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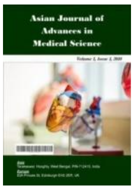

MALARIA VECTOR CONTROL HISTORY AND CHALLENGES IN ETHIOPIA: MINI REVIEW

SOLOMON KINDE[1*], ABATE WALDETENSAI[1], ALEMINESH HAILEMARIYAM[1] AND YONAS WULETAW[1]

[1]Ethiopia Public Health Institute, Public Health Entomology Research Team, Addis Ababa, Ethiopia.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Mini-review Article

ABSTRACT

In Ethiopia, malaria has been an ancient and historical vector-borne disease. Over 75% of the land surface is malarious, and around 60% of the population is malaria at risk with varying intensity. In 1966, concerted eradication efforts began with the motivation being to eradicate malaria from Ethiopia by 1980. And indoor residual spray (IRS) with Dichloro Diphenyl Trichloroethane (DDT) and trained local staff on vector control methods was the main focus. However, malaria prevalence increased, and the major epidemic occurs every 5-8 years. It manifests a significant problem to the economic and social development of the country. The government directed a malaria control action plan under the objectives of Roll Back Malaria (RBM), which guided prevention and control activities. Between 2005 to 2018, Ethiopia distributed around 100 million long-lasting insecticide nets (LLINs), and 93.7% of the at-risk population were protected up to 2018 by the IRS. The malaria prevalence rate in 2011 was 1.3 whereas, in 2015, it decreased to 0.5. Ethiopia plans to achieve nationwide malaria elimination by 2030. Malaria is still public health threaten disease & accounts for 30% of the overall disability-adjusted life years lost in Ethiopia. And vector control interventions effectiveness has a serious obstacle due to resistance development to all available insecticide and the flexibility of *Anopheles* mosquito species behavior. Focuses on the history of malaria eradication and control and the controversial issues in malaria elimination. Requires thoughtful consideration of all risks, benefits, and challenges.

Keywords: Malaria; vector control; elimination; eradication; vector resistance.

1. INTRODUCTION

In Ethiopia, malaria has been an ancient and historical vector-borne disease. Its transmission documentation begins probably in the 1930s [1]. Over 75% of the land surface of the country is malarious. Around 60% of the population is at risk of malaria disease, one of the public health problems to date with varying intensity [2,3]. Before 1930, in the country, about the epidemiology of malaria in Ethiopia little was known. Between 1936 and 1941, conducted the earliest malaria surveys. They investigated the general health status, the dominant vectors, and infection prevalence. This investigation laid the foundation for understanding the basic malaria epidemiology across the country [4,5]. In March 1966, concerted eradication efforts began with the motivation being to eradicate malaria from Ethiopia by 1980 [6,7]. However, during the late 1980s and the second half of the 1990s, malaria

**Corresponding author: Email: solomonkinde1972@gmail.com;*

epidemics frequency increased, and malaria vector control service was much more depleted [8,9]. Following this challenge, in 2000, the government planned new action and signed the Abuja declaration to halve malaria mortality by 2010 [10]. Starting from 2001, the national malaria strategic plan developed with unprecedented investment and sustained high coverage of LLINs and IRS, which led to a marked reduction of malaria morbidity and mortality with some annual variation as of the rollback era [11]. The ministry of health developed a malaria elimination road map in 2014 to eliminate the disease by 2030 [12].

However, evidence from different areas indicates that the disease is still a life-threatening disease & accounts for 30% of the overall disability-adjusted life years lost in Ethiopia. Three fourth the country's land is malarious, 53% of the total community living in the malaria-risk area. Moreover, malaria vectors have the rapid spread of resistance against all the classes of insecticides resistance, bed net miss-use, and the flexibility of mosquito behavior, which all pose a challenge to eliminate the disease [13-16]. Reviews related to malaria control, prevention, and elimination interventions are important gap identification methods for one country. Moreover, in Ethiopia, not enough history-based reviews relate to challenges and gaps for malaria control intervention.

A periodic joint malaria program needs a program performance review (MPR) for reviewing the progress and performance of country malaria control programs within the national health and development strategies. It is to improve performance and redefine the strategic direction and focus of the program to summarize the findings and actions emerging from the control effort history.

The objective of this mini-review is to review the literature and provide an update on past and current Ethiopian efforts to control malaria vectors, discuss the challenges surrounding these efforts, and suggest priorities for future malaria elimination strategies.

2. METHODS

2.1 Search Method

The authors searched the computerized medical bibliographic on PubMed, EMBASE, CINAHI, and Web of Science in the following keywords: Malaria and its control, malaria burden in Ethiopia, the success of malaria control in Ethiopia, malaria control challenges in Ethiopia, Malaria vector control in Ethiopia based on review guideline. Articles and documents that evaluated malaria vector control history from 1937-2020 included. The review relied on published on peer review, journals, and web-based organizational published data. Articles not related to malaria vector control and elimination were excluded.

2.2 Malaria Disease Burden History in Ethiopia

In Ethiopia, the epidemiology of malaria before the late 1930s was not known [1]. Though due to limited sources of documents, malaria is believed to be a disease of ancient times and documented the problem causes an impact on the health and socioeconomic status of the country [17]. Over 75% of the land surface is below 2000 meter above sea level, and differences in altitude and climate in a year. Transmission shows seasonal from September to December and from March to May following rainy seasons [18]. Since 1953, an epidemic has occurred near Gonder along lake Tana and has caused around 7000 deaths. Highland areas of the country include; Showa, Gojam, Beghemder, Wollo, part of Wollega, Arusi, Harer, and Sidamo epidemics with unusual intensity occurred between July and December in 1958. That resulted in high morbidity and mortality [19]. This major epidemic occurs every 5-8 years with the commonest focal epidemics form: 1980, 1986/87/88, 1990, 1997/98, and 2002/03 [20-22]. Higher rainfall, temperature, and humidity could be the driving factor for the epidemic. Usually, transmission patterns show, unstable that results in all age groups of the population the protective immunity are generally low and become at risk for malaria infection [23]. Clinical malaria cases in 1990 around four to five million, to almost one million in the 2018 reporting period, and yet, the disease remains public health problem [24,25].

2.3 Impacts of Malaria in Ethiopia

In Ethiopia, the malaria season coincides with peak economic activities. Because both rainfall and temperature levels are high and conducive for cultivation, weeding, harvesting, and winnowing. Similarly, Vector density and infection rate also peak in the same season [26]. So, in many years it causes direct impact like individual and public expenditure costs related to prevention and control of the disease. Indirect costs include; lost productivity or income due to illness or death. It manifests a significant problem to the economic and social development of the country due to epidemic occurrence in various areas during harvesting season. This Couse to reduce agricultural productivity and the consequence lead to food insecurity and poverty. Therefore, a large number of people are kept from work by debilitating illnesses [27]. On the other hand, because of fear of malaria, people movement abstain from working or settle in highly endemic areas. Overall, malaria causes not only health issues but also overwhelming economic growth [26].

2.4 Malaria Eradication and Control Program in Ethiopia

Between 1936 and 1941, Ethiopia conducted the earliest malaria surveys. It was the foundation for the Ethiopian government for the first time to organize malaria control efforts and eradication projects in 1959 [4,5]. Following this, four pilot projects were established in selected places: The Kobo Chercher plain, the Dembia plain, the upper Awash valley, and the low land area of Gambella [28]. IRS with DDT and trained local staff on vector control methods was the main focus. Based on the results from the four pilot projects, the Ethiopian government kept a commitment to national malaria eradication. The national malaria training center was established at Nazareth in 1959 to accomplish the eradication program. Then intensive eradication efforts began in 1966, with a desire to eradicate malaria from Ethiopia by 1980 [6,7]. However, up to the 1990s, the epidemic occurrence increased in frequency, and malaria control service became much more tired, so the government directed a new malaria control action plan. In 2000, signed the Abuja declaration in support of the Roll Back Malaria to decrease 50% of malaria mortality by 2010 [8-10]. From 2001, develop a national malaria strategic plan at a different time (2001- 2005, 2006-2010,2010-2013 and 2014-2020) with the objectives of RBM, which guided prevention and control activities. Due to these sustained and ongoing efforts, markedly increased the public health intervention for the at-risk communities [22,29,30]. In 2021, the program will be named a national malaria elimination program, which calls for further reorientation to achieve the national endeavor of elimination. Malaria control efforts show good progress to control the disease, malaria cases, and death decline with varying intensity. The Ethiopia ministry of health remains committed to eliminating malaria by 2030 [12].

2.5 Malaria Vector Control Intervention Types: Past and Current

2.5.1 Indoor residual spraying (IRS)

Indoor residual spray (IRS) for houses with WHO-recommended insecticide is one component of vector control intervention. Used to kill the adult vectors that rest on the wall and roof of the house and domestic animal shelters in epidemic-prone areas and malaria risk communities with low access to health care facilities [13]. Pyrethroids, organochlorines, organophosphates, and carbamates classes of insecticides, are recommended by WHO for IRS [31].

Ethiopia adopted IRS for vector control as a policy for malaria control. IRS with DDT was first implemented in the mid-1960s [32]. Then it was used as part of pilot eradication projects in the Dembia plain, near Tana Lake, Kobo Chercher, Wollo, Gambella, the Awash valley pilot project, and Shewa province. It was a choice of insecticide for more than 40 years [33-35]. Despite the program showing progress to control the disease, malaria cases and death have not significantly decreased due to emerging malaria vectors resistant to DDT (resistant vectors detected in some areas; Gambella, Awash valley, and Ziway areas [35-36].

Dieldrin was used for a short time and replaced by deltamethrin in 2007. some areas, to a limited extent, malathion insecticide was used as IRS to control malaria vectors for over ten years [32]. Then it was discontinued due to deltamethrin and pyrethroid insecticide's high-level resistance development of malaria vectors and its impact on LLINs resistance development.

Bendiocarb, and propoxur are in use and primiphos-methyl (acetylic 300cs) in a limited area. Bendiocarb was used only for a short period, then abandoned due to short residual efficacy, and was replaced by propoxur. Based on a 2015 malaria indicator survey (MIS), 29% of malarious area households, are protected by the IRS in 2008, then gradually markedly increased to 93.7% of the at-risk population in 2018 [12]. Generally, according to the 2015 malaria indicator survey, the prevalence rate in 2011 was 1.3 whereas, in 2015, it decreased to 0.5 [37]. Between 2016 and 2019, malaria-related cases and death in all age groups fell by 52.6% and 41.7%, respectively [37]. However, these two insecticide-based vector control interventions (IRS &LLINs) face challenges [38,39].

2.6 Insecticide Treated Nets (ITN)

Insecticide-treated nets (ITN), for the first time implementation, began with a plan to protect resettled communities in the northwestern area of Tigray [40]. Moreover, the distribution of ITN begins for around 220 malarious districts during early 2000. Between 2000 and mid-2005, were distributed near to 1.8 million nets for the at-risk communities [41]. Then gradually the percentage of households with one ITN increased from 3% in 2005 to 66% in 2007 [42]. But, several national surveys showed a considerable gap between ITN possession and use [43].

2.7 Long-lasting Insecticide-treated Nets (LLINs)

LLINs were introduced in 2004 as a malaria vector control method by targeting 100% ownership and 80% utilization in the national strategic plan. Then scaled up, and the country was widely distributed freely in 2005 [44]. Only a few sub-Sahara African countries provide malaria control and prevention services free [44,35,36,45]. Therefore, to achieve the target set, LLINs were distributed every three years through a catch-up campaign. Between 2005 to 2018 Ethiopia, distributed around 100 million LLINs to achieve 100% coverage (at least one LLINs per sleeping space in malaria-endemic areas). As a result, the past few years markedly increased the distribution coverage in all malaria-endemic districts of the country [12]. Currently, LLINs, are actively promoted to control and eliminate malaria [12]. However, many reports indicated that still, there is very poor utilization of bed nets [43].

2.8 Larval Source Management

Larval source management was introduced in 1997 and used in selected areas [46]. This control strategy targets the aquatic stages of mosquitoes, and it has an impact on malaria control through environmental management. Temephos used in various districts for many years. Recently as part of the IVM strategy, this method can be used only as a supplementary control method to fill the gap for other interventions in different districts by using local communities and health extension workers (HEW) if the breeding sites are well defined [22,47].

2.9 Shrinking Malaria Map

Since 1966, the government eradication efforts began with large epidemiological data being assembled and mapped. But despite scaled coverage of DDT, spraying has little impact on eradication and is not feasible under that circumstance and maintained eradication as a long-term goal and shifts selective control based on malaria epidemiology [6,7]. Malaria control programs showed considerable success due to ongoing persistent efforts in malaria vector control on the number of cases and death. And this gives a lesson to stop the disease and its impact on health and the economy.

The ministry of health developed a malaria elimination road map in 2014 to eliminate the disease by 2030. There are 845 districts, of which 565 are malarious. Recently the district number, leaving from high stratum to moderate and moderate to low will keep increasing [29]. In 2016 the district for shrinking malaria map was 239, from which four were malaria-free, and in 2020, it reached to 20 district. And the incidence progressively decreased with some annual variation (Fig. 3) [12].

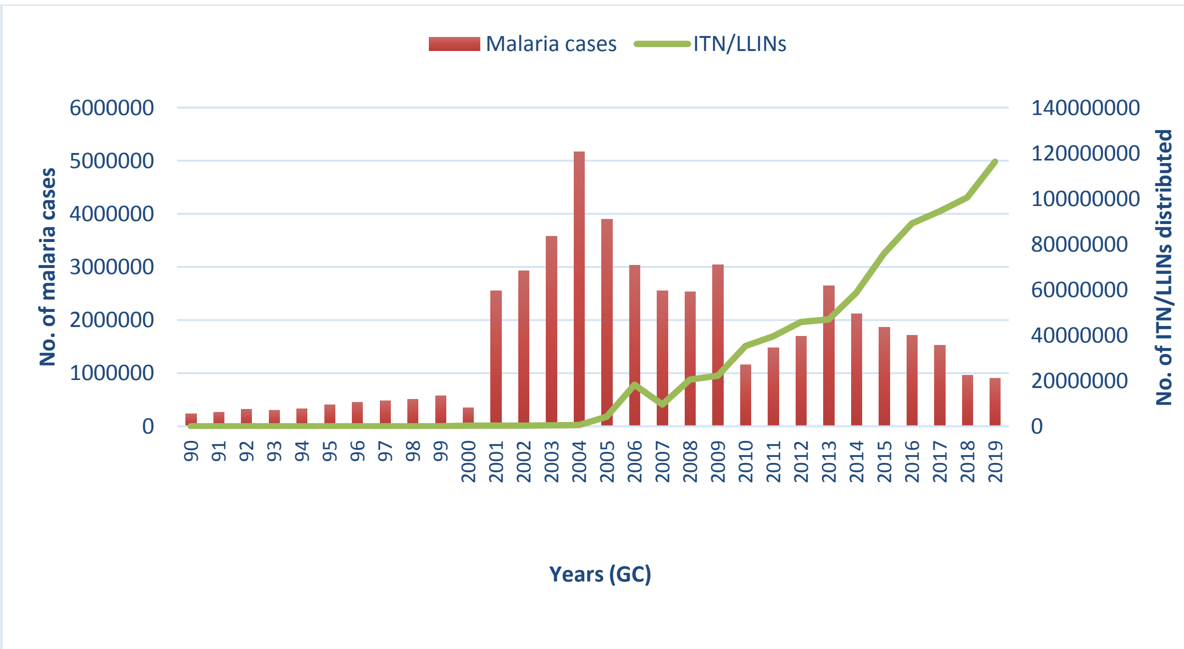

Fig. 1. Trends for annual number of malaria cases (1990-2019) and ITN/LLINs distributed (2000-2019) [24,25]

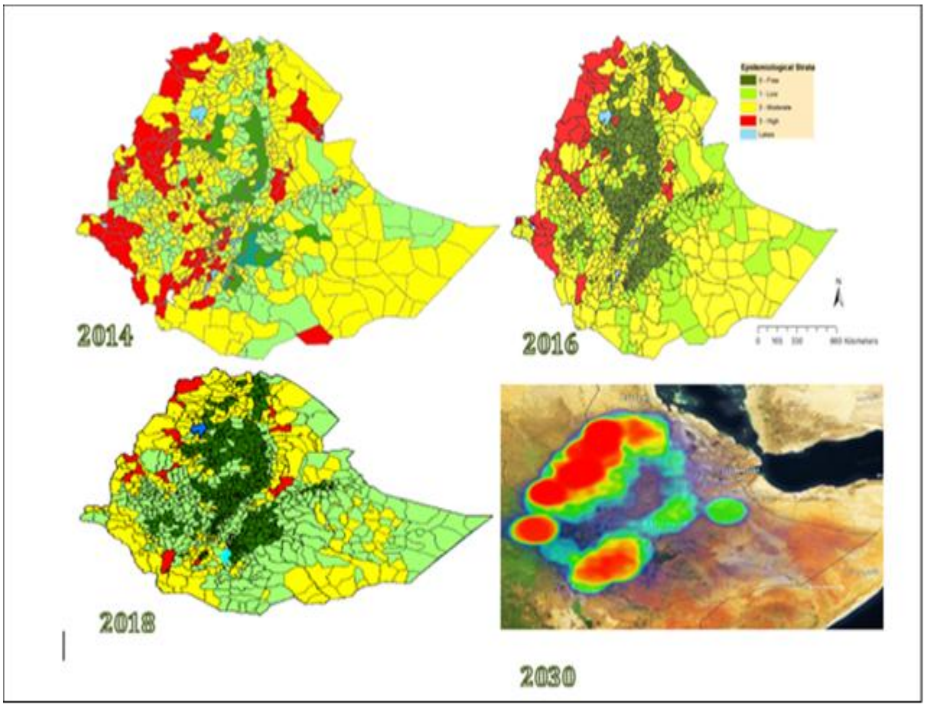

Fig. 2. The shrinking malaria map from 2014 [12]

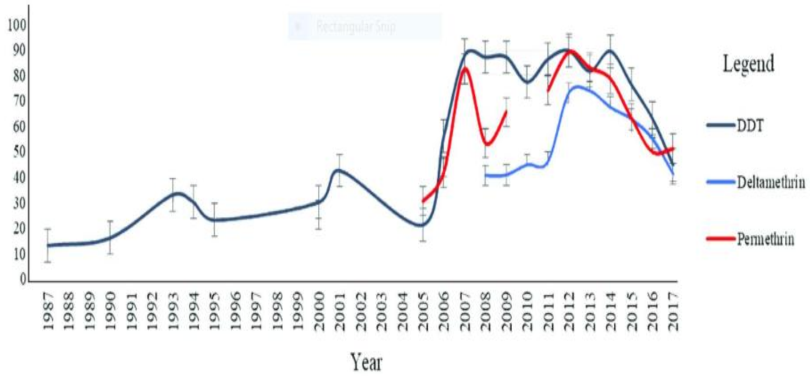

Fig. 3. Trends of resistance of *Anopheles arabiensis* populations to DDT, Deltamethrin, and Permethrin in Ethiopia from 1987-2017 [65]

2.10 Malaria Vector Control Challenge

2.10.1 Insecticide resistance

Malaria control effectiveness has a serious obstacle due to malaria vectors resistance to the insecticide used for IRS and LLINs, [48]. Thus some species have developed physiological or metabolic resistance or both [48,49]. In Ethiopia, up to now, *An. arabiensis* developed resistance to all classes of insecticide includes; DDT, Permethrin, Deltamethrin, Lambda-cyhalothrin, and Malathion in varying ranges and different localities (Fig. 3) [38,39]. Studies indicated that between 2005 and 2011 increased the level of resistance to all classes of insecticides. DDT resistance was common in many areas [13]. Malaria Vectors susceptibility to bendiocarb was variable from place to place [50]. The only recommended insecticide class used to impregnate the net is a pyrethroid, and it was used again by the IRS operation. Therefore, vectors developed resistance at various ranges [50,51]. Generally, as a result of these increased and spread of resistance in mosquito species to all classes of insecticides have the potential to compromise the gains achieved through malaria vector control and may be challenged to eliminate the disease.

2.11 Behavior Resistance of Malaria Vectors

Anopheles arabiensis is historically known as the primary malaria vector in Ethiopia [52]. Human biting activities of this vector are indoors even it varies according to localities. But due to the widespread application of indoor intervention recently, there is growing evidence that this species feeds more outdoors [53,54]. In addition, other secondary vector species such as *An. pharonsis* and *An. funestus* bite more outdoors than indoors [36]. It indicates, when scaled up IRS and LLINs intervention, mosquitoes change behavioral patterns with an increased proportion of human attacks during evening or morning when most people are active and unprotected (Fig. 4). Another threat is the expansion of insecticide-resistant vectors into new areas. For example, *An. stephensi* is a vector of south Asia and resistant to mostly used insecticide. But it is now discovered in the horn of Africa (Djibouti, eastern region of Ethiopia) [55]. Therefore, this plasticity of mosquito behavior might affect the effectiveness of the indoor intervention.

2.12 Residual Malaria Transmission

After a full coverage of LLINs and IRS, residual malaria transmission. (low-level malaria transmission may continue in the presence of good coverage of LLINs and IRS) due to changed biting and resting behavior (bite outdoor or bite indoor and leaving the house before exposure to a lethal dose of insecticide) [56]. This behavioral avoidance was a challenge to eliminate malaria from many countries [57].

2.13 Future Perspective for Malaria Elimination

The history of previous and current malaria prevention and control efforts provides many lessons for future malaria elimination. Strengthening existing major interventions is very crucial. There is a need for the gradual elimination of malaria from all border, endemic regions. Strengthen efforts to fill the intervention gap and to cease malaria transmission completely (three-part strategy) [58-60]. Those *Anopheles* mosquitoes that bite outdoors should target to abort the disease transmission [61]. Considering supplementary tools like Mosquito proofing houses, repellents, LSM, and others is very important. The fast rapid spread of insecticide resistance against all available insecticides is a critical challenge. In South Africa, DDT insecticide was reintroduced and used to control malaria vectors. But due to this increased vector resistance to pyrethroids, and became ineffective to reach the pre-elimination stage [62]. A similar study in central Sudan because of the insecticide resistance challenge makes it impossible to block the transmission [62]. Therefore, there is a need to implement regular insecticide resistance management [63]. Entomological surveillance is must consider as a core intervention during elimination. Good knowledge about the local vector breeding, resting, and feeding behavior to optimize the strategies and intervention tools. For example, in Morocco, repeated entomological studies supported to decrease in the vectorial capacity of the *Anopheles* mosquito [62]. Empowering the community and social mobilization by using health extension workers (HEW) is crucial.

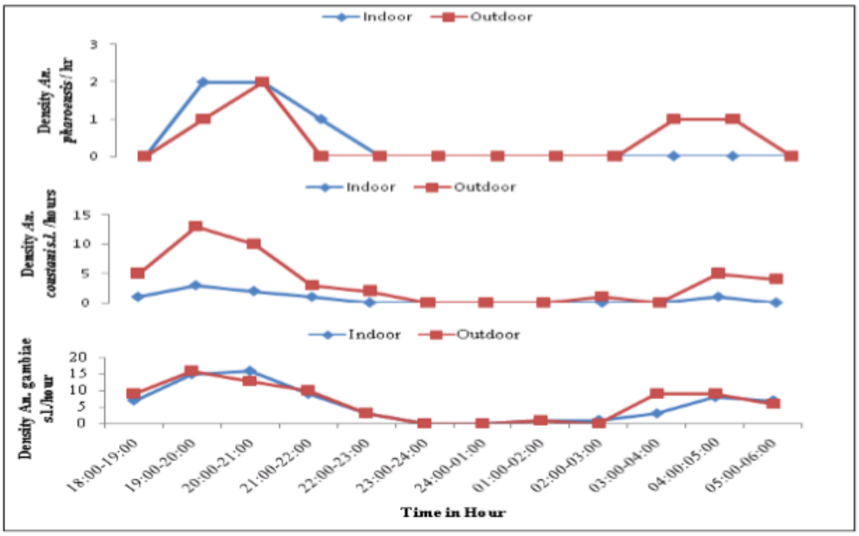

Fig. 4. Hourly indoor and outdoor biting activities of *An. gambiae s.l* (presumably *An. arabiensis*), *An. pharoensis* and *An. coustani* group in Seka Chekorsa district, Jima zone, southwestern Ethiopia (June-December 2012) [64]

3. CONCLUSION

This review assessed the history of vector control success and challenge and the future perspective. To eliminate malaria requires thoughtful consideration of all risks, benefits, and challenges. Therefore, focusing on improved quality, targeting, and utilization of core intervention for all at-risk populations. Need to design new vector control strategies and tools that target outdoor and early-feeding mosquitoes. In addition, knowledge of local mosquito vector species and accurate and reliable community-based surveillance systems will also be fundamental.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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