

# Key takeaways from China's success in eliminating malaria: leveraging existing evidence for a malaria-free world

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**To cite:** Feng X, Huang F, Yin J, *et al.* Key takeaways from China's success in eliminating malaria: leveraging existing evidence for a malaria-free world. *BMJ Global Health* 2022;**7**:e008351. doi:10.1136/bmjgh-2021-008351

**Handling editor** Seye Abimbola

Received 22 December 2021  
Accepted 27 March 2022

## ABSTRACT

Although the total number of malaria cases and fatalities have declined globally since 2010, there were still 241 million malaria cases identified across 85 countries and territories in 2020. As the global malaria eradication process accelerates, more countries have launched their own initiatives of elimination. Notably, China achieved this goal by 2021, ending thousands of years of endemic. Undoubtedly, tremendous experience and vital lessons have been accrued en route to the malaria-free goal in malaria-eliminated countries including China. To enhance prospects of a malaria-free world by bridging the key evidence from a malaria-eliminated country to the contexts of affected, this personal view highlights concerted commitments and universal investment in healthcare, improved surveillance and response system, constant capacity building, demand-oriented scientific research, and multiway cooperation, which have helped China to eliminate this ancient scourge. We discuss how these key takeaways could be leveraged to different contexts. We also argue the long-term challenges and barriers on the pathway to malaria elimination and underline the needs for consistent efforts to maintain zero indigenous cases and prevent re-introduction of malaria. Through concerted efforts from global collaboration, a malaria-free world can become a reality.

## SUMMARY BOX

- ⇒ Globally, there were an estimated 241 million malaria cases and 627 000 deaths reported by WHO in 2021, revealing that malaria leads to more deaths than previously thought in the context of the COVID-19 pandemic.
- ⇒ China's successes in eliminating malaria relied on multifaceted advantages, including but not limited to concerted commitments from the government, universal investment in healthcare, time-bound surveillance and response system, constant capacity building, demand-oriented scientific research, and multichannel cooperation.
- ⇒ The lessons and experiences from China's successes will be important references for countries targeting malaria elimination.



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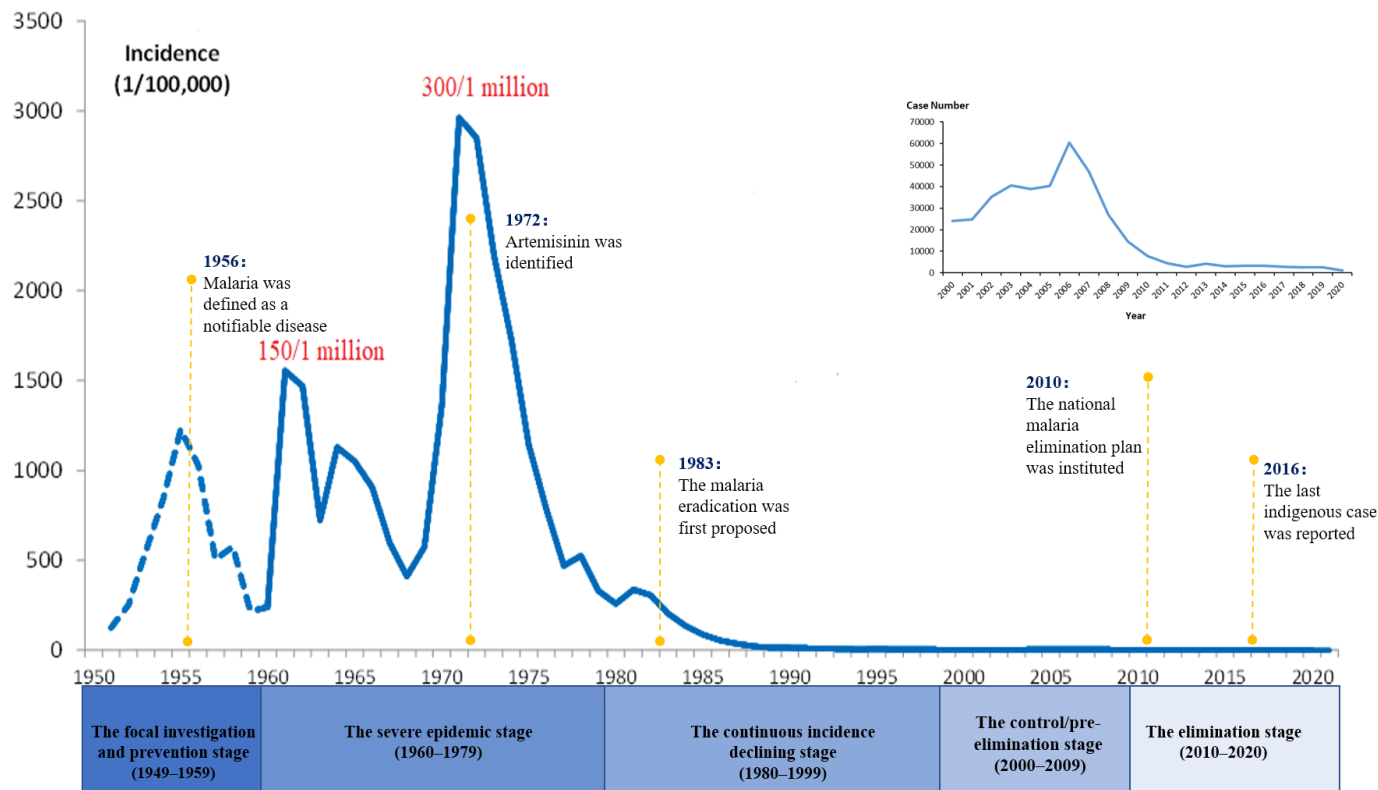
## INTRODUCTION

Even though China has achieved dramatic success in the fight against malaria in the past decades, malaria continues to take a heavy toll worldwide. According to the latest estimates from the WHO, there were approximately 241 million new cases and 627 000 deaths due to malaria in 2020.<sup>1</sup> Malaria is heavily concentrated in sub-Saharan Africa, particularly among groups who lack access to healthcare and are vulnerable to infection. A re-invigorated action is needed to fight for a malaria-free world.<sup>2</sup>

Malaria has been endemic in China for a long time. It was recorded in oracle bone inscriptions as early as 3000 years ago. In the 1940s, about three-fourths (350 million) of the total population (450 million) was

in danger of malaria. It was estimated that at least 30 million malaria cases occurred annually, with a 1% fatality rate in 1949.<sup>3 4</sup> Malaria has been managed as a notifiable disease in China since 1956 (figure 1). After arduous efforts through several generations over seven decades, malaria cases and disease burden have been significantly reduced.<sup>5 6</sup> In 2010, in response to a global malaria eradication initiative proposed at the UN Millennium Development Goals high-level meeting, the Chinese government launched its National Action Plan for Malaria Elimination intending to eliminate malaria by 2020 in a stratified and staged manner.<sup>7 8</sup>

Since 2017, no indigenous cases have been reported for more than four consecutive years in China. By 2020, all 24 previously malaria-endemic provinces received national recognition of malaria elimination.<sup>7 9 10</sup> After a field mission in May 2021 by an independent certification panel, the WHO declared that China was certified malaria-free on 30 June 2021. Malaria has become another major eliminated infectious disease in China, following smallpox, poliomyelitis, leprosy, filariasis, neonatal



**Figure 1** Malaria incidence in China from 1949 to 2020 and major events in the process of eliminating malaria. \*According to the epidemiological characteristics of malaria throughout different historical periods, the course of malaria elimination in China could be classified into the following stages: the focal investigation and prevention stage (1949–1959); the severe epidemic stage (1960–1979); the continuous incidence declining stage (1980–1999); the control/pre-elimination stage (2000–2009); and the elimination stage (2010–2020).

tetanus and blinding trachoma. Malaria elimination in this most populous nation is a major milestone not only for Chinese public health but also for the world in the malaria eradication.<sup>11 12</sup>

As a large country with a vast territory and a large population, China has experienced the entire process including variable settings from a serious epidemic to elimination of malaria over seven decades. Many lessons and successful experience and challenges in China are worth summarising for reference, especially to assist other affected countries that desire to eliminate malaria. Both in the field and within academic and government institutions in China, malaria control and scientific research professionals have summarised the experience and best practices to create a batch of operational programmes or procedures. One of them, for example, called the 1–3–7 approach,<sup>13</sup> has been acknowledged and written in technical manuals by the WHO. However, there is still a lack of in-depth analysis and comprehensive summary of experience and lessons learnt during malaria elimination in China. In this personal view, we summarise the key takeaways from China’s success in eliminating malaria and discussed existing evidence that could be leveraged to countries with different malaria contexts.

**KEY IMPLICATIONS LEARNT FROM MALARIA ELIMINATION IN CHINA**

During the battle against malaria over the past 70 years in China, various integrated interventions have been deployed for malaria under the principle of *Governmental Leadership, Multisectoral Cooperation and Whole-Society Participation*. The success of malaria control and elimination was mainly attributed to the following factors.

**Strong governmental leadership based on science, evidence and financial support**

In China, malaria control and elimination have involved many sectors, including Health, Customs, Finance and others, under the unified leadership of governments at all levels.<sup>14 15</sup> Based on the periodic malaria prevalence patterns and characteristics, combined with laboratory and field evidence on parasites, vectors, and the local population, the central government initiated national programmes and developed a series of strategic and technical instructions, which guided the assignment of responsibilities, resources allocations, and staff of public health institutions to take appropriate technical measures where malaria was epidemic or when a malaria outbreak occurred. China’s substantial and sustaining funds have shown determination and perseverance of the country in eliminating malaria. For instance, since 2010, the central

and provincial governments and The Global Fund to Fight AIDS, Tuberculosis and Malaria have invested a total of ¥1.38 billion as special funds to promote the national malaria elimination efforts at all levels.

### Adaptive and robust surveillance and response system

Based on the existing national health system, China has set up malaria prevention and control teams from the national to rural levels to cover the entire country. China has experienced a big transition from population-based to case-based surveillance and response from malaria control to elimination.<sup>16 17</sup> China's malaria surveillance has progressed from paper-based to information-based automation and from a single to a diversified monitoring approach.<sup>18</sup> Malaria cases have been reported in real time via the National Information System for Infectious Diseases Surveillance since 2004. An additional monitoring system, the National Information System for Malaria Control and Elimination, was also established in 2011 to monitor and document cases by using the 1–3–7 approach. In this model, all malaria cases should be reported via web within 1 day, with the completion of subsequent case confirmation and epidemiological investigation within 3 days. The following foci investigation and response should then be finished within 7 days. These efforts have improved the speed and precision of surveillance and responses. Since 2011, the national malaria diagnosis reference laboratory network has been established with a quality assurance system based on national and provincial Center for Disease Control and Prevention (CDC). Since then, it has played critical roles in quality control among a broader network including public hospitals at different levels, private hospitals and township hospitals, all of which are capable of performing laboratory testing for malaria. Since 2016, a national antimalarial surveillance network has been established, which has played a more important role in the surveillance and response system, especially in genotyping drug-resistant malaria and following up patients from high malaria-endemic areas.

### Constant capacity building

Regular and occasional training periods have been organised and performed at different levels in China, covering malaria detection at ports, malaria diagnosis and treatment at medical institutions, and epidemiological investigation and foci response by CDCs.<sup>19</sup> Meanwhile, on-site technical guidance, skills competition and quality controls have been conducted to help maintain and update the skills of the professionals. Through the qualified workforce at different levels, a minimal loss of malaria services during delivery has been achieved. Throughout the COVID-19 pandemic, China has maintained training for health providers through an online platform and has held virtual meetings for the exchange of information on case investigations and relevant topics. As a result, malaria elimination activities have been carried out normally and routinely. All malaria cases were

treated in accordance with the 1–3–7 approach. No introduced malaria was reported in the country.

### Demand-oriented scientific research

Research in basic science and field applications has focused on key issues in control and elimination strategies as well as technology, covering pathogen biology, vector biology, diagnostics, antimalarial drugs, and strategies and interventions. Scientific research has played a significant role in fighting malaria in different historical periods in China.<sup>8</sup> This has been included as one of the principles in *Prevention First, Scientific Control, Adaptive Action, and Classified Guidance* for the control and elimination phases. For example, as early as 1967, the Chinese government launched the 523 Project, a research programme aimed at finding new treatments for malaria. This project led to an outstanding result regarding the discovery and extraction of artemisinin from *Artemisia annua* by Tu Youyou and her team (figure 1). The WHO has endorsed artemisinin-based combination therapies (ACTs) as the first-line and second-line treatment for malaria.<sup>20</sup> In the 1980s, in order to control endemic malaria, China was one of the first countries to extensively field test insecticide-treated nets (ITNs), well before they became a WHO-recommended intervention for malaria control. In recent years, the 1–3–7 approach has been developed to guide elimination activities according to the national malaria elimination programme. This model has a reliable and straightforward set of targets that could be adopted by other countries with similar disease elimination programmes. The timely transformation and application of those research results have notably advanced the science and technology on malaria control and elimination.

### In-depth intranational collaboration and international cooperation

In response to intranational collaborations, the *Joint Malaria Control and Prevention in Central Five Provinces* (Jiangsu, Anhui, Shandong, Hubei and Henan) was established in 1974. The *Joint Malaria Control and Prevention in Southern Three Provinces* (Guangdong, Guangxi and Hainan) was launched in 1992. In addition, since 2017, 24 originally endemic provinces have been divided into four Joint Regions. The regional collaboration mechanisms have not only strengthened timely information sharing and experience exchange but also improved the medical staff capabilities in case management and foci responses, which in turn facilitated the malaria elimination process. Meanwhile, the close collaboration and cooperation with the WHO, the Global Fund, and other international agencies have played an important role by providing advanced concepts, technologies and financial support to eliminate malaria in China.<sup>21</sup> The information sharing and cross-border cooperation under bilateral and multilateral mechanisms promoted the reduction of malaria burden, particularly on the China–Myanmar border.<sup>22–24</sup> Supporting malaria control in Africa and Asia through cooperation with the government of China will

**Table 1** Major gaps towards malaria elimination and potential opportunities and actions needed

Gap	Current state	Desired state	Opportunity	Action needed
Malaria control progress staggered and reversed	<ul style="list-style-type: none"> <li>▶ Resurgence on morbidity and mortality</li> <li>▶ Malaria is still endemic in 85 countries and territories<sup>1,37</sup></li> </ul>	<ul style="list-style-type: none"> <li>▶ Malaria fatalities declined to a low level</li> <li>▶ Ultimate goal for a malaria-free world</li> </ul>	<ul style="list-style-type: none"> <li>▶ Over 100 countries have eliminated malaria</li> <li>▶ More countries are moving towards the elimination of malaria</li> <li>▶ Some African countries have eliminated malaria</li> </ul>	<ul style="list-style-type: none"> <li>▶ Global malaria response back on track</li> <li>▶ Increased and improved coverage of current tools</li> </ul>
Financial shortage and insufficient government involvement	<ul style="list-style-type: none"> <li>▶ Backdrop of financial support with population growth</li> <li>▶ Depending on external funding</li> <li>▶ Lack of governmental support and commitment<sup>38</sup></li> </ul>	<ul style="list-style-type: none"> <li>▶ Filling the funding gaps</li> <li>▶ Unwavering commitment of government</li> </ul>	<ul style="list-style-type: none"> <li>▶ Progress in world economic development, especially in Africa</li> <li>▶ Commitments from national governments, pharmaceutical companies, the Global Fund, and the Bill and Melinda Gates Foundation</li> </ul>	<ul style="list-style-type: none"> <li>▶ Funding support from the government, private sectors and stakeholders</li> <li>▶ Multilateral cooperation, including both international and subnational</li> </ul>
Prioritise malaria among all infectious diseases	<ul style="list-style-type: none"> <li>▶ Continued gaps in fighting AIDS, tuberculosis, dengue and new emergence diseases</li> <li>▶ Fragile, overwhelmed African health systems</li> <li>▶ The widespread impact of COVID-19<sup>39,40</sup></li> </ul>	<ul style="list-style-type: none"> <li>▶ Universal health coverage and access to health services</li> <li>▶ An integrated effective health system</li> </ul>	<ul style="list-style-type: none"> <li>▶ Access to quality of water, sanitation and hygiene conditions</li> <li>▶ Technological advances and innovations in new tools, for example, vaccines</li> </ul>	<ul style="list-style-type: none"> <li>▶ Prevention of new cases of malaria</li> <li>▶ Revamped health systems</li> <li>▶ To reduce the impact of other diseases on malaria</li> </ul>
Prevention and treatment	<ul style="list-style-type: none"> <li>▶ Insufficient access to bed nets</li> <li>▶ Uncovered protection by indoor residual spray (IRS)</li> <li>▶ Lack access to the tools that prevent, diagnose and treat the disease</li> <li>▶ 70% of all malaria deaths occurred under the age of five</li> <li>▶ Not accessing the WHO-recommended regimens for women and children<sup>41,42</sup></li> </ul>	<ul style="list-style-type: none"> <li>▶ Expanding key interventions' access to most vulnerable</li> <li>▶ Delivering malaria control tools to those most in need</li> <li>▶ Flexible and tailored strategies to local contexts</li> <li>▶ Ideal vaccine protection</li> </ul>	<ul style="list-style-type: none"> <li>▶ The WHO Global Malaria Programme put high priority to close gaps in access to proven malaria control tools</li> <li>▶ Increased investment in proven prevention measures</li> <li>▶ Development and deployment of new diagnostic and treatment tools</li> </ul>	<ul style="list-style-type: none"> <li>▶ Scale-up of effective tools, including expanded access to ITNs, IRS and ACTs</li> <li>▶ More comprehensive analysis on gaps in prevention, diagnostic testing and treatment</li> <li>▶ Seasonal malaria chemoprevention (SMC) for children under 5 years of age</li> <li>▶ Community mobilisation</li> </ul>
Insecticides and drug resistance	<ul style="list-style-type: none"> <li>▶ Developing and spread of insecticide resistance in more than 60 countries</li> <li>▶ Mounting evidences on resistance of parasites to artemisinin derivatives</li> <li>▶ Multidrug-resistant parasites and potential spread<sup>43</sup></li> </ul>	<ul style="list-style-type: none"> <li>▶ Available therapeutic antimalarial regimen and effective vector control tools</li> <li>▶ Delay the appearance of insecticide resistance</li> <li>▶ Containing artemisinin resistance in subregional and regional areas</li> </ul>	<ul style="list-style-type: none"> <li>▶ Supplemented by other vector control methods</li> <li>▶ Geospatial and temporal mapping of the emergence and spread</li> <li>▶ Parallel, robust investments in the research and development of new tools</li> </ul>	<ul style="list-style-type: none"> <li>▶ Integrated surveillance and monitoring on insecticides and drug resistance</li> <li>▶ To invent active ingredients except pyrethroid</li> <li>▶ To innovate antimalaria drugs</li> <li>▶ To adopt more efficacious treatment regimens</li> </ul>

bring in synergies and improve the health and economy of the countries.

**EXISTING EVIDENCE COULD BE LEVERAGED TO THE MALARIA-ENDEMIC CONTEXTS**

Malaria elimination has become a high-priority goal for many countries, especially some African countries that carry a high malaria burden (eg, millions of cases). The strategies to achieve malaria elimination are evolving as both successes and challenges emerge.

**Gap analysis for elimination in different local situations**

It is important to identify locally relevant gaps based on the WHO elimination standards, since the prevalence of malaria varies from country to country. Specifically, it is of high priority to identify major detection, treatment and prevention gaps in malaria-endemic countries to achieve both control and elimination of malaria.<sup>25,26</sup> Slowdown

in financial support along with population growth has stalled progress against malaria (table 1). According to data in 2015, only an annual increase of \$6.5 billion could correspond to at least a 40% global reduction in malaria case incidence and mortality. Furthermore, insufficient coverage with bed nets and indoor residual spraying, and delayed detection and treatment, indicate continued gaps in the basic prevention, diagnostic and treatment tools in sub-Saharan Africa. The WHO has given guidance on the tools, activities and dynamic strategies required to achieve interruption of transmission and prevent malaria re-establishment. The dilemma is how to adapt and update strategies to local situations based on current recommendations.

**Achievable plans and programs for malaria elimination**

Evaluating the feasibility or prospects of elimination under the premise of fully considering the actual

situations is a crucial step in malaria-endemic countries. In fact, China has formulated over 20 legislations and regulations relevant to malaria control and elimination. After more than half a century of fighting against malaria to reduce the incidence to less than 1/10 000 in most malaria-endemic counties, 13 ministries and commissions jointly issued the National Action Plan for Malaria Elimination (2010–2020) in 2010, which aimed to successfully achieve the goal of malaria elimination in the country by 2020.<sup>27</sup> Then, the specific plans or programs at subnational level for malaria elimination were tailored, with full consideration of local situation, feasibility of objectives and implementation ability.

### Robust and resilient healthcare system

To achieve a country or a world free of malaria, health systems always face great challenges. An integrated healthcare system is an essential requirement to achieve malaria control and elimination. The healthcare system needs to ensure that the populations at malaria risk can receive prompt and precise malaria diagnosis and be covered with quality-assured interventions to prevent and treat infections rapidly. Moreover, the interventions adapted to different epidemiological settings must be carried out to reduce the disease burden. Therefore, a robust health system is essential irrespective of the stages to eliminate malaria. This system should guarantee financing, fast health service delivery, qualified medicine access, a sensitive disease information system, and efficient governance with great political commitment and leadership.

Effective intervention implementations rely on data and technologies to precisely monitor and report malaria cases. The collection of malaria data is an important first step in a public health approach to respond to the health threats. Without accurate and timely data, it is difficult to assess the disease situation accurately and plan interventions. It is essential to continuously develop methodologically sound systems to generate, analyse and use high-quality data for making decisions and tailoring responses. In addition, it is also critical to empower local communities and healthcare personnel to provide timely and appropriate malaria services, as community engagement is a key determinant of malaria elimination.

### Start from small and step-by-step

With limited resources and conditions, it may not be possible to achieve nationwide elimination. Therefore, a pilot study or demonstration project is highly recommended in malaria-endemic countries to prepare for an elimination programme. China initiated its own antimalarial programme in some demonstration areas, usually at the county level, and then scaled up the successful practices to other areas. In addition, malaria elimination is a gradual process. In endemic areas, control is usually achieved first, followed by the transition and breakthrough from control to elimination. Moreover, pilot studies in the field in endemic areas could be carried out through bilateral or multilateral cooperation. Adjustments and

optimisations should be made according to local situations. Practical experience from countries that have achieved malaria elimination can be successfully applied to local areas.<sup>16 28 29</sup>

### Motivation and buttressing effects of socioeconomic progress

Countries that have eliminated malaria usually have high levels of economic growth and social development, which can facilitate the control and elimination of malaria by offering necessary guarantees and core support. China's economy has been developing constantly and rapidly since 1978. The GDP per capita has risen from ¥385 in 1978 to ¥70 000 in 2019. Malaria elimination in China largely benefited from the economic and social development, which supported case detection and tracing, a surveillance and response network, drug supply, health education and many other relevant aspects.<sup>30</sup> A previous systematic review and meta-analysis indicated that socioeconomic development could provide highly effective and sustainable support against malaria in the long term.<sup>31</sup>

### SUGGESTIONS FOR COUNTRIES NEARING THE MALARIA ELIMINATION PHASE

Countries in South-East Asia/Asia Pacific have the potential to move towards zero indigenous cases. According to the WHO world malaria report, countries with fewer than 100 indigenous cases are most likely to have elimination within reach.

### Refined management of insubstantial indigenous cases and residual foci

A single spark can start a prairie fire. Insubstantial indigenous cases or residual foci could lead to the reintroduction of malaria outbreaks, which can impede the success of elimination.<sup>4 24 32</sup> Thus, it is important to establish adaptive and practical strategies with a robust surveillance and response system based on the existing tools to monitor every single indigenous case and potential foci. For example, the 1–3–7 approach was a key measure in the elimination phase in China. This model requires refined management of insubstantial indigenous cases and residual foci, which effectively prevent the re-transmission of malaria. This approach has been adopted by the *WHO Malaria Surveillance, Monitoring & Evaluation, a Reference Manual*. Recently, the 1–3–7 approach has been popularised and applied in many countries and regions worldwide and has greatly contributed to the progress towards malaria elimination, such as in Cambodia.<sup>33</sup>

### Sustained financial support and government leadership

The Chinese government continues to provide funding for surveillance and response to malaria after malaria elimination. The Ministry of Finance and the National Health Commission have allocated ¥67.65 million into the essential public health services specifically to support and manage malaria in 2021. Malaria-related funds of the central essential public health services will continue

to provide the required funding as a routine budget to continue achieving a malaria-free status. Considering that evidence from other countries has shown that malaria can rebound once funding and interventions are interrupted, it is essential to secure sustained financial support and government leadership to retain malaria elimination.

### Keeping vigilance and maintain the capacity

Maintaining the capacity of health facilities on malaria detection, diagnosis, treatment and response is required in the context of the last mile of elimination and even after the elimination of this disease.<sup>19</sup> Malaria can occur anywhere in a country. Maintaining vigilance in general health service requires that all clinical providers who see patients with fever receive training on malaria and malaria surveillance to recognise malaria, provide diagnosis and treatment to suspected cases promptly, or refer suspected cases to dedicated nearby healthcare facilities. Low vigilance in healthcare service may lead to delayed case detection, resulting in potential outbreaks.

### Cohesive cooperation and joint actions

Cohesive cooperation and joint actions between sectors, regions and countries are critical when considering the challenges to achieve elimination. These include malaria among mobile and migrant populations, the spread of drug and insecticide resistance, border malaria, and funding issues. Efficient information sharing and action coordination between relevant stakeholders would help accelerate malaria

elimination.<sup>21</sup> Notably, border malaria is a hot topic of regional and national public health concerns in the Greater Mekong Subregion (GMS) due to its complex epidemiological settings, transmission dynamics and multidrug resistance. Appropriately border malaria control schemes require an integrated cooperation and joint actions between and within the GMS countries.

### CHALLENGES ON THE WAY TO ELIMINATION AND AHEAD

China has experienced many challenges in achieving malaria elimination (table 2). The most important was that while elimination has been achieved in most areas, some provinces still had a high prevalence of malaria. The biggest challenge was the transformation of malaria prevention and control strategies during the malaria elimination phase, especially the transition from the control phase to the elimination phase, the transition from targeting population to targeting individual malaria cases. This process involved changes in funding and control and prevention measures, and affected the overall efficiency and evaluation of achieving malaria elimination. In addition, from another perspective, some of the experience and lessons China has gained in eliminating malaria are derived from the most significant challenges ever.

The available examples of malaria elimination have demonstrated the feasibility of eliminating malaria within countries and regions. However, there are many unresolved challenges ahead that may affect elimination of malaria in countries with different malaria-endemic situations.

**Table 2** Primary challenges on the way to malaria elimination and corresponding strategies in China

Stage (year)	Primary challenges	Strategies coping with challenges
The focal investigation and prevention stage (1949–1959)	<ul style="list-style-type: none"> <li>▶ High morbidity and mortality</li> <li>▶ Lack of professional agencies</li> <li>▶ Lack of baseline data</li> </ul>	<ul style="list-style-type: none"> <li>▶ Establish professional agencies</li> <li>▶ Carry out baseline investigation and field trials</li> <li>▶ Initiate National Malaria Control Programme</li> <li>▶ Notifiable disease enrolment</li> </ul>
The severe epidemic stage (1960–1979)	<ul style="list-style-type: none"> <li>▶ Vivax malaria pandemics in central China</li> </ul>	<ul style="list-style-type: none"> <li>▶ Mass drug administration (MDA) with prophylactic and radical medications</li> <li>▶ Mass protection</li> <li>▶ Initiate intranational cooperation mechanisms</li> </ul>
The continuous incidence declining stage (1980–1999)	<ul style="list-style-type: none"> <li>▶ Severe epidemic in remote areas</li> <li>▶ Unstable epidemic</li> </ul>	<ul style="list-style-type: none"> <li>▶ Comprehensive measures based on vector habits in receptive areas with different <i>Anopheles spp.</i></li> </ul>
The control/pre-elimination stage (2000–2009)	<ul style="list-style-type: none"> <li>▶ Serious under-reporting of malaria</li> <li>▶ High transmission in Yunnan and Hainan in southern China</li> <li>▶ Resurgence and outbreaks in central China</li> </ul>	<ul style="list-style-type: none"> <li>▶ Strengthen blood test, early diagnosis and appropriate treatment, LLINs (Long-lasting insecticide impregnated nets)/ITNs distribution, health education, and monitoring and evaluation with support from the Global Fund</li> <li>▶ Establish web-based reporting system</li> <li>▶ Target MDA in central China</li> </ul>
The elimination stage	<ul style="list-style-type: none"> <li>▶ Lack of changes in concepts and strategies from control to elimination</li> <li>▶ Border malaria</li> <li>▶ Imported malaria</li> <li>▶ Long-term no malaria case debilitates the health workers' capacity</li> </ul>	<ul style="list-style-type: none"> <li>▶ Adaptive case-centric and focus-centric comprehensive strategy and 1-3-7 approach</li> <li>▶ Construction and re-inforcement of elimination-specific reporting system and diagnosis reference laboratory network</li> <li>▶ Three defensive lines strategy and '3+1' strategy in border areas of Yunnan province</li> <li>▶ Imported malaria management through multisectoral cooperation</li> <li>▶ Various capacity-building and maintenance measures</li> </ul>

Despite great successes in malaria management and elimination, there are still nearly 2000–3000 imported malaria cases every year in China, due to international exchange of workers, commerce, tourism, and other personal travel to and from areas with a high incidence of malaria such as Africa and South-East Asia. These cases are distributed in each province. In addition, the pressure of preventing re-establishment of transmission after introducing imported malaria has increased due to the insignificant changes in malaria vectors. Therefore, it is necessary to maintain sufficient and long-term surveillance and response capacity to sustain the gained achievements. Border malaria remains a threat, especially on the China–Myanmar border, given that Myanmar still has substantial malaria incidence in areas bordering the Yunnan province. Malaria elimination has been achieved on the Chinese side; however, many migrants crossing the border and the lack of barriers for malaria vectors heighten the risk of importation, introduction and re-establishment of malaria. Strong multisectoral collaboration and international cooperation between bordering countries with endemic malaria is recommended.<sup>34</sup>

Countries that are on the verge of eliminating malaria may face problems similar to China. Countries where malaria is still endemic have even greater challenges. There are many technical and logistical challenges related to the reduction of malaria occurrence and death, protection of vulnerable groups, improvements of the healthcare system, and investments in malaria programmes and research.

Furthermore, biological threats to the fight against malaria include parasite *pfhrp2/3* deletions, which increases diagnostic difficulties. Next, due to the emergence of resistance against drugs and insecticides, there is a pressing need to develop and deploy complementary strategies. Finally, vector resistance to various insecticides highlights the need to guide resistance management and implement a national insecticide resistance monitoring and management plan.

As we move towards the digital era, data-driven approaches or tools for mapping, planning and tracking life-saving interventions in low-resource areas are critical. Artificial intelligence based monitoring and surveillance are recommended, which can improve data reporting and stimulate data-driven conversations and decision-making by connecting healthcare staff at all levels.

## CONCLUSION

Current prevention and intervention approaches have led to significant progress in malaria control and elimination. However, many efforts are still needed to achieve a malaria-free world. Malaria elimination is not the final goal for public health in China. Instead, it is a new starting point for China to promote work on preventing imported malaria and engaging in global health by disseminating successful approaches from China to other countries where malaria is still endemic.

China's global health cooperation related to malaria has grown to include medical team deployments, training programme installations, medicine and medical equipment donations, joint research and academic exchanges, and bilateral and multilateral pilot control projects. For example, many centres use ACTs that were created by the Guangdong team in China to treat malaria in Comoros, Sao Tome and Principe, Papua New Guinea, and Togo. The China–UK–Tanzania tripartite project using a 1,7-malaria Reactive Community-based Testing and Response model has demonstrated remarkable achievements in their pilot areas, although their shortcomings and potential risks require further investigation.<sup>35 36</sup>

In the future, China will particularly focus on malaria re-transmission risk, improve management on imported malaria and mobile populations, and maintain surveillance and response capacity in the post-elimination phase. In addition, China will overcome challenges in diagnosis and drug and insecticide resistance, as well as continue to be widely involved in global healthcare. It is expected that the experience and lessons learnt from the Chinese national malaria control and elimination programmes will contribute to achieving the final goal of malaria eradication worldwide.

**Contributors** ZGX and XYF contributed to the original idea and conceived the paper. XYF, ZGX, FH, JHY and RBW wrote the initial draft of the paper. XYF and ZGX contributed to the revision of the manuscript, and the final version was reviewed by ZGX. ZGX accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. All authors approved the final manuscript.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon request.

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