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REVIEW ARTICLE

Prevention of Re-establishment of Malaria Transmission in China: Insights from the World Malaria Report 2025

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Abstract

The World Health Organization (WHO) "World Malaria Report 2025" outlined global and regional malaria morbidity and mortality patterns; assessed progress toward the WHO's 2016–2030 Global Technical Strategy milestones; and described funding for malaria initiatives and research. It further examined achievements and gaps across prevention, diagnosis, treatment, elimination, and re-establishment interventions; discussed emerging biological threats; and included a dedicated chapter on escalating antimalarial drug resistance challenges. This article highlights the key points of the report and provides a snapshot of the global malaria burden and advancements. In addition, it briefly summarizes China's efforts and challenges faced in preventing the re-establishment of malaria transmission, and future prospects for the maintenance of malaria-free status.

Key words: Malaria, Surveillance, Biological threats, Antimalarial drug resistance, Prevention of re-establishment

On December 4, 2025, the World Health Organization (WHO) released the "World Malaria Report 2025" [1], based on 2024 data from 80 malaria-endemic countries. This report outlines malaria morbidity and mortality patterns worldwide and by region, and assesses advancement toward the WHO Global Technical Strategy for Malaria 2016–2030 (GTS) milestones and targets [2]. It further describes funding for malaria-related initiatives and research, highlights progress and deficiencies across various intervention domains (including prevention, diagnosis, treatment, elimination, and prevention of re-establishment), and addresses emerging biological threats [1]. Notably, the report includes a chapter focusing on progress and challenges regarding antimalarial drug resistance, reflecting escalating global concerns [1]. This report provides essential evidence for understanding both achievements and emerging biological threats jeopardizing malaria elimination goals, and offers a critical reference for formulating malaria control and elimination strategies. However, because of limitations in data availability and quality, the report's analysis at the national level provides primarily regional aggregate data, excessively relies on model estimates, and lacks an empirical basis. Herein, we highlight key points from the "World Malaria Report 2025" and examine implications for China's efforts and challenges in preventing the re-establishment of malaria transmission.

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SNAPSHOT OF GLOBAL MALARIA BURDEN AND ADVANCEMENTS

Global trends in malaria cases and deaths

The GTS set targets to decrease malaria case incidence and mortality rates with respect to the 2015 baseline by at least 40% by 2020, 75% by 2025, and 90% by 2030 [2]. Despite substantial progress since 2000, the ambitious GTS morbidity and mortality targets for 2020 were not met worldwide by 2024. Furthermore, both the GTS and Sustainable Development Goal targets [3] for 2025 and 2030 are not likely to be achieved.

In 2024, an estimated 282 million malaria cases were reported in 80 malaria-endemic countries worldwide, including French Guiana, which reported an increase of approximately 9 million cases (3%) with respect to 2023 (Fig 1) [1,4]. Between 2000 and 2015, the malaria case numbers across 108 countries slightly decreased overall, by approximately 3.8%, from 239 million to 230 million cases. During the same period, the malaria case incidence rate decreased by 25.6%, from 79.4 to 59.0 cases per 1000 at-risk population. However, since 2015, cases have sharply risen, by 22.6%. This increase was concentrated in two WHO regions: the WHO African Region, which accounted for 88% of the increase, and the WHO Eastern Mediterranean Region (12%). In contrast, the Southeast Asia Region showed a concurrent decrease. Between 2015 and 2024, malaria incidence also increased by 8.5%. The estimated increase was multifactorial and context-specific across nations. For example, factors including increased conflict, extreme climate events, and the coronavirus disease (COVID-19) pandemic contributed to not only disruptions in essential malaria services but also improved surveillance systems in many high-burden countries.

Simultaneously, approximately 610000 malaria deaths were reported globally in 2024, representing an increase

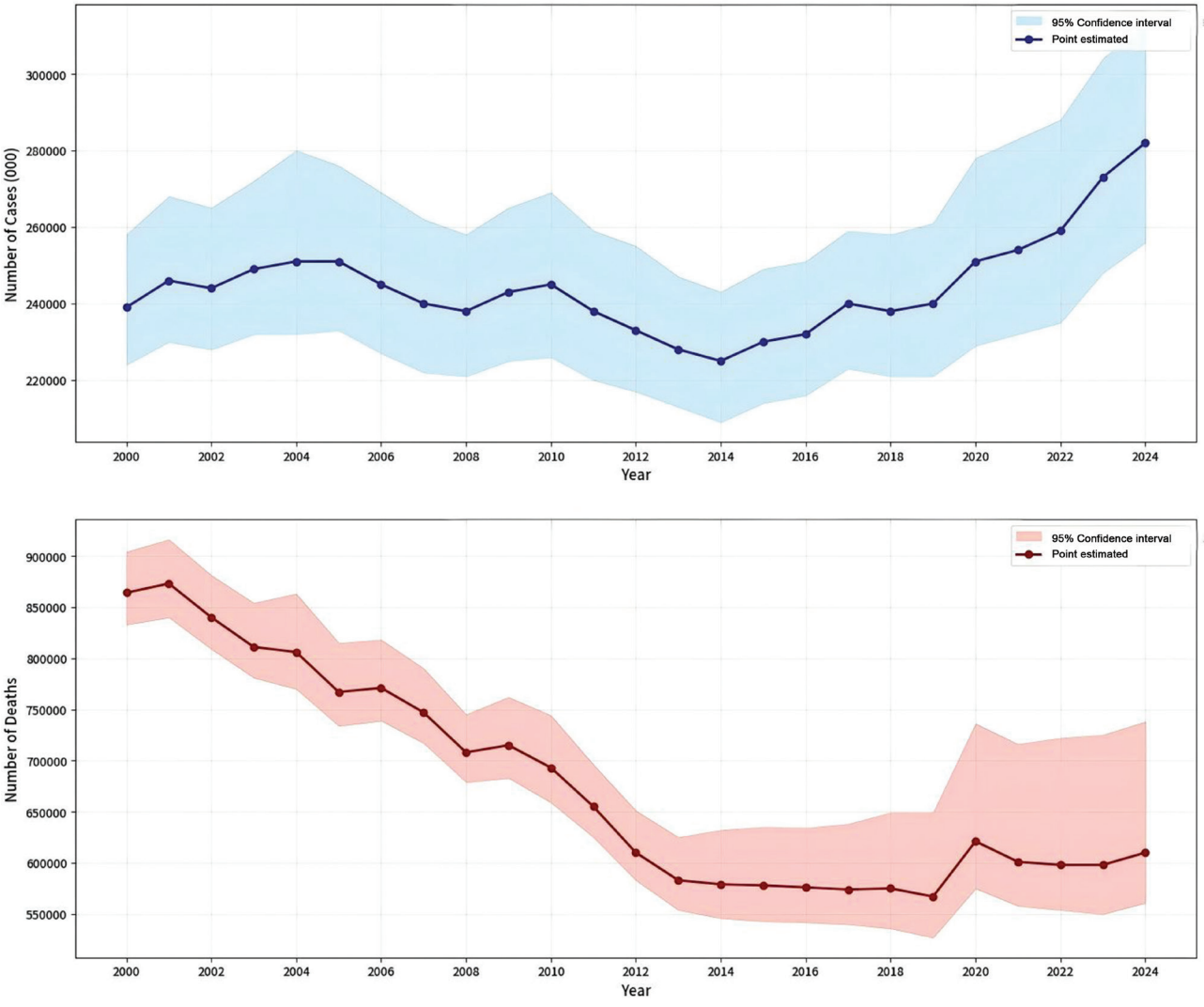

FIGURE 1 | Global estimated malaria cases and deaths, 2000–2024.

of 12000 cases with respect to 2023 (Fig 1) [1,4]. From 2000 to 2015, the number of malaria deaths declined by 33.1%, from 864000 to 578000. During the same period, the malaria mortality rate was nearly halved, from 28.6 to 14.9 per 100000 at-risk population. Between 2015 and 2024, malaria deaths increased 5.5%, and more than one-third of this increase occurred between 2023 and 2024. Although mortality rates have continued to decline in recent years, the rate of decline has substantially slowed, to 7.4% in the 9 years since 2015.

Malaria elimination progress

With continued progress toward malaria elimination, more countries have achieved and maintained zero indigenous cases. By 2024, 21 countries (22.6%) met the GTS morbidity milestone (≥70% malaria case incidence decrease or zero cases); however, the incidence increased in 30 countries (32.3%) [1,2]. Regarding mortality, 35 countries (37.6%) met the milestone (≥70% decrease), but rates also rose in 17 countries (18.3%) [1,2]. Notably, progress slowed between 2015 and 2024, during which the number of countries reporting fewer than 1000 or 10000 cases remained nearly unchanged.

Malaria elimination certification is the WHO's official recognition of a country's malaria-free status. By 2025, a total of 47 countries and one territory had achieved malaria-free status (Fig 2) [5]. In 2024, Egypt [6] and Cabo Verde [7] were certified malaria free. However, 80 countries remained endemic, representing a decrease from the 108 in 2000. In 2025, Timor-Leste [8], Suriname [9], and Georgia [10] received the WHO certification. Furthermore, Bhutan, Saudi Arabia, and Malaysia have achieved multi-year zero transmission but await certification, and Türkiye has applied.

Although nations worldwide are advancing toward malaria elimination, the varying experiences across different countries highlight both the momentum and fragility of progress. For example, in the Greater Mekong Subregion, through the WHO Mekong Malaria Elimination program [11], six countries are pursuing malaria elimination by 2030, with an accelerated target to end indigenous *Plasmodium falciparum* transmission by 2025, because of multidrug resistance threats. Between 2015 and 2024, the region achieved a 36.8% decrease in indigenous malaria cases and an 88.8% decrease in *P. falciparum* cases. In 2021, China was certified malaria-free [12], and Cambodia, the Lao People's Democratic Republic, and Vietnam reported substantial decreases of 99.5%, 99.1%, and 97.4% between 2015 and 2024, respectively. However, Myanmar continues to carry 95.5% of the region's malaria burden and 97.7% of its *P. falciparum* case burden, despite a 17.1% decrease from 2023 to 2024. Thailand, after previous successes, experienced a gradual case increase since 2021, and subsequently achieved a 14.6% overall decline in 2024 but a concerning 34.5% increase in *P. falciparum* cases concentrated along the Myanmar border.

Prevention of malaria re-establishment

The WHO has defined prevention of re-establishment of malaria transmission as a global malaria goal and provided global guidance to support countries that are malaria-free or near elimination [13]. The document outlines key concepts, strategies, and management principles, emphasizing early detection, prompt notification, rapid response, and strong surveillance systems. The guidance targets program managers, coordinators, public health policymakers, and health staff at the national and sub-national levels, particularly in tropical/subtropical regions with high malaria

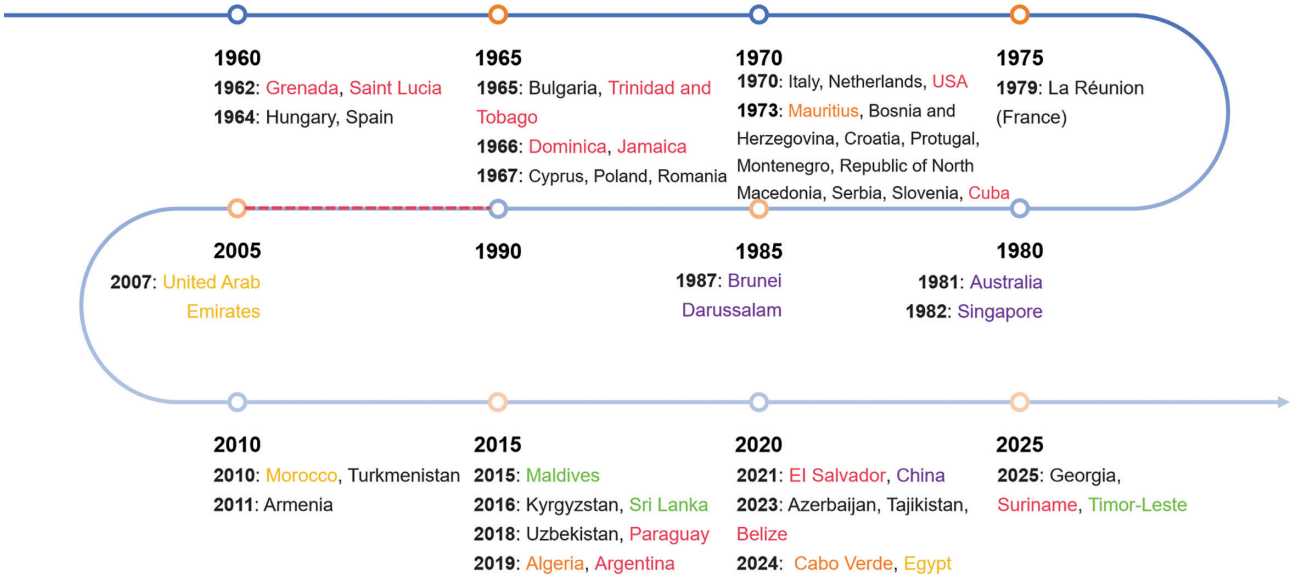

FIGURE 2 | Countries and areas certified malaria free since 1960. Countries and territories in different regions are color-coded as follows: red: Americas; black: Europe; orange: Africa; purple: Western Pacific; yellow: Eastern Mediterranean; green: Southeast Asia.

re-establishment risk. Although most malaria-free countries have sustained elimination, challenges including population mobility, climate change, and constrained health financing threaten continued success. The guidance provides strategic recommendations for maintaining vigilance, securing investments, and strengthening multi-sectoral coordination and cross-border collaboration; country examples illustrating practical implementation are additionally provided.

In countries that have already eliminated malaria, maintaining malaria surveillance remains crucial. Robust surveillance and response systems capable of timely detection, diagnosis, reporting, and appropriate treatment can prevent malaria resurgence, avert further transmission, and maintain malaria-free status. Notably, returnees with a travel history to malaria-endemic regions require special attention. Moreover, to consolidate elimination achievements and advance global goals, strong international collaboration across multiple fields, such as coordinated data sharing and joint responses, is crucial in malaria surveillance. Many persisting challenges remain to be addressed.

Status of malaria interventions facing biological threats

The WHO monitors four key biological threats to malaria control and elimination: *pfhrp2/3* gene deletions, antimalarial drug resistance, insecticide resistance, and invasive *Anopheles* species [14]. Surveillance of these threats enables early detection and continual monitoring, thereby providing national malaria programs with timely and accurate data to optimize control strategies, and supporting effective policy-making for malaria case management and vector control.

Gene deletions in *pfhrp2/3* in *P. falciparum* were first reported in Peru in 2010 [15]. Increasing numbers of countries have since reported confirmed cases of these deletions. Among the 80 currently malaria-endemic countries, data were available for only 51. The prevalence distribution was as follows: ≤1% in 17 countries; >1% to 8% in 24 countries; >8% to 15% in 4 countries (Guatemala, Honduras, Somalia, and South Sudan); and >15% in six countries (Brazil, Djibouti, Eritrea, Ethiopia, Nicaragua, and Peru) [1]. However, because recent sample data are lacking, the WHO recommends that affected countries and the countries bordering them conduct representative *pfhrp2/3* gene deletions baseline surveys among suspected malaria cases [16]. Rapid diagnostic tests (RDT) kits remain a critical tool for rapid malaria diagnosis by enabling timely treatment. Although most RDTs target the HRP2 antigen [17], *pfhrp2/3* gene deletions limit the effectiveness of HRP2-based RDTs [18,19]. Importantly, no WHO-prequalified RDTs currently meet the performance requirements for *P. falciparum* detection by using alternative targets such as Pf-LDH [20], although new products including both HRP2 and Pf-LDH on single or separate test lines are in the WHO prequalification pipeline [21]. Other measures, including the identification of novel biomarkers, enhancement of non-HRP2 RDT performance, and strengthening of laboratory networks, are also encouraged to support the use of molecular characterization to determine the presence or absence of these gene deletions.

The emergence of multidrug resistance is a public health concern that threatens the sustainability of global efforts to decrease the malaria burden. However, therapeutic efficacy studies (TES) from 2015–2025 have suggested that the recommended antimalarial treatments have remained predominantly effective across WHO regions. Most relevant studies have reported *P. falciparum* and *P. vivax* failure rates below 10% [1,22]. Artemisinin-based combination therapy (ACT) remains the recommended treatment for uncomplicated falciparum malaria. Nevertheless, its therapeutic efficacy faces challenges due to decreasing activity of ACT components. The failure rates exceeded 10% in 15 of 185 studies on artemether-lumefantrine (AL) and 3 of 48 studies on dihydroartemisinin-piperaquine (DHA-PPQ) against *P. falciparum* in Africa, and 2 of 22 AL studies and 13 of 28 DHA-PPQ studies against *P. falciparum* in the Western Pacific. These findings prompted treatment changes adopting artesunate-mefloquine in Cambodia and artesunate-pyronaridine in Vietnam.

Mosquito insecticide resistance has challenged malaria prevention by driving insecticide-treated net innovation. The use of dual active ingredient nets combining pyrethroids with chlorfenapyr or pyriproxyfen increased from 8% of deliveries in 2022 to 47% in 2024, thus surpassing the use of pyrethroid-Piperonyl butoxide (PBO) nets (30%) for the first time; however, use of conventional pyrethroid-only nets decreased from 45% to 23% [1]. Indoor residual spraying currently uses seven insecticide classes (pyrethroids, carbamates, organophosphates, neonicotinoids, isoxazolines, pyrroles, and meta-diamides). DDT is being phased out, and indoor residual spraying (IRS) use has declined because of cost. From 2020 to 2024, insecticide resistance monitoring data from 58 countries (including 55 malaria-endemic countries) confirmed resistance to at least one class at one site in 48 countries (83%). Pyrethroids dominated (53% of all bioassay results), and resistance was detected in 91% of monitored countries (48/53). However, organophosphates (20% of all bioassay results, 9/43 countries, 21%), carbamates (7% of all bioassay results, 20/34 countries, 59%), and neonicotinoids (12% of all bioassay results, 12/23 countries, 52%) showed progressively lower monitoring coverage and variable resistance prevalence.

Anopheles stephensi, native to Asia and the Arabian Peninsula, efficiently transmits both *P. falciparum* and *P. vivax*. This mosquito breeds in urban water containers and can survive extreme dry-season temperatures. It exhibits resistance to pyrethroids, organophosphates, carbamates, and organochlorines in its native range, and resistance to carbamates, pyrethroids, and organophosphates in the Horn of Africa [23]. Since its first detection in Djibouti in 2012 [24], the presence of this mosquito species has been confirmed in countries across Africa and Asia [25], including Ethiopia [26], Sri Lanka [27], Sudan [28], Somalia

[29], Nigeria [30], Eritrea [31], Yemen [32-34], Ghana [35,36], Kenya [37], and Niger [38]. However, surveillance in Cameroon, Senegal, Tanzania, Liberia, Burundi, and Mozambique has returned negative results [39]. Given its threat to malaria control, the WHO urges surveillance efforts to map spread; achieve immediate detection and reporting; and take urgent action to prevent urban/peri-urban expansion, particularly between the Horn of Africa and West Africa [40-43].

Progress and challenges in antimalarial drug resistance

Antimalarial drug resistance poses a critical threat to malaria elimination. Partial artemisinin resistance and partner drug pressure are escalating amid health system vulnerabilities, including insufficient treatment coverage and regulation (particularly in the private sector), as well as surveillance gaps, thus echoing the history of the spread of chloroquine and sulfadoxine-pyrimethamine resistance. Drug resistance arises from an interplay among biological adaptation, human behavior, and health system performance. Genetic mutations can spread under conditions influenced by prevention coverage, diagnostic accuracy, treatment adherence, and surveillance capacity, and gaps that allow for subtherapeutic drug exposure and undetected circulation of resistant parasites [44].

The private sector plays a critical yet problematic role, particularly in sub-Saharan Africa and Asia, where a high proportion of patients with fever seek medical care outside public healthcare facilities [1]. Despite the expansion of access to healthcare services, the private sector often provides presumptive treatment without testing; dispenses incomplete, non-WHO-prequalified, or even non-nationally approved therapies; and provides injectable malaria treatments for uncomplicated febrile illnesses, thereby exposing parasites to subtherapeutic concentrations [45-47]. Although ACT subsidy programs and RDT integration have improved treatment quality and affordability, resistance continues to be facilitated by weak regulation, poor surveillance integration, and a lack of timely data on private provider practices. Therefore, urgent needs exist to strengthen oversight, ensure complete diagnostic-guided treatment, and close quality assurance gaps across both public and private care channels [48].

Robust surveillance through TES in most malaria-endemic settings [49] and integrated drug efficacy studies in several low transmission countries [50], complemented by *in vitro* testing of parasite susceptibility and genotypic analysis of markers such as PfKelch13 [51], are essential for early detection of declining antimalarial efficacy and for guiding policy changes before resistance becomes entrenched. Although ACTs revolutionized malaria treatment by combining a fast-acting artemisinin derivative with longer-acting partner drugs, partial artemisinin resistance, characterized by PfKelch13 mutations and delayed parasite clearance, emerged along the Cambodia–Thailand border by the mid-2000s, thus increasing pressure on partner drugs and rasing the risk of multidrug resistance, and threatening treatment efficacy, as observed with piperaquine in Cambodia. Although the Greater Mekong Subregion successfully contained this threat through coordinated investment via the Global Fund's Regional Artemisinin-resistance Initiative [52] and the WHO's MME program [11], progress remains fragile in conflict zones. This achievement was dependent primarily on strengthened surveillance, rapid data sharing, strong policy responses, and targeted elimination of resistance drivers, and it achieved near-elimination in former epicenters such as Cambodia and the Lao People's Democratic Republic. However, challenges persist in sub-Saharan Africa, where resistance is emerging in high-transmission settings with limited surveillance and constrained resources. Therefore, enhanced monitoring and adaptive containment strategies beyond Southeast Asia are urgently needed. Meanwhile, critical gaps remain: only 15 African countries have reported TES data since 2020, because of funding shortages, political neglect, and COVID-19 disruptions, thus leaving vast areas without current data; consequently, urgent needs exist to expand surveillance coverage, enhance data sharing, and strengthen molecular monitoring to safeguard treatment efficacy across high-transmission settings [53].

PREVENTION OF MALARIA RE-ESTABLISHMENT IN CHINA

China received WHO malaria elimination certification in June 2021 [12]. However, risks of imported malaria persist. Fortunately, China has maintained zero indigenous malaria cases since 2017 through multiple sustained efforts.

Maintaining robust malaria surveillance

In 2024, malaria cases in China reached the highest annual total since 2017 (3157 cases, representing a 26.9% increase with respect to the 2488 cases reported in 2023) [54-56]. Among them, 3155 cases were imported (including 2006 *P. falciparum* cases, 798 *P. vivax* cases, 274 *P. ovale* cases, 65 *P. malariae* cases, and 12 mixed infections), whereas two cases were due to transfusion infections (*P. falciparum*). In addition, 15 deaths were reported (all due to *P. falciparum*) [56]. Since 2017, a total of 16571 imported malaria cases have been reported in China, and *P. falciparum* has remained the dominant species each year (48.87%–66.01% of annual cases); however, the proportion of *P. vivax* cases (10.81%–25.29%) was only slightly lower than that of *P. ovale* cases in 2019 and 2021 [54-61] (Fig 3). The sharp decrease in reported cases during 2020 and 2022 was due to COVID-19 travel restrictions, and the case numbers rebounded immediately after the restrictions were lifted. In addition, no clinically diagnosed cases have been reported since 2020 (Fig 3).

Imported malaria cases originated primarily from African and Asian countries, whereas a minority came

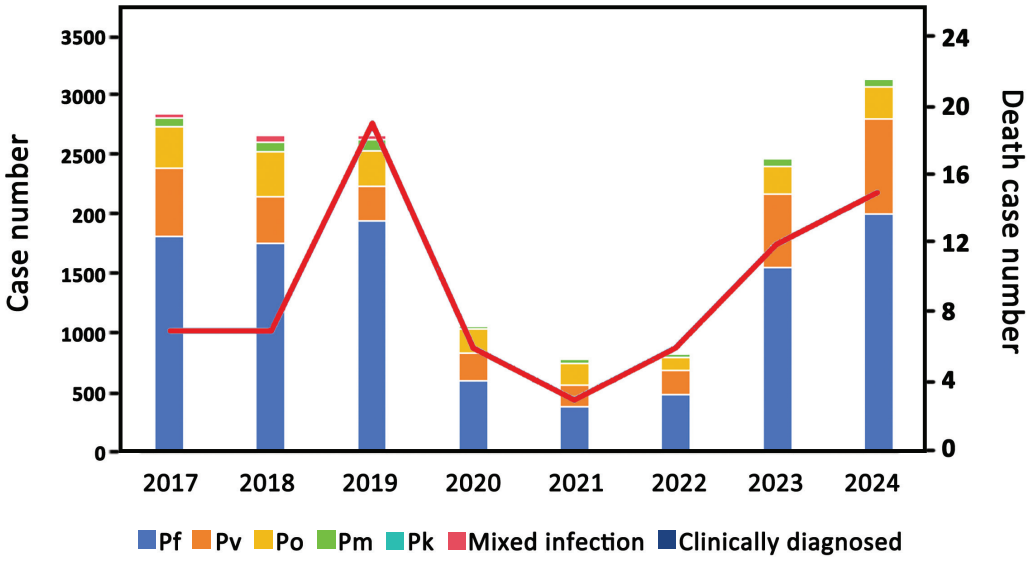

FIGURE 3 | Imported malaria cases and deaths reported in China, 2017–2024.

from malaria-endemic countries in Oceania, South America, and North America [62]. Furthermore, *P. falciparum* infections were acquired primarily in African countries such as Nigeria, Ghana, Angola, Cameroon, the Democratic Republic of the Congo, Côte d'Ivoire, and Guinea, although *P. vivax* infections came predominantly from Myanmar. Domestically, nearly all provinces reported imported malaria cases each year. Imported *P. vivax* cases were most frequently reported from Yunnan, although other historically malaria-endemic regions also had documented cases [63]. Notably, malaria death cases were reported each year across multiple provinces, and transfusion-related cases were reported across several provinces over multiple years [54–57]. Recurrent *P. malariae* cases (primarily in Guangdong) additionally warrant attention [64]. Malaria cases were reported year-round and showed no clear seasonal trends, although modest peaks were generally observed at the beginning, middle, and end of each year.

Sustaining malaria vector management

Mosquito vector surveillance is critical in interrupting malaria transmission. After malaria elimination, China has continued to strengthen its *Anopheles* mosquito surveillance efforts. The distribution of *Anopheles* mosquitoes across regions is an important basis for dynamic stratification of the risk of re-establishment of malaria transmission in areas where malaria was previously prevalent [65,66]. Provinces must make dynamic adjustments according to the annual imported malaria cases and *Anopheles* mosquito surveillance data, although a risk assessment is conducted at the national level, and the risk stratification is adjusted every 3 years [65,66].

A vector surveillance network covering vector biology, etiology, and insecticide resistance monitoring has been established [67]. Furthermore, activities such as *Anopheles* population monitoring, density monitoring, and insecticide sensitivity monitoring are performed through the establishment of national and provincial sentinel sites for malaria vector surveillance [65,66]. Continual surveillance and timely information sharing play important roles in *Anopheles* mosquito surveillance, as well as in risk assessment, prediction, and early warning of malaria re-transmission. During malaria focus investigation and response, historical vector data from the past 3 years in the affected counties should be retrospectively reviewed [65,66]. If relevant data are lacking, an *Anopheles* population survey at the focus should be conducted, and appropriate vector control measures should be implemented according to local malaria-transmitting *Anopheles* status [65,66]. These measures not only target local malaria *Anopheles* but also are crucial for preventing the invasion of *Anopheles* mosquitoes. The risk of re-establishment of transmission caused by imported malaria cases and the invasion of *Anopheles* mosquitoes persists [68,69]. If invading mosquitoes find suitable breeding environments within China and come into contact with imported cases, local transmission may occur. In particular, at the China-Myanmar border area in Yunnan Province, which has a suitable climate and abundant malaria-transmitting *Anopheles*, the risk of cross-border malaria transmission caused by *Anopheles* invasion remains relatively high [70–72].

Strengthening policy guarantee

A strategic and legal framework underpins malaria control in China's post-elimination phase. Malaria remains classified as a category B notifiable infectious disease [73] and therefore requires 24-hour reporting of confirmed or suspected cases, thus providing the legal foundation for the "1-3-7" approach [74]. The "Management Measures for Preventing Re-establishment of Malaria Transmission"

[65] and its companion, "Technical Plan for Preventing Re-establishment of Malaria Transmission" [66], developed during the preparation for elimination certification, marked a deliberate shift from case containment during the malaria elimination phase to timely detection and precise interruption of imported infectious sources after elimination. This shift has required better multi-sectoral cooperation, and stronger surveillance and response efforts, to promptly identify and properly treat imported cases; investigate and assess the transmission risk of imported cases; and provide timely management of foci or populations at risk of re-establishment of malaria transmission, in line with the WHO guidelines and practical work experience. In addition, in response to the increased risk of concentrated outbreaks and secondary transmission among returning travelers in multiple locations after the resumption of international flights during the COVID-19 pandemic, a guideline was promptly issued to help local authorities raise awareness regarding prevention and control measures, strengthen the implementation of various measures, and comprehensively ensure prevention of malaria re-establishment [75]. However, the current framework remains heavily dependent on case-triggered post-arrival detection, and an adaptive lag exists in national technical plan updates.

Enhancing malaria laboratory testing capabilities

Accurate and prompt diagnosis of cases is critical for malaria control and elimination, and for the timely detection of foci and prevention of malaria reintroduction after elimination. In the post-elimination phase, China continues to strengthen the construction of a malaria diagnosis reference laboratory network [76,77]. Both the "Management Measures for Preventing Re-establishment of Malaria Transmission" and "Technical Plan for Preventing Re-establishment of Malaria Transmission" specified the malaria laboratory diagnostic capacities required at various medical and health institutions, and mandated further development of the reference laboratory network to achieve full provincial coverage. The national reference laboratory network, which covered all 24 historically malaria-endemic provinces during the elimination phase, newly incorporated Ningxia and Beijing as members in 2021 and 2025, respectively. Further expansion to the remaining provinces is underway. Moreover, many provinces, including Shandong and Yunnan, are also advancing the development of provincial malaria diagnosis laboratory networks that cover all prefectures and counties across their administrative regions.

Several important programs have been undertaken by leveraging this reference laboratory network platform. First, external assessments of laboratory capabilities were conducted, focusing primarily on *Plasmodium* blood smear microscopy and nucleic acid testing proficiency evaluations [78]. Second, senior malaria microscopists were trained to become qualified teaching staff for *Plasmodium* microscopy in each province [79]. Third, technical support was provided for the national technique competitions for diagnosis of parasitic diseases, including technical training and competency assessment for blood smear preparation and *Plasmodium* microscopy [80]. Fourth, the current report on drug resistance of imported malaria parasites indicates that AS plus DHA-PPQ (2023) and CQ (2021–2023) remain effective for imported *P. falciparum* and *P. vivax* malaria isolates in China, according to integrated drug efficacy studies; however, late parasitological failure was found in one *P. falciparum* case (1/26) and two *P. vivax* cases (2/116) treated with DHA-PPQ and CQ, respectively [81]. Moreover, different mutation sites, several of which were newly identified, were also detected in these samples through molecular surveillance.

In addition, two new national standards for *Plasmodium* detection were released in 2025, for immune-chromatographic testing [82] and nucleic acid identification of the species [83].

Prioritizing border malaria and health education

Globally, border malaria control and elimination remain persistent challenges, owing to complex environmental, geographic, administrative, and anthropological factors. Notably, China shares the longest land borders worldwide with 14 countries, nine of which are malaria-endemic. Myanmar has long been a major source of reported malaria cases, particularly *P. vivax* cases, in China, although the Greater Mekong Subregion has made considerable progress in decreasing malaria transmission and remains on track for its elimination by 2030. Beyond being found in Yunnan, these *P. vivax* cases were also widely distributed in other areas, and many areas in China have *Anopheles sinensis* mosquitoes that are capable of *P. vivax* transmission [63]. In fact, introduced *P. vivax* cases associated with the imported cases from Southeast Asia have been reported in Longhui in Hunan Province and Dandong in Liaoning Province during the elimination phase [57,84]. Multiple surveys have been conducted in border areas, such as Yunnan, Guangxi, and Liaoning, to assess the implementation of measures to prevent re-establishment and evaluate associated risk, and have been complemented by cross-border workshops to facilitate dialogue. However, binding enforcement mechanisms to ensure coordinated vector control or case management across jurisdictions are lacking.

Importantly, patients must seek healthcare promptly; therefore, they require good awareness of malaria prevention and treatment. People with malaria returning from abroad are often unaware of the dangers of malaria and the need to seek healthcare promptly; moreover, they often do not visit a physician in time after experiencing fever or discomfort, or actively inform physicians of their travel history. In the post-elimination phase, front-line health providers' vigilance, and malaria diagnosis and treatment capabilities, might also be weakened. These aspects are critical reasons for the persistence of malaria deaths in China. Taking World Malaria Day and National Malaria

Day as key opportunities, China undertook various forms of malaria awareness campaigns, to increase public awareness of malaria symptoms, transmission, prevention, and treatment, as well as to promote understanding of, and adherence to, timely diagnosis, standardized treatment, and preventive measures. These activities extended beyond health sectors, and involved multiple sectors and even neighboring countries in joint initiatives.

Strengthening international cooperation

Achievements in China's malaria control and elimination offer valuable lessons for global efforts. However, sustained impact requires both technical and systemic challenges to be addressed. China's participation in the global malaria eradication efforts has not only accelerated the attainment of the goals but also decreased imported malaria cases in China from the malaria-endemic areas.

China has systematically documented 70 years of malaria control and elimination experience from multiple perspectives and shared it with the world [76,85-90]. However, the strategies and measures suitable for China might not be appropriate under the different health system conditions of other malaria-endemic countries or regions. The transferability of China's approach remains contingent on local adaptation rather than direct replication.

China has promoted strategy localization, particularly the "1, 7-mRCTR" adaptation of the "1-3-7" approach in African countries including Tanzania, Zambia, Burkina Faso, and Senegal [91-95], through dispatched medical teams, WHO collaborating centers, and networks including the China-Africa Malaria Elimination Cooperation Network (INCAM) [96,97]. Moreover, China has worked with multiple countries at the borders in the Lancang-Mekong region, to jointly promote and continually strengthen malaria prevention and control mechanisms, and take decisive measures to collectively address threats such as antimalarial drug resistance in the region [98]. Although these initiatives have achieved tangible outputs, their long-term effectiveness might potentially be influenced by factors such as uncertain host-country ownership after external support diminishes.

China will continue to actively participate in global efforts to eradicate malaria and gain momentum in anti-malaria efforts worldwide through technological innovation. On the one hand, only WHO-prequalified products are eligible for procurement by the United Nations and other international organizations, China has actively promoted the global application of artemisinin since its discovery more than 50 years ago. Artemisinin-based combination therapies have become the standard antimalarial treatments recommended by the WHO. As of 2025, China had a total of 39 malaria-related products prequalified by the WHO, including 29 complete pharmaceutical products and 10 active pharmaceutical ingredients, representing the largest portfolio of WHO-prequalified antimalarial products worldwide [99]. In 2023–2024 alone, 40 mg/320 mg tablets of the antimalarial drug dihydroartemisinin-piperaquine developed by KPC Pharmaceutical, Inc.; the One Step Malaria Pf Test and One Step Malaria Pf/Pv Tri-line Test developed and manufactured by InTec; and the Malaria P.f (HRP2/pLDH) Test Kit developed by Guangzhou Wondfo Biotech Co., Ltd., were approved. Additionally, two child-friendly formulations of primaquine independently developed by Guilin Pharmaceutical Co., Ltd., a subsidiary of Fosun Pharma, gained approval in November 2025. However, the global anti-malarial market remains highly competitive, and Chinese antimalarial brands must further strengthen their market positioning and commercialization strategies. On the other hand, international funding mechanisms are currently supporting the research and development of China's malaria prevention and control products and their promotion and application in other malaria-endemic areas. For example, the National Natural Science Foundation of China and the Bill & Melinda Gates Foundation launched programs to strengthen international cooperation to develop innovative solutions for malaria vector control, focusing on outdoor vector control strategies, tools, and products, with the goal of accelerating progress toward malaria eradication [100]. However, technological contributions remain supply driven, and greater alignment with endemic-country demand would enhance relevance.

IMPLICATIONS AND PROSPECTS

Although China has maintained zero indigenous malaria case reports since 2017, the transmission environment has not substantially changed. Given the global malaria epidemiology, the spread of artemisinin resistance, the diagnostic challenges posed by HRP2/3 deletion, the complex situation along the China-Myanmar border [101,102], and the continued rise in imported malaria cases in China in recent years [55,56], coupled with previous instances of secondary transmission from imported cases in multiple countries [103-108], the risk of secondary transmission is substantial if imported sources of infection cannot be detected in a timely and accurate manner. In China and other countries certified as malaria-free, the core of preventing re-establishment of malaria transmission involves maintaining a sensitive and efficient surveillance system, preserving professional prevention and control capacity, and strengthening joint prevention and control. Therefore, to prevent malaria re-establishment, the following efforts must be continued, at a minimum.

First, maintaining a comprehensive support system including personnel, finance, and supplies is essential. For personnel support, a professional workforce dedicated to malaria prevention and control should be maintained; the first-visit responsibility system in medical institutions should be strengthened; physicians' awareness regarding the need to inquire about overseas travel history should be increased; efficient channels should be established for facilities lacking malaria testing capacity to refer patients to higher-level medical institutions or CDCs to avoid

fatalities; and regular training and assessment mechanisms should be implemented to prevent a decline in diagnostic capabilities. For financial investments, adequate funding must be ensured to prevent malaria re-establishment, resources should be allocated according to differentiated risk levels, and international funding support should be actively pursued. For supply reserves, national and provincial reserves of antimalarial drugs, RDTs (including non-HRP2-dependent tests for PfHRP2/3 gene deletion cases), and microscopy consumables must be ensured. Moreover, rotation of insecticides suitable for multi-insecticide-resistant *Anopheles* mosquitoes is required for sustainable implementation of surveillance, testing, emergency response, and cross-border joint prevention and control efforts. For health education, customized malaria prevention and control health education content aimed at specific target audiences should be developed. Efforts should be made to cooperate with overseas Chinese enterprises to enforce pre-departure training and post-return health checks.

Regarding detection and surveillance, a sensitive, precise, and timely monitoring and early warning network must be established. First, the laboratory network system must be optimized by strengthening the development of the malaria diagnosis reference laboratory network. Molecular testing capabilities should be enhanced to conduct species identification, mixed infection, and drug resistance gene analysis, and a monitoring mechanism for PfHRP2/3 gene deletion should be established. Second, principles for case identification and regular management, such as the "1-3-7" approach, should be strictly enforced. Active screening should be implemented for asymptomatic infections among inbound travelers from high-transmission areas. Sufficient vigilance should be maintained for zoonotic malaria such as *P. knowlesi*, an emerging threat whose transmission from wildlife reservoirs cannot be eliminated through current malaria control measures [109,110], although very few cases infected with *P. knowlesi* have been reported in China to date. Third, drug resistance surveillance should be advanced through drug

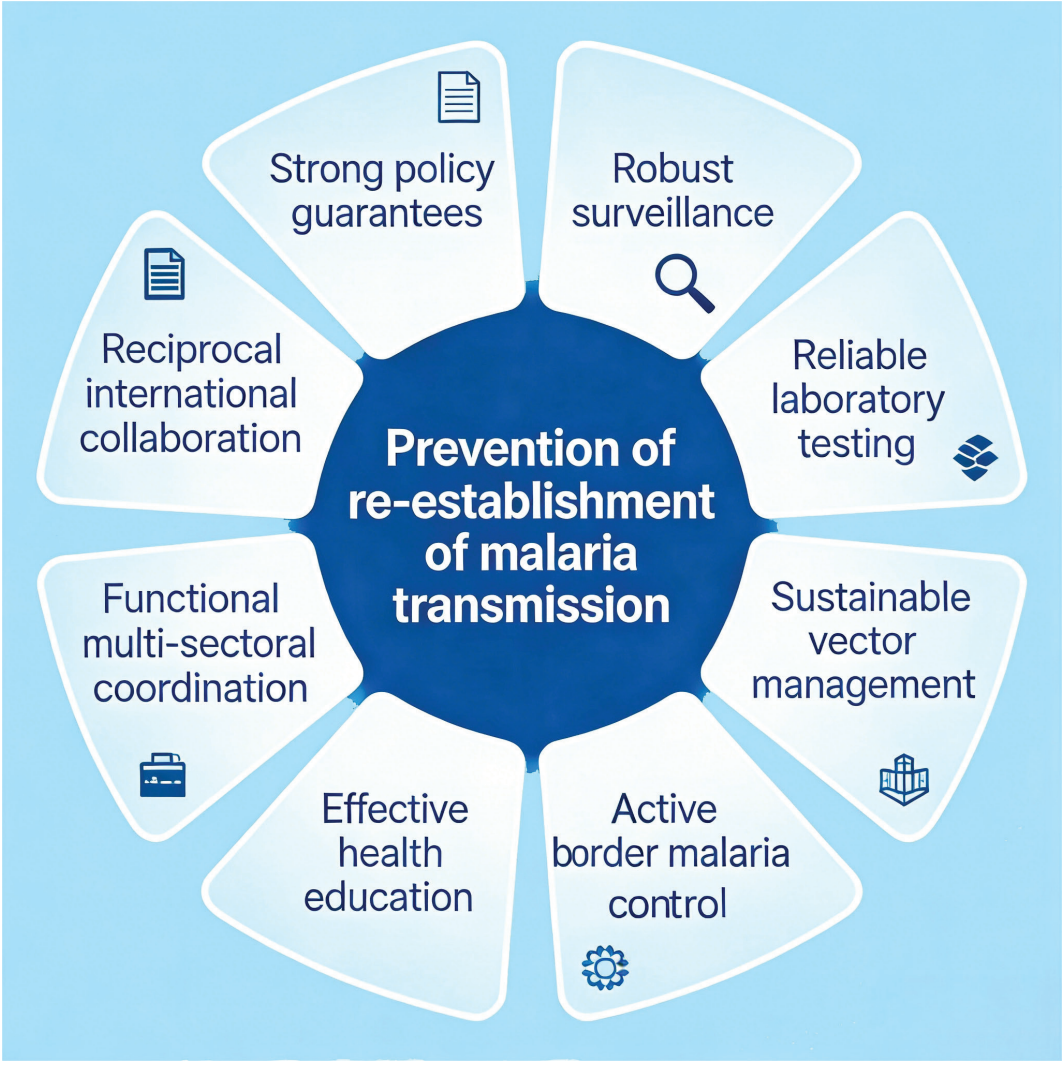

FIGURE 4 | A multifaceted approach to preventing re-establishment of malaria transmission.

efficacy studies and molecular marker surveillance, to enable dynamic evidence-based adjustment of treatment protocols. Fourth, sustainable vector management strategies should be implemented by establishing a robust mosquito vector surveillance system; enhancing mosquito population and density surveillance, and insecticide resistance monitoring and management; and promoting stratified vector control strategies. Regarding invasive mosquitoes, border quarantine measures should be strengthened to prevent the introduction of malaria vectors. In areas suitable for *Anopheles* survival, proactive surveillance should be enhanced according to vector behavior, alongside ecological improvement and other integrated control measures to decrease breeding, minimize human-vector contact, and interrupt malaria transmission. Fifth, technological innovation should be driven through wider deployment of highly sensitive and intelligent detection and monitoring technologies, improving cross-border and national data sharing platforms, and integrating multi-source data to create a traceability database for imported cases, thus enabling comprehensive analysis and early warning. In parallel, sustained investment in research and development for innovative malaria vector control solutions and new antimalarial drugs will be essential to maintain a malaria-free status.

In addition, a comprehensive joint prevention and control network must be established and continually strengthened. Domestic efforts should advance the operational mechanisms of collaboration between health authorities and multiple departments such as customs, commerce, education, culture and tourism, immigration management, public security, and justice. Internationally, cross-border joint prevention and control and scientific research cooperation with neighboring countries should be deepened through technical assistance and experience sharing, support for establishing joint sentinel sites with standardized case definitions, cross-trained response teams, and pooled financing mechanisms, to operationalize a "one-border" approach to containment and address the biological reality in which transmission risk is distributed across, rather than contained within, administrative boundaries. In addition, active participation in global malaria eradication efforts should be pursued by supporting African countries in malaria prevention and control through platforms such as China-Africa cooperation and the Belt and Road Initiative, as well as close collaboration with the WHO. Furthermore, enterprises and society should be encouraged to participate in this program, to establish whole-society synergy in jointly protecting against imported malaria. Enterprises operating overseas (in malaria-endemic areas) should be required to implement on-site prevention and control responsibilities and provide malaria health education.

Above all, malaria elimination is not an endpoint, and maintaining malaria-free status requires strong policy guarantees, robust surveillance, reliable laboratory testing, sustainable vector management, active border malaria control, effective health education, functional multi-sectoral coordination, and reciprocal international collaboration (Fig 4).

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this article.

ETHICS STATEMENT

No direct interactions with human or animal subjects were involved. Therefore, ethical approval and informed consent were not required.

AUTHOR CONTRIBUTIONS

JHY performed conceptualization. All authors participated in the preparation and review of the original draft. All authors have read and approved the published version of the manuscript.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest. This study represents the authors' personal opinions alone and does not represent the views of their institutions.

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