and these can be co-opted for diagnosis of submicroscopic malaria.<sup>36 37</sup> In India, the barrier to adopting molecular tools in its routine programme would be the prohibitive cost of infrastructure and training of the laboratory workforce. However, countries like China and Sri Lanka have shown the way that it is possible to use these more sensitive tools as routine diagnostics. The establishment of the National Reference Laboratory for quality assurance was adopted by China, El Salvador, Uzbekistan, Paraguay and Armenia. Having such central hub that connects all states and district-level laboratories can step up India's centralized diagnostic structure.

### Management

1. India, in its national guidelines, has a special emphasis on *P. vivax* elimination. The foreseeable barriers for India are poor compliance of PQ treatment, inadequate follow-up of patients with *P. vivax* malaria, cross-border and migration issues. Compliance to antimalarials, especially for *P. vivax* malaria, which needs 14-day treatment with PQ is a daunting challenge in India. Almost half of India's malaria burden is *P. vivax* malaria. It is widely acknowledged that it will be difficult to achieve elimination of *P. vivax* as compared

with *P. falciparum*. Adoption of single-day treatment with tafenoquine may be considered by India after due regulatory consideration.<sup>38</sup> The issue of compliance can be overcome if the *P. vivax* antimalarial therapy is administered as directly observed treatment (DOT). We could follow the Sri Lankan example which to tackle the *P. vivax* resurgence in army camps adopted PQ directly observed treatment for infected army personnel.<sup>20 21</sup> El Salvador and Uzbekistan supervised the PQ treatment. Similarly, Armenia had also introduced DOTs for both *P. falciparum* and *P. vivax* control in their national programme. Good compliance to 14-day radical treatment with primaquine along with estimation of glucose-6-phosphate dehydrogenase (G6PD) deficiency in the population, addressing low-density infections and tackling asymptomatics will play pivotal role in *P. vivax* elimination.

2. Follow-up of *P. vivax* cases to capture relapse cases: *P. vivax* malaria is characterised by latent hypnozoites which can get activated in variable durations. Therefore, it is important to follow these cases so as to capture relapse cases and treat them on time. In the national guidelines of Sri Lanka, El Salvador, Armenia, Algeria and Maldives, at least 6 months to 1 year of follow-up was practised.
3. Cross-border malaria: countries which have achieved malaria elimination have robust mitigation strategies against imported malaria. Cross-country cooperation is at the centre of the elimination programme. Strict surveillance of cross-border transmission as embraced by China, Algeria, El Salvador, Sri Lanka, Armenia, Paraguay and Uzbekistan with deployment of mobile teams and examination of travellers from malaria-endemic countries through RACD could be possible steps which need induction in our control guidelines. India has porous borders with many neighbouring malaria-endemic countries and also poses a threat to the neighbouring countries which are at the cusp of elimination such as Bhutan.<sup>39</sup> Therefore, India should institute strong parasite and vector surveillance programmes to curtail exchange. Cross-border malaria issues have been handled well by China, Algeria, El Salvador, Sri Lanka, Armenia, Paraguay and Uzbekistan by intense surveillance of migrants and travellers.
4. Internal migration: El Salvador had carried out active surveillance and chloroquine+primaquine (CQ+PQ) single-dose prophylaxis for migrant populations in employments such as cotton production, coffee fields or factories.<sup>13</sup> In India, the interstate movement of people is high for employment, tourism and other purposes. Special attention is needed in areas where malaria elimination status has progressed from control to pre-elimination phase. For example, the state of Punjab has shown a drastic decline in the number of malaria cases.<sup>40</sup> However, there is always a risk of re-establishment owing to the constant influx of migrant labourers for construction/agriculture activities in the state. This mobile population is very often from

malaria-endemic states such as Bihar, Chhattisgarh and Jharkhand and thus could act as reservoirs for the parasite resulting in re-establishment of infection. Thus, India could also consider devising plans for screening, treating and reporting of malaria cases among such migrant populations.

5. Many malaria elimination demonstration projects have successfully shown that adopting certain strategies can dent the malaria endemicity situation. One of the programmes, the Comprehensive Case Management Plan (CCMP), has been adopted by the government of Odisha as the Durgama Anchalare Malaria Nirakarana (DAMaN) programme for mitigation of malaria in inaccessible areas and has contributed to a remarkable decline in malaria. Biannual screening of malaria in mass surveys and subsequent treatment has been adopted as a programme strategy in this state's malaria plan.<sup>41</sup>
6. In order to implement public-private partnerships, Indian policy makers should devise a well-defined strategy to work locally and focally at panchayat/district levels with emphasis on common platform for reporting, regular communication and assessment of progress.

#### Vector control and management of resistance

1. Robust vector surveillance using smart tools: China, Algeria and Sri Lanka adopted a robust vector surveillance with the use of GIS and spatiotemporal analysis. Similar to these platforms, a web-based database of vector surveillance should be adopted in India.
2. Insecticide resistance management (IRM): Resistance to routinely used insecticides (DDT and some synthetic pyrethroids) has been reported in the malaria-endemic areas of India. Frequency of insecticide resistance should be monitored at sentinel sites periodically. IRM with rotational or mosaic pattern with insecticides of different mechanisms of action has been deployed by Sri Lanka. Focal IRS in areas such as plantations, factories and along countries' border with high endemicity regions have been adopted by China, Sri Lanka and El Salvador. Environmental engineering methods were adopted by Argentina. All these strategies and tools could be useful to India with its diverse geographical regions. Laboratory studies conducted in India are indicative that newer tools like attractive toxic sugar baits (ATSBs) could be a promising vector control.<sup>42</sup>
3. Integrated vector management (IVM): IRM and IVM, although discussed in India, are not holistically implemented. In Maldives, elimination of malaria vectors was one of the key contributing factors to maintaining a malaria-free status since 1984. El Salvador and Armenia implemented water management projects to reduce mosquito breeding sites and also planted neem trees to prevent mosquitoes in the surrounding areas. India should consider IVM as an umbrella vector management programme.

### Role of partners

Currently, the different partners and stakeholders in India are working in silos towards the common goal of malaria elimination. There is a lack of cohesion at the central level and thus at the peripheral levels. Experiences of other countries can be leveraged on using the strengths of partner organisations and taking them in the fold of the national programme. Sri Lanka's successful elimination was achieved despite facing a civil war. Indian policy makers could involve NGOs, private partners and voluntary collaborative network, as adopted by Sri Lanka, El Salvador, Armenia, Paraguay and Algeria, to enhance successful deployment of all components of malaria elimination. Involvement of intersectoral ministries and uninterrupted funding were adopted in Sri Lanka to eliminate the disease. National and international partners are crucial to achieving malaria elimination, especially for overcoming the last-mile challenges.<sup>39</sup>

### Prevention of re-establishment strategies

POR of malaria transmission in a malaria-free country is a daunting task. After elimination, active case detection (ACD) with mobile malaria clinics is still maintained in Sri Lanka. Algeria has taken stern steps in quickly identifying any imported malaria, followed by appropriate POR actions. Obligatory notification and reporting of malaria and timely epidemiological investigation of each imported case and focus are followed by Paraguay, Uzbekistan, El Salvador and Maldives. These activities would need to be undertaken by the states which have eliminated malaria to prevent its re-establishment from other states. India would need robust alert systems and prompt surveillance and diagnostics to mitigate the threat of imported malaria, as done by other countries.

### Domestic funding and sustained political commitment

In addition to global and international funding (GFATM, World Bank, President's Malaria Initiative (PMI)/United States Agency for International Development (USAID)), China, Sri Lanka, Algeria, Armenia, Uzbekistan and El Salvador allotted heavy domestic funding for malaria elimination.<sup>2</sup> In India, the national programme is mainly funded by the Government of India, but the Global Fund is the major financial source for procurement of long-lasting insecticidal nets (LLINs) in India. From 2016 to 2018, ~80% (~40 million) of the LLINs distributed in the country were procured by the Global Fund financial resources. Political and financial commitment from the government is vital to maintain the momentum of the malaria elimination programme in India.<sup>43</sup> India needs to pledge substantial funds for sustenance of the national programme for malaria elimination and beyond. Provision of funds in the scenario of withdrawal of the Global Fund also needs to be created.

### Promoting research

Research and Development (R&D) need constant thrust as the limitations of the currently available tools can

hinder the achievement of malaria elimination, and threats like drug and vector resistance need investment in research to discover newer tools. Malaria-free countries have invested in research to identify the most optimum strategies, tools and operations. China invested in R&D and artemisinin derivatives have been the cornerstone of malaria treatment. In 1967, the CDC Division of Parasitic Diseases was set up in San Salvador.<sup>44</sup> Efforts should be put in to develop and validate non-histidine-rich protein (non-HRP) 2/3-based RDTs, feasibility of a single dose of tafenoquine for *P. vivax* malaria<sup>38</sup>, field-friendly molecular tools, and robust research to assess the impact of climate change on malaria transmission.<sup>45</sup> Research into the possible zoonotic transmission of malaria parasites in India should also be considered. Innovative approaches to mosquito control like ATSB,<sup>42</sup> insecticide impregnated clothing, hammocks etc could be explored to address the challenges associated with forest malaria,<sup>5</sup> outdoor biting and insecticide resistance. Concerted efforts have been initiated in this direction by a nodal research body of the Government of India.<sup>46</sup> Consolidation and implementation of the research findings into policy and practice would provide the necessary thrust to malaria elimination in India. However, poor investment and lack of priority to continue research once elimination is near or achieved can derail research programmes on promising tools. Advocacy for continued and breakthrough research needs to be made at the highest level.

### INDIA'S TRACK RECORD IN ELIMINATION OF OTHER INFECTIOUS DISEASES

Despite enormous population and diverse geographical conditions, India has successfully eliminated polio (2014),<sup>47</sup> smallpox (1977)<sup>48</sup> and guinea worm disease (2000)<sup>49 50</sup> and is possibly on track to eliminate tuberculosis by 2025.

India was certified polio-free in 2014. Considering the scale at which the polio vaccination drive was conducted, it can be considered as one of the biggest success stories. However, the path was not easy for India. The challenges ranged from arranging logistics for a large population and reaching even the hard-to-reach areas, building trust, changing perceptions and convincing the communities to accept vaccines amidst anti-vaccine movements.<sup>51</sup> This was achieved by enhanced communication within the community, by involving local representatives and religious leaders, and by providing basic health packages to address immediate concerns regarding other health issues. Screening of migrant and mobile populations and international travellers played a crucial role in identifying potential sources of continued transmission. In addition to government officials, several partners worked collectively in the polio elimination drive. Defining the role and accountability of each of the public and private stakeholder was also done to avoid redundancy in the tasks performed. Further, the accuracy of data was monitored to get reliable information on disease prevalence. The



need for training healthcare workers was identified and addressed by capacity building and repeated trainings.<sup>52</sup>

## CONCLUSION

As India is hurtling towards malaria elimination, it is the most appropriate time to review and assess the strategies and practices by countries that have been successful in achieving malaria elimination. The same can be tailored according to India and neighbouring South Asian countries as they share several commonalities in the context of environmental conditions, vectors, parasites, community behaviour and health infrastructures. These shared features could be the basis of cross-learnings and can help India and others steer their malaria elimination programme.

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