

Recollection

Approaching Malaria Elimination in China

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Malaria has been one of the most important public health problems over China and world. When dated back to the mid-20th century, malaria seriously affected the health of Chinese people with widespread epidemics. About 30 million malaria cases with an estimated 1% mortality rate were recorded in China each year in the 1940s, which caused an extremely high disease burden and a toll on the labor force (1–2). Even as recently as the 1970s, a peak in the incidence of malaria was recorded with 24.1 million cases (1–2).

Since the establishment of the People's Republic of China, strong political commitments, the leadership of all levels of governments, and active participation of the whole society, China has implemented a 60-year (1950–2009) control program and a 10-year (2010–2019) elimination program against malaria. As these programs have progressed, China has made great contributions towards global malaria control and elimination. One contribution is the discovery of artemisinin led by Professor Tu Youyou, the first Chinese native winner of the Nobel Prize on Physiology and Medicine, saving the lives of tens of millions malaria patients who are suffering from *Plasmodium falciparum* infection. The other is an achievement that China has reported no locally-transmitted malaria cases since 2017, which has become an encouraging model to significantly reduce the morbidity and mortality and, therefore, enhance the confidence that other endemic countries can achieve this as well. This paper reviews the achievements of China's malaria control and elimination with a focus on remaining challenges.

Control and Elimination Phases

China's control and elimination phases can be roughly divided into five stages, and different strategies and measures have been taken at corresponding stages.

Focused control (1949–1959): Before the foundation of the People's Republic of China in 1949, there were 1,829 endemic counties (or cities) in China, accounting for 70% to 80% of the total number at that time. It was estimated that 30 million malaria cases

occurred annually and about 350 million people were at risk of infections. The control strategy in this period focused on epidemic investigation and reduction of the morbidity and mortality of malaria in key areas to contain local epidemics and outbreaks (3–4). In August of 1956, the Ministry of Health formulated the Malaria Control Plan and listed malaria as a mandatory reportable infectious disease.

Epidemic control (1960–1979): Based on investigations and focused control in the 1950s, China continued to carry out a planned malaria control and prevention program. Due to complicating factors, two malaria outbreaks in 1960 and 1970 resulted in a national average incidence of 155.39/10,000 and 296.11/10,000, respectively. Therefore, subsequent efforts were mainly to strengthen anti-malarial measures to control malaria epidemics as quickly as possible. After 1971, the incidence of malaria continued decreasing, and by 1979, it had dropped to 25.75/10,000 decreasing by 91.31% compared with 1970 (3,5).

Strengthened control (1980–1999): After implementing combined control measures, the incidence of malaria in China had steadily declined. By 1995, only Yunnan and Hainan provinces reported local cases of *P. falciparum*, and the central region had essentially eliminated it (6). During this period, China adopted a comprehensive strategy focusing on the control and prevention of malaria in highly endemic areas with more than 1% incidence rate and other endemic areas of *P. falciparum*. The number of malaria cases reported in 1999 dropped to 29,000, compared with 3.3 million in 1980, and the number of deaths also decreased dramatically to less than 70 in 1999 (7–8).

Consolidating achievements (2000–2009): By the end of the 20th century, endemic malaria in most parts of China had been controlled. Starting from 2003, the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFFATM) provided China with the funding to support control activities in high transmission areas and bordering areas and build capacity, which played

an important role in consolidating China's achievements in malaria control. However, an unexpected outbreak occurred in Anhui and Henan provinces earlier this century, resulting in an increase in the number of counties with an annual incidence rate of more than 10/10,000. After intensified measures were implemented in the affected areas, the outbreak was effectively controlled (3,8,9). During this decade, malaria cases and deaths were declined further from a total number of 24,088 cases nationwide and 39 deaths in 2000 to 7,855 cases and 19 deaths in 2010 (1–2) (Figure 1).

Malaria elimination (2010–2020): In 2010, the Chinese Ministry of Health (currently the National Health Commission of China) issued the China Malaria Elimination Action Plan, 2010–2020, showing that China has officially shifted its direction from the malaria control phase to the elimination phase. Based on the conditions of malaria in 2006–2008, a total of 2,858 counties in China were stratified into 4 categories, 75 counties as Type 1 (indigenous cases detected in 3 consecutive years with an incidence of 1/10,000 or higher), 678 as Type 2 (indigenous cases detected with a rate lower than 1/10,000 at least in one of 3 years), 1,432 as Type 3 (no indigenous cases within 3 years), and 664 as Type 4 (non-endemic areas) (10).

In 2010, 12 counties of 6 provincial-level

administrative divisions (PLADs) were selected as a pilot for malaria elimination including Shanghai, Fujian, Zhejiang, Shandong, Hebei, and Guangdong. Based on the lessons learned from the pilot areas, the national malaria elimination program has made great progress, and the “1-3-7” temporal approach has been developed including strict timelines for any confirmed or suspect cases as follows: within 1 day, any malaria cases must be reported as soon as they have been diagnosed; within 3 days, the county-level center for disease control and prevention (CDC) takes responsibility for investigating the cases and determining where the infections come from and whether there is a risk for spread; within 7 days, the county-level CDC, in collaboration with local health workers, takes appropriate measures to deal with any potential threat of malaria transmission (11–12).

The year of 2017 was a milestone in China as no indigenous malaria cases were reported nationwide. Afterwards, the verification of subnational malaria elimination is in progress. By the end of 2019, 21 of 24 former endemic PLADs have officially finished their subnational verifications, and the remaining 3 provinces have passed technical reviews by the national expert panel of malaria elimination (10).

Key Lessons and Challenges

In the process of the 60-year control and 10-year

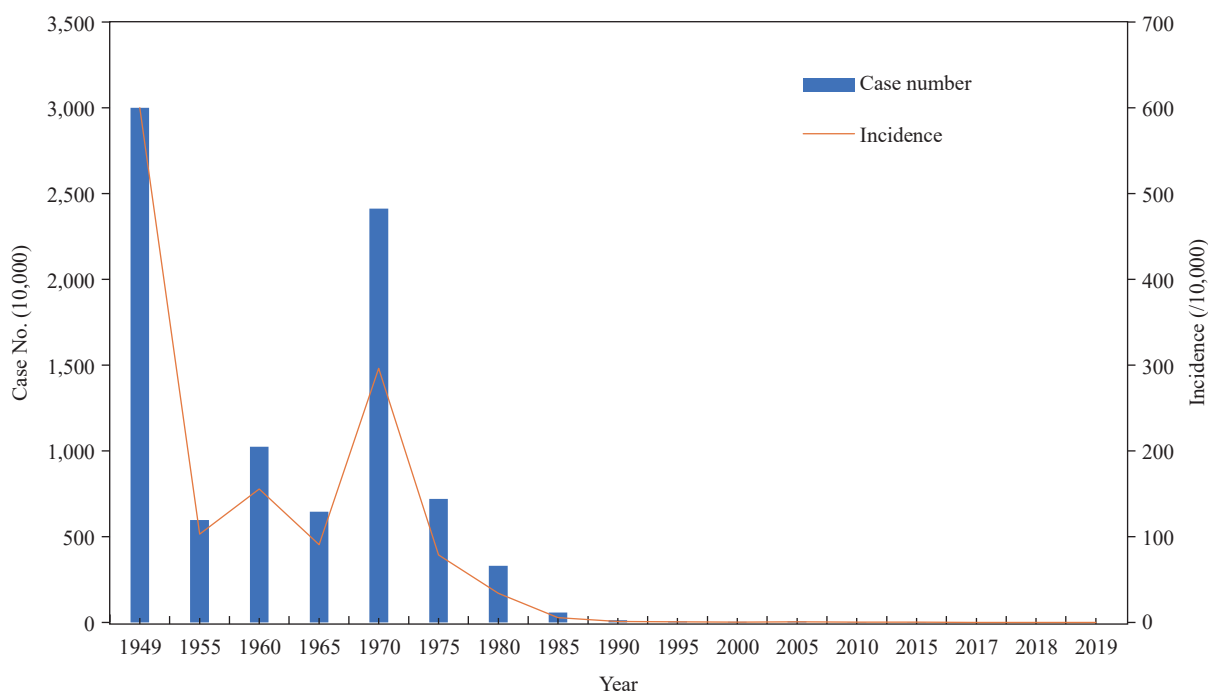


FIGURE 1. Trend of malaria case numbers and incidence in China from 1949 to 2019.

elimination programs, China has accumulated several experiences and the lessons, and the latter could be particularly useful in coping with future challenges. China is approaching the last steps to reach nationwide malaria elimination. If the challenges are addressed properly, China will become sustainably free of indigenous malaria cases. If not, however, all efforts made for the elimination would be lost. The painful lessons taken from repeated emergence in a few countries remind us that we should be vigilant.

Country ownership: Some of the key drivers and sustainable factors contributing to China's success in effectively controlling and eliminating malaria have been country ownership and government leadership. Other factors also involve multi-sectoral cooperation, constant investment, international collaboration, and the combined efforts of disease control agencies, healthcare facilities, and customs implementing quarantine control. Moreover, adequate funding has shown the impact of country ownership in eliminating malaria. In the transition from the control phase to elimination phase, the GFFATM did provide key funding to assist China in containing malaria transmission, strengthening capacity, and initiating the campaign for malaria elimination, but the Chinese government also simultaneously increased investments in malaria control and elimination. When the GFFATM's funding stopped in mid-2012, the central government quickly filled in the gap by means of the Central Transfer Payment (CTP), which ensured that

required funding to support the elimination was sustained (13) (Figure 2).

Moreover, funding resources will be one of fundamental pillars at post-elimination. After a country declares elimination of malaria, governmental financial support or investment on malaria surveillance may decline or be reduced, and human resources will be adjusted and transferred to other more urgent posts. To avoid such a risky situation, it is necessary to request the governments to recognize the potential threat of reemerging malaria outbreaks and keep their commitment and continuous support to the functioning of the surveillance system and vital human resources.

Note: GFFATM stands for the funding from the Global Fund to Fight AIDS, Tuberculosis and Malaria. CG stands for the funding from the Chinese Central Government by Central Transfer Payment (CTP). IC stands for indigenous cases of malaria. Since 2016, a novel funding mechanism called the factor-based CTP has been introduced into the program management to replace previous malaria-specific CTP. So it becomes difficult to obtain an exact amount of funding because this funding mechanism is dependent on the priority-oriented consideration at the provincial level.

Capacity building: As an obligatory task, a variety of training every year has been organized at different levels from national, provincial, prefectural, and county-level with a focus on the key knowledge and skills to cover control strategy, implementation

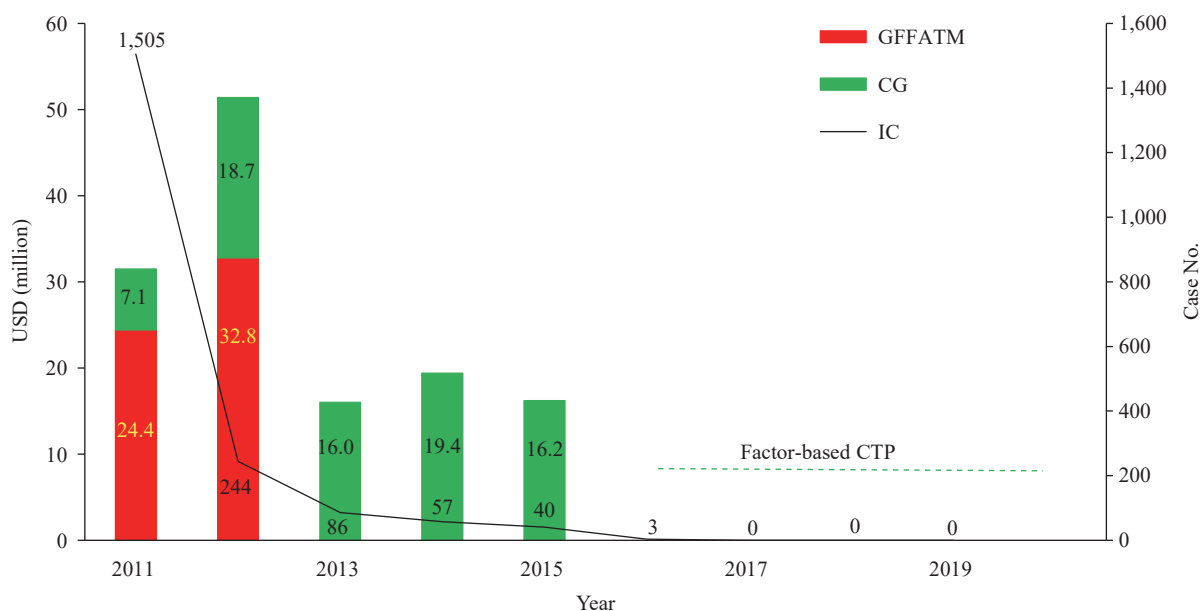


FIGURE 2. Trend of the investment and indigenous cases in China since 2011.

measures, epidemiological investigation, use of detection tools, risk assessment, and information and program management. Since 2010, a surveillance network consisting of well-distributed sentinel sites has been established. At nearly the same time, a laboratory network from the national and provincial reference laboratories for malaria diagnosis has been established and extended to county-level malaria-testing laboratories. Since 2011, the National Technical Competition, which is regarded as the Olympics for China's parasitic diseases control and prevention field, has been held annually for 9 years.

All of these efforts aim to maintain an essential human resource and an efficient disease control and prevention system to quickly identify and respond to any potential risks of transmission, outbreak, importation, and re-transmission of malaria.

Cross-border issues: Yunnan Province borders three malaria-endemic countries, the Lao People's Democratic Republic, Myanmar, and Vietnam, and has been the high risk area and a frontline of malaria control and elimination in China because Yunnan is subject to frequent cross-border migration. Currently Yunnan remains vigilant in detecting imported malaria cases. To effectively detect infected persons near the border, 68 malaria posts have been established as a defense line and are equipped with microscopes and rapid diagnostic tests (RDTs) to rapidly do blood sample tests and report cases. In addition, China has also been providing technical assistance to the bordering countries to help them reduce malaria transmission and burden of disease (1–2).

Imported malaria: Globalization has increasingly created a huge of migration flow and mobile populations, which causes a high risk of disease spreading. Consequently, the threat of imported malaria will remain for a long time. Cases with *Plasmodium* infections may come from neighboring countries by border crossings or from other continents by flights or ship. If current efforts on surveillance and response cannot be maintained, malaria may come back and retransmit in previously endemic areas where anopheline mosquitos, the primary carriers of *Plasmodium*, still exist. It has been reported that, from 2010 to 2018, a total of 33,729 cases of malaria were detected nationwide, of these 5,998 were local infections (17.8%) and 27,719 were imported cases (82.2%) (3). Therefore, the sensitivity and effectiveness of the surveillance and response system against malaria are crucial in the past, present, and future, and the clinicians' awareness and ability on identifying,

treating, and reporting malaria may play the most important role because infected persons with symptoms usually go to clinics or hospitals to get medical help first.

In 2013, an emergency event took place, in which 874 cases of malaria were detected in 4,052 workers returning from overseas and were reported within 4 months, from May to August in Shanglin County, Guangxi Province, China (14). By taking prompt measures including health education, massive screening, rapid clinical treatment and vector control, no deaths or secondary transmission were reported. However, it is a warning signal that such an event may happen again in future and the surveillance system has to be prepared to respond to emergency situations like the Shanglin case.

In recent years, a few PLADs have occasionally reported non-imported malaria cases sporadically including the cases that were isolated or some that were separated at a distance. Four cases reported in Hunan Province were an example of the cases thought to be indigenous but eventually confirmed to be introduced. These infections share common characteristics such as no local indigenous malaria for years and no recorded evidence of history of traveling to the endemic areas. Due to these unknown factors, therefore, inferences should be made on the origins of infections based on molecular tracking technology for cases where epidemiology alone is not sufficient. These phenomena might partly be due to unknown biological features of species of *Plasmodium* or vectors, and more studies are necessary to explore the mechanisms.

Global public health cooperation: China has proposed an initiative to build a global community with a shared future and actively assist other highly endemic countries in Africa and the Southeast Asia to control malaria. Through international cooperation, China aims to share its lessons in malaria control and elimination and eventually contribute to the goal of making a healthier world. This effort will be able to benefit and impact a healthier world on at least the following points: 1) the sustained ability of malaria control and surveillance of Chinese experts can provide technical support to other endemic countries; 2) supporting malaria control in endemic countries will make a great contribution to the local peoples' health and global malaria elimination process; 3) the efforts will reduce the pressure of imported malaria from highly endemic areas to lower or non-endemic areas (15–16).

Conflict of interest: The authors declare no

competing interests.

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REFERENCES

1. Zhou XN. Roadmap analysis on malaria elimination in China. Shanghai: Shanghai Scientific and Technical Publishers. 2019. <http://www.sjfx.com/books/bookspec/view.asp?id=2020100001015943>. (In Chinese)
2. Tang LH, Gao Q. China malaria from control to elimination. Shanghai Scientific and Technical Publishers. 2013. (In Chinese).
3. Feng J, Zhou SS. From control to elimination: the historical retrospect of malaria control and prevention in China. *Chin J Parasitol Parasit Dis* 2019;37(5):505-13. <http://www.jsczz.cn/CN/Y2019/V37/I5/505>. (In Chinese).
4. Zhou ZJ. The malaria situation in the People's Republic of China. *Bull World Health Organ* 1981;59(6):931-6. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2396122/>.
5. Qian HL, Tang HL. Achievements and prospects of malaria control in China in the past 50 years. *Chin J Epidemiol* 2000;21(3):225 - 7. <http://dx.doi.org/10.3760/j.issn:0254-6450.2000.03.017>. (In Chinese).
6. Advisory Committee on Malaria, MOPH. Malaria situation in China in 1995. *Chin J Parasitol Parasit Dis* 1996, 14(3):3 - 6. <http://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&filenam=ZJSB603.000&dbnameCJFD9697>. (In Chinese).
7. Tang HL. Achievements in malaria control and prevention in China. *Chin J Parasitol Parasit Dis* 1999;17(5):257 - 9. <http://www.jsczz.cn/CN/Y1999/V17/I5/1>. (In Chinese)
8. Ministry of Health Malaria Expert Advisory Meeting. Salaria situation in the People's republic of China in 2000. *Chin J Parasitol Parasit Dis* 2001;19(5):257-9. <http://www.jsczz.cn/CN/Y2001/V19/I5/1>. (In Chinese)
9. Zhou SS, Wang Y, Xia ZG. Malaria situation in the People's republic of China in 2009. *Chin J Parasitol Parasit Dis* 2011;29(1):1-3. <http://www.jsczz.cn/CN/Y2011/V29/I1/1>. (In Chinese).
10. Feng J, Tu H, Zhang L, Zhang SS, Jiang S, Xia ZG, et al. Mapping transmission foci to eliminate malaria in the People's Republic of China, 2010–2015: a retrospective analysis. *BMC Infect Dis* 2018;18(1):115. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5840925/>.
11. Cao J, Sturrock HJW, Cotter C, Zhou SS, Zhou HY, Liu YB, et al. Communicating and monitoring surveillance and response activities for malaria elimination: China's "1-3-7" strategy. *PLoS Med* 2014; 11(5):e1001642. <http://dx.doi.org/10.1371/journal.pmed.1001642>.
12. Wang DQ, Cotter C, Sun XD, Bennett A, Gosling RD, Xiao N. Adapting the local response for malaria elimination through evaluation of the 1-3-7 system performance in the China-Myanmar border region. *Malar J* 2017;16(1):54. <http://dx.doi.org/10.1186/s12936-017-1707-1>.
13. Lai SJ, Li ZJ, Wardrop NA, Sun JL, Head MG, Huang ZJ, et al. Malaria in China, 2011–2015: an observational study. *Bull World Health Organ* 2017;95:564 - 73. <http://dx.doi.org/10.2471/BLT.17.191668>.
14. Li ZJ, Yang YC, Xiao N, Zhou S, Lin KM, Wang DQ, et al. Malaria imported from Ghana by returning gold miners, China, 2013. *Emerg Infect Dis* 2015;21(5):864 - 7. <http://dx.doi.org/10.3201/2105.141712>.
15. Qian YJ, Zhang LH, Xia ZG, Vong S, Yang WZ, Wang DQ, Xiao N. Preparation for malaria resurgence in China: approach in risk assessment and rapid response. *Adv Parasitol* 2014;86:267 - 88. <http://dx.doi.org/10.1016/B978-0-12-800869-0.00010-X>.
16. Chen J, Xiao N. Correspondence—Chinese action towards global malaria eradication. *Lancet* 2016;388(10048):959. [http://dx.doi.org/10.1016/S0140-6736\(16\)31490-8](http://dx.doi.org/10.1016/S0140-6736(16)31490-8).