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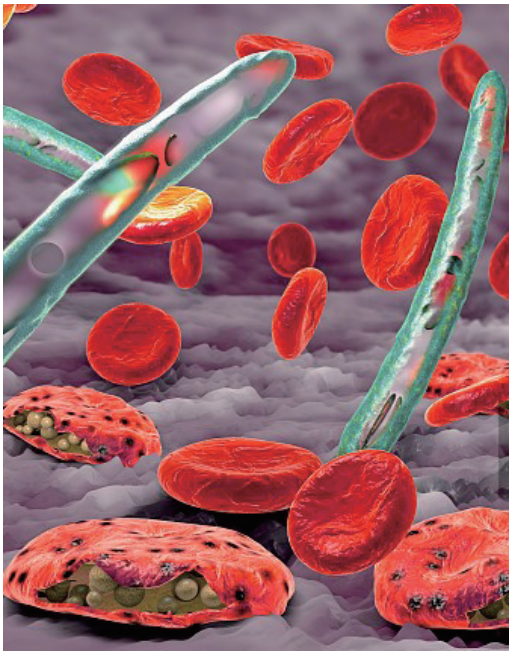

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Cover Image: 3D illustration of blood cell, Plasmodium causing malaria illness (adapted from https://www.vcg.com/).

Announcements

The 13th World Malaria Day — April 25, 2020

World Malaria Day, established by the World Health Assembly at its 60th session in May 2007, is commemorated each year on April 25. According to the World Health Organization's (WHO) World Malaria Report 2019, an estimated 228 million cases of malaria (95% confidence interval [CI]: 206–258 million) occurred worldwide and most of the cases (213 million, 93%) were in the WHO African Region in 2018. There were an estimated 405,000 deaths from malaria, of which 272,000 (67%) were children aged under 5 years old. There were no global gains in reducing new infections over the period of 2014 through 2018, and nearly as many people died of malaria in 2018 as the year before (*1*).

On World Malaria Day 2020, the WHO joins the RBM Partnership to End Malaria in promoting "Zero Malaria Starts with Me", a grassroots campaign that aims to keep malaria high on the political agenda, mobilize additional resources, and empower communities to take ownership of malaria prevention and care (*2*).

During the COVID-19 pandemic, the malaria community must remain committed to supporting the prevention of malaria infection, illness, and death through preventive and case management services, while maintaining a safe environment for patients, clients, and staff. Deaths due to malaria and its comorbidities (anemia, undernutrition, etc.) must continue to be prevented. The National Health Commission of China has announced China's 2020 National Malaria Day theme: "Eliminating malaria and containing COVID-19: co-mitigation of imported cases and re-establishment" (*3*).

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Vital Surveillances

Imported Malaria Cases — China, 2012–2018

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ABSTRACT

Introduction: In 2017, no indigenous malaria cases were reported in China, but imported malaria was a challenge for the elimination program. This study analyzed the status and trends of imported malaria in China from 2012 to 2018 to provide evidence for further strategies and adjustments to current interventions.

Methods: Data on individuals were collected from the Parasitic Diseases Information Reporting Management System (PDIRMS) from 2012 to 2018. *Plasmodium* species, case classification, temporal distribution, spatial distribution, and source of imported cases were analyzed to investigate imported malaria characteristics.

Results: In total, 21,376 malaria cases were recorded in the PDIRMS from 2012 to 2018. Among them, 20,938 (98.0%) cases were imported malaria cases (IMCs). The number and proportion of IMCs increased from 2012 (n=2,474, 91.0%) to 2018 (n=2,511, 99.7%). IMCs consisted of 13,510 (64.5%) *P. falciparum*, 4,803 (22.9%) *P. vivax*, 1,725 (8.2%) *P. ovale*, 376 (1.8%) *P. malariae*, 2 (0.01%) *P. knowlesi*, 348 (1.7%) mixed infections, and 174 (0.8%) clinically-diagnosed cases. The proportion of imported *P. falciparum* cases increased from 2012 (n=1403, 57.4%) to 2018 (n=1655, 66.0%), while imported *P. vivax* cases showed a decreasing trend from 2012 (n = 901, 43.7%) to 2018 (n=352, 14.0%). IMCs were mainly reported in Yunnan (n=2,922, 14.0%), Guangxi (n=2,827, 13.5%), and Jiangsu (2,067, 9.9%). IMCs were reported throughout the entire year, and the highest number of IMCs was reported in June 2013. IMCs originated from 67 countries from 4 continents, and the largest proportion were from Myanmar (n=3,081, 14.7%) and Ghana (n=2,704, 12.9%).

Conclusion and Implications for Public Health Practice: The total number of IMCs increased in China. Therefore, two actions are needed to continue

the elimination of malaria in China: prevent re-establishment caused by imported *P. vivax* because *Anopheles sinensis* is still widely distributed; and ensure timely diagnosis and appropriate treatment to avoid fatal cases caused by imported *P. falciparum*.

INTRODUCTION

China has succeeded in controlling indigenous malaria and has reached milestones towards malaria elimination since the National Malaria Elimination Action Plan has launched in 2010 (*1*–*3*). In 2017, for the first time, no indigenous cases were reported in China (*4*). However, with increasing globalization, larger numbers of people go to or return from malaria endemic areas and present challenges to malaria elimination in China (*5*).

Imported malaria cases (IMCs) may increase risks in malaria-free localities where *Anopheles* mosquitoes still exist. In addition, severe malaria infections caused by *Plasmodium falciparum* are catastrophic if diagnosis and treatment are not timely.

In 2012, the Parasitic Diseases Information Reporting Management System (PDIRMS) was set up to determine whether every case was indigenous or imported. Therefore, the objective of this study was to characterize the epidemiological status and trends of IMCs from 2012 to 2018 to provide evidence-based data to support the adjustment of appropriate strategies and activities towards the achievement of malaria elimination not only in China but also in other countries with similar elimination processes.

METHODS

Data from 31 provincial-level administrative divisions (PLADs) were collected via the PDIRMS from 2012 to 2018 and carefully reviewed. *Plasmodium* species, case classification [indigenous*, imported†, or other (induced§, introduced¶, relapse** or recrudesce††)], and source of imported cases were analyzed to explore the characteristics of IMCs. Clinically-diagnosed cases§§ and laboratory-confirmed cases¶¶ were included in this analysis. Data from Hong Kong, Macao, and Taiwan were excluded from the study. Moreover, data from foreign nationals were not concluded. Statistical analysis was performed using the chi-square test for trends by software SPSS (version 21.0, IBM Corp., New York, US), and $p < 0.05$ was considered statistically significant.

RESULTS

In total, 21,376 malaria cases were recorded in the PDIRMS from 2012 to 2018. Among them, 20,938 (98.0%) cases were IMCs. The number and proportion of IMCs increased from 2012 (n=2,474, 91.0%) to 2018 (n=2,511, 99.7%) with statistical significance (evaluated by chi-square test for trends, $\chi^2 = 435.423$, $p < 0.001$). IMCs consisted of 20,764 laboratory-confirm cases and 174 clinically-diagnosed cases. The laboratory-confirmed cases consisted of 13,510 (64.5%) *P. falciparum* cases, 4,803 (22.9%) *P. vivax* cases, 1,725 (8.2%) *P. ovale* cases, 376 (1.8%) *P. malariae* cases, 2 (0.01%) *P. knowlesi* cases, 348 (1.7%) mixed infection cases (Table 1). Among these cases, the proportion of imported *P. falciparum* cases increased from 2012 (n=1,403, 57.4%) to 2018 (n=1,655, 66.0%), while imported *P. vivax* cases decreased from 2012 (n=901, 43.7%) to 2018 (n=352, 14.0%). In addition, imported *P. malariae* and *P. ovale* cases also increased during the same timeframe. In 2012, the proportion of *P. malariae* and *P. ovale* cases was 2.3% (n=56), while in 2018, this proportion peaked at 18.0% (n=453). Most IMCs were male (n=19,877, 94.9%), and 1,061 cases (5.1%) were female. The highest number of IMCs was observed in the age group of 46 to 50 years, and most IMCs occurred in migrant workers (n=14,300, 68.3%).

* Indigenous case: a case contracted locally with no evidence of importation and no direct link to transmission from an imported case. In this study, an indigenous case refers to malaria acquired by mosquito transmission in the People's Republic of China.
† Imported case: a malaria case or infection in which the infection was acquired outside the area in which it was diagnosed. Here, it refers to the patient who acquired the illness from a known malaria-prevalent region outside the People's Republic of China.
§ Induced case: a case in which the origin of the illness can be traced to a blood transfusion or other form of parenteral inoculation of the parasite but not to transmission by a natural mosquito-borne inoculation.
¶ Introduced case: a case contracted locally with strong epidemiological evidence linking it directly to a known imported case (first-generation local transmission).
** Relapse case: a malaria case attributed to activation of hypnozoites of *P. vivax* or *P. ovale* acquired previously.
†† Recrudescent case: recurrence of asexual parasitaemia of the same genotype(s) that caused the original illness due to incomplete clearance of asexual parasites after antimalarial treatment.
§§ Clinically diagnosed case: an individual with malaria-related symptoms (fever [axillary temperature ≥37.5 °C], chills, severe malaise, headache, or vomiting) at the time of examination.
¶¶ Laboratory-diagnosed case: a clinical case confirmed by microscopy, polymerase chain reaction, or rapid diagnostic tests in the laboratory.

TABLE 1. Clinically-diagnosed and laboratory-confirmed imported malaria cases in China (2012–2018).

Year	Subtotal	Laboratory-confirmed cases						Clinically-diagnosed cases
		P. vivax	*P. falciparum*	*P. ovale*	*P. malariae*	*P. knowlesi*	Mixed	
2012	2,474	901	1,403		56*	0	0	39
2013	4,042	859	2,899	133	51	0	65	35
2014	3,022	798	1,876	231	53	1	44	19
2015	3,077	779	1,895	266	65	0	55	17
2016	3,139	622	2,066	315	64	0	59	14
2017	2,672	496	1,716	350	65	1	35	9
2018	2,511	348	1,655	374	78	0	51	5
Total	20,938	4,803	13,510	1,725	376	2	348	174

* The number of imported *P. ovale* and *P. malariae* was not counted separated, so herein we provide the total number of *P. ovale* and *P. malariae*.

IMCs were mainly reported in the PLADs of Yunnan (n=2,922, 14.0%), Guangxi (n=2,827, 13.5%), and Jiangsu (n=2,067, 9.9%) (Table 2). The distribution of IMCs broadened with cases reported in 618 counties in 2012 and 688 counties in 2018. The temporal distribution showed that IMCs were reported throughout the entire year, and the highest number of IMCs was reported in June 2013 (n=857) (Figure 1).

IMCs originated from 67 countries from 4 continents, and among them, 16,720 cases (79.9%) originated from Africa, mainly central and western Africa, which accounted for 33.5% (n=7,007) and 32.5% (n=6,806) of all IMCs, respectively. IMCs from Africa in this time period showed an increasing trend with 58.8% in 2012 (n=1,454) and 90.4% in 2018 (n=2,470). The imported *P. falciparum* cases from Africa also showed an increasing trend. In 2012, 32 African countries reported 1,177 *P. falciparum* cases, while in 2018, 35 African countries reported 1,641 *P. falciparum* cases. The cases imported from Africa were mainly from Ghana (n=2,704, 12.9%), Angola (n=2,085, 10.0%), and Nigeria (n=1,939, 9.3%) (Table 3).

The cases from another major infection source, namely, Southeast Asia, gradually declined. In this area, 3,999 cases (19.1%) were reported in 2012-2018 with a 77.1% decrease from 2012 (n=955) to 2018 (n=219). In Myanmar, the major source of imported cases in Southeast Asia, the number of *P. vivax* cases greatly decreased. In 2012, there were 554 *P. vivax* cases imported from Myanmar, accounting for 22.4% of the IMCs in the same year. In 2018, however, there were only 154 cases imported from Myanmar, accounting for only 6.1% of the IMCs. Moreover, 5 countries from South America and 2 countries from Oceania reported 30 and 75 cases, respectively.

From 2012 to 2018, China reported 111 malaria death cases (0.5%, 111/20,936) among the IMCs, and most of these cases died of *P. falciparum* infection (n=108, 97.3%), and China also reported 3 unclassified cases. The deaths mainly reported in Sichuan (n=13, 11.7%), Henan (n=12, 10.8%), and Beijing (n=12, 10.8%). The highest number of deaths occurred in 2014 (n=25).

DISCUSSION

For countries that are approaching or have achieved elimination, imported malaria presents a high risk for resurgence or re-establishment (*6*–*7*). In 2018, Hunan Province reported 4 introduced cases (*P. vivax*, first generation), which prompted the Center for Disease Control and Prevention (CDC) staff to strengthen the sensitivity of the surveillance system (*8*). Since 2012, the proportion of IMCs has increased due to the increased numbers of Chinese workers going to and coming back from abroad. According to data reported by the National Bureau of Statistics of China, the number of migrant workers was 606,000 in 2018, which increased by 16.6% compared to that in 2012 (505,563).

The increasing trend of imported *P. falciparum* cases from 2012 to 2018 may be explained by the increasing number of migrant workers who travelled to or returned from Africa. The number of imported *P. vivax* cases increased before 2012 (*9*) but decreased after 2012. This decreasing trend may have been due to the decline of malaria cases imported from Southeast Asia, especially Myanmar. Several factors have contributed to the reduction of *P. vivax* in Myanmar. First, the number of *P. vivax* cases in Myanmar continues to decline, and the number of *P. vivax* cases

TABLE 2. Imported malaria cases in 31 provincial-level administrative divisions (PLADs) in China (2012–2018).

PLADs	Total cases	Imported cases		Proportion of imported cases (%) in the whole country
		Number	Proportion (%)	
Yunnan	3,285	2,922	88.9	14.0
Guangxi	2,828	2,827	99.9	13.5
Jiangsu	2,070	2,067	99.9	9.9
Sichuan	1,697	1,697	100.0	8.1
Henan	1,285	1,285	100.0	6.1
Shandong	1,283	1,282	99.9	6.1
Zhejiang	1,241	1,241	100.0	5.9
Guangdong	1,038	1,035	99.7	4.9
Hunan	969	964	99.5	4.6
Hubei	884	875	99.0	4.2
Anhui	876	845	96.5	4.0
Fujian	637	637	100.0	3.0
Beijing	561	561	100.0	2.7
Shannxi	424	424	100.0	2.0
Liaoning	355	353	99.4	1.7
Hebei	323	323	100.0	1.5
Jiangxi	304	304	100.0	1.5
Shanghai	284	284	100.0	1.4
Chongqing	209	209	100.0	1.0
Gansu	162	162	100.0	0.8
Guizhou	150	150	100.0	0.7
Jilin	105	105	100.0	0.5
Shanxi	93	93	100.0	0.4
Hainan	81	80	98.8	0.4
Tianjin	62	62	100.0	0.3
Heilongjiang	41	41	100.0	0.2
Xinjiang	37	37	100.0	0.1
Ningxia	29	29	100.0	0.1
Inner Monglia	19	19	100.0	0.1
Qinghai	14	14	100.0	0.1
Tibet	30	9	30.0	0.0
Total	21,376	20,936	97.9	100.0

decreased from 53,351 in 2007 to 29,944 in 2017 (*10*–*11*). Second, Yunnan Province, which neighbors Myanmar, adopted a "three defense line" strategy in the border areas to carry out joint prevention and control with Myanmar to strengthen the surveillance of IMCs (*12*). Therefore, the number of *P. vivax* cases reported by the Yunnan Province also declined significantly with a 76.8% reduction from 2012 (599 cases) to 2018 (137 cases). Third, the flow of Chinese nationals changed direction, especially for those in the border areas of Yunnan Province (*13*).

With regard to the increasing number of *P. malariae* and *P. ovale* cases, the increasing number of overseas workers may be one of the factors contributing to this trend as well as the establishment of the provincial reference laboratories. China has established 24 provincial reference laboratories for all the endemic provinces, which have achieved case detection and reconfirmation using polymerase chain reaction and microscopy within 3 day after reporting through the

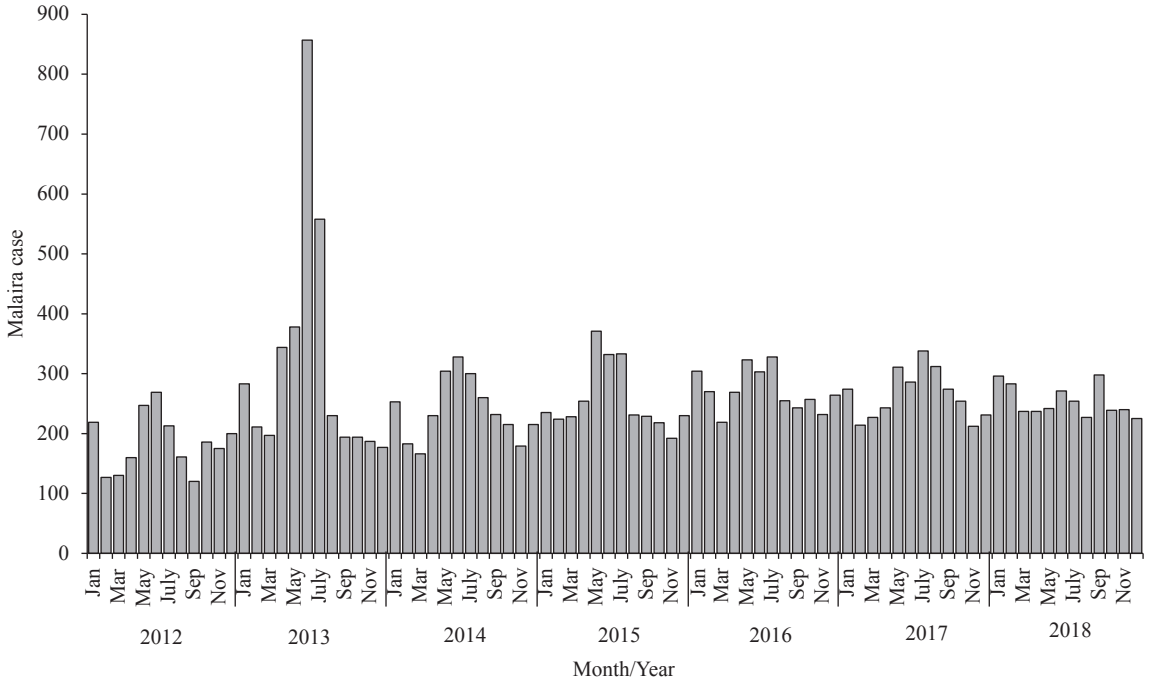

FIGURE 1. Temporal distribution of imported malaria cases in China (2012–2018).

TABLE 3. Source of imported cases reported in China (2012–2018).

Regions	Country	2012	2013	2014	2015	2016	2017	2018	Total
Africa		1,454	3,243	2,295	2,487	2,689	2,282	2,270	16,720
Southeast Africa		196	311	380	457	541	436	395	2,716
	Ethiopia	38	62	118	150	148	113	95	724
	Mozambique	22	48	68	75	84	103	104	504
	Uganda	16	28	28	53	139	66	41	371
	Tanzania	13	34	41	52	49	46	58	293
	Sudan	63	72	44	44	7	15	10	255
	Zambia	17	37	42	48	47	30	33	254
	Kenya	7	6	11	9	14	23	13	83
	Malawi	9	9	10	6	11	13	13	71
	Madagascar	5	3	9	9	4	8	7	45
	South Sudan	0	1	2	3	20	9	10	45
	Rwanda	2	2	5	6	14	5	5	39
	Zimbabwe	2	3	2	1	2	3	0	13
	Djibouti	0	0	0	0	1	2	5	8
	Egypt	2	5	0	0	1	0	0	8
	Eritrea	0	0	0	1	0	0	1	2
	Somalia	0	1	0	0	0	0	0	1
West Africa		641	1,870	879	723	828	950	915	6,806
	Ghana	235	1349	188	172	241	347	172	2,704
	Nigeria	207	225	341	283	273	286	324	1,939
	Guinea	58	75	64	98	72	80	129	576
	Côte d'Ivoire	18	16	41	64	104	97	127	467

TABLE 3. (Continued)

Regions	Country	2012	2013	2014	2015	2016	2017	2018	Total
	Liberia	44	86	88	34	39	61	56	408
	Sierra Leone	43	55	53	34	43	44	63	335
	Benin	5	22	33	10	17	9	12	108
	Togo	2	24	50	9	6	4	10	105
	Mali	17	14	11	8	10	13	11	84
	Burkina Faso	6	3	8	6	3	4	3	33
	Niger	0	0	0	1	17	4	3	25
	Senegal	5	1	0	2	3	1	4	16
	Mauritania	1	0	2	0	0	0	0	3
	Gambia	0	0	0	2	0	0	1	3
Central Africa		550	1,038	1,015	1,283	1,292	882	947	7,007
	Angola	151	437	272	416	410	192	207	2,085
	Equatorial Guinea	247	300	287	272	185	132	115	1,538
	Cameroon	17	101	175	248	242	190	159	1,132
	Democratic Republic of the Congo	47	64	118	175	244	151	236	1,035
	Republic of Congo	33	53	83	101	154	119	98	641
	Gabon	35	42	34	43	37	53	73	317
	Chad	11	36	38	25	9	13	30	162
	The Central African Republic	9	5	5	2	8	28	25	82
	Burundi	0	0	3	1	3	4	4	15
South Africa		11	21	17	12	14	9	5	89
	South Africa	11	20	15	12	13	8	5	84
	Namibia	0	1	1	0	1	1	0	4
	Comoros	0	0	1	0	0	0	0	1
North Africa		5	1	0	0	6	4	7	23
	Libya	3	0	0	0	5	3	6	17
	Algeria	2	1	0	0	1	1	1	6
Africa (Other regions)		51	2	4	12	8	1	1	79
Asia		955	774	706	566	420	359	219	3,999
Southeast Asia		906	736	674	548	392	291	192	3,739
	Myanmar	766	605	495	477	326	245	167	3,081
	Indonesia	36	71	142	35	27	18	7	336
	Laos	37	38	18	12	27	13	5	150
	Cambodia	57	19	9	17	6	14	11	133
	Vietnam	4	0	3	2	1	1	1	12
	Thailand	1	3	5	1	0	0	0	10
	Malaysia	2	0	2	2	2	0	0	8
The Philippines	0	0	0	2	3	0	1	6	
	Timor-Leste	3	0	0	0	0	0	0	3
East Asia		2	1	0	1	1	1	1	7
	Democratic People's Republic of Korea	1	1	0	1	1	0	0	4
	Republic of Korea	1	0	0	0	0	1	1	3

TABLE 3. (Continued)

Regions	Country	2012	2013	2014	2015	2016	2017	2018	Total
South Asia		47	37	32	17	26	67	26	252
	Pakistan	31	22	17	10	18	63	22	183
	India	14	15	15	7	7	3	4	65
	Afghanistan	2	0	0	0	0	0	0	2
	Nepal	0	0	0	0	0	1	0	1
	Bangladesh	0	0	0	0	1	0	0	1
South America		1	5	2	3	2	10	7	30
	Guyana	0	3	2	2	1	6	4	18
	Venezuela	0	0	0	1	1	1	3	6
	Brazil	1	0	0	0	0	2	0	3
	Ecuador	0	1	0	0	0	1	0	2
	Surinam	0	1	0	0	0	0	0	1
Oceania		6	8	8	1	16	21	15	75
	Papua New Guinea	6	7	8	1	14	19	15	70
	Solomon Islands	0	1	0	0	2	2	0	5
Unknown sources		58	12	10	20	13	0	0	113
Total		2,474	4,042	3,021	3,077	3,139	2,672	2,511	20,936

PDIRMS (*14*). The capacity of the CDC staff to focus on microscopy has strengthened through training by the External Competency Assessment of Malaria Microscopists (ECAMM) held by the World Health Organization (WHO) since 2015. Currently, 19 CDC staff members have obtained first-level certification, and an additional 13 CDC staff members have obtained second-level certification (*4*).

This study indicated that the number of imported *P. vivax* cases decreased, while imported *P. falciparum* cases increased. Therefore, accurate diagnosis and prompt investigation and response need to be strengthened as well as implementation of mobile population-specific measures, especially at the China-Myanmar border to prevent re-establishment caused by imported *P. vivax* cases (*15*). Moreover, timely and appropriate treatment by medical staff should be improved to avoid fatal malaria cases caused by imported *P. falciparum*.

This study is subject to at least a few limitations. First, not all IMCs had exact epidemiological information in 2012–2018. Second, there were 113 unknown cases imported from abroad. Third, not all IMCs were confirmed by laboratory methods as 174 clinically-diagnosed cases were included in this study. Finally, an accurate number of *P. ovale* and *P. malariae* cases was not obtained in 2012.

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Preplanned Studies

Malaria Diagnosis and Verification — China, 2017–2018

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Summary

What is already known about this topic?

Prompt, accurate diagnosis is an essential part of malaria elimination strategies. Insufficient malaria diagnosis capacity will be a potential risk for malaria reintroduction.

What is added by this report?

Health facilities at the county and prefectural levels were the most concentrated facilities for initial diagnosis of malaria (68.2%) and confirmation (76.4%). More than 65% of cases could not be diagnosed within 1 day of onset, and only 89.4% of laboratory-confirmed cases were accurate.

What are the implications for public health practice?

Malaria health education should be strengthened to improve public awareness and health professionals' vigilance of malaria, thereby shortening the diagnostic intervals. In addition, the capacity of malaria diagnosis, especially Plasmodium speciation, should be improved to ensure accurate diagnosis and appropriate treatment.

Malaria had previously been one of the most serious infectious diseases in China. Fortunately, China is close to achieving malaria elimination nationwide with country-led and country-owned efforts, such as the strong case-based surveillance and response systems, especially after inauguration of the National Malaria Elimination Action Plan 2010–2020 of China. No indigenous malaria cases have been reported since 2017, although there were still more than 2,500 imported cases annually including over 100 patients with severe symptoms and approximately 10 deaths in 2017 and 2018, respectively (*1*–*2*). The prompt and reliable detection of parasites and diagnosis of malaria cases is an essential component in national malaria elimination programs as it not only assures that all patients receive appropriate treatments but also greatly improves the reliability of surveillance to the point of stopping malaria transmission. Even after elimination, it is still crucial to prevent malaria reintroduction (malaria reintroduction refers to the occurrence of introduced cases: cases of the first-generation local transmission that are epidemiologically linked to a confirmed imported case in a country or area where the disease had previously been eliminated) (*3*–*4*) and consolidate the accomplishment.

Prompt parasitological diagnosis by microscopy or a rapid diagnostic test is recommended by the World Health Organization for all patients suspected of having malaria based on a defined set of clinical criteria before therapy is initiated (*4*). To ensure the quality of malaria diagnosis, a reliable National Malaria Diagnosis Reference Laboratory Network (NMDRLN) has been established in China composed of 1 national and 24 historically-malaria-endemic provincial laboratories (*5*). The function of the network is for case verification and also for capacity building and maintenance. Species belonging to *Plasmodium* in all reported cases must be validated using microscopy and PCR in network laboratories. Malaria microscopists from both the national and provincial levels performed quite well in *Plasmodium* spp. speciation but not those from the below provincial levels, according to a series of external competency assessments and national technique competitions on malaria microscopy (*6*). Currently, all health facilities have potential access to testing and can become the first line of defense against imported malaria, but limited data were found about their performance in the process of malaria diagnosis in routine work.

Individual malaria case data in 2017 and 2018 were extracted from the Parasitic Diseases Information Reporting Management System (PDIRMS) of China CDC and included the date of onset, the date of the first diagnosis, the date of confirmed diagnosis, the results of the first diagnosis and confirmed diagnosis and verification, the facility for case diagnosis and reporting, the geographical distribution and *Plasmodium* species composition. This study aims to analyze the performance of different health facilities [medical institution, centers for disease control and prevention (CDC), Entry-Exit Inspection and Quarantine (EIQ)] and their malaria diagnostic competency at different levels, the intervals from onset to the first and confirmed diagnosis, as well as the agreement rate of species identification between the

confirmed diagnosis and NMDRLN verifications. All extracted data were processed with Microsoft Excel 2007 and SPSS (version 21.0, IBM Corp. USA). Then, the differences from groups were evaluated by Pearson chi-square tests. Statistical significance was set as 0.05.

A total of 5,539 imported malaria cases were reported between 2017 and 2018. They were first diagnosed by clinicians in individual clinics (238, 4.3%), village clinics (242, 4.4%), township health centers (526, 9.5%), county medical institutions (1,451, 26.2%), county CDCs (502, 9.1%), prefectural medical institutions (1,731, 31.3%), prefectural CDCs (49, 0.9%), provincial medical institutions (630, 11.4%), provincial CDCs (11, 0.2%), prefectural EIQs (39, 0.7%), provincial EIQs (28, 0.5%), and unspecified facilities (92, 1.7%). Correspondingly, there were 1 (0.0%), 2 (0.0%), 339 (6.1%), 1,258 (22.7%), 623 (11.2%), 2,219 (40.1%), 94 (1.7%), 867 (15.7%), 41 (0.7%), 37 (0.7%), 26 (0.5%), and 32 (0.6%) cases confirmed in the above health facilities, respectively (Table 1). In addition, the detailed distributions in each province/municipality/autonomous region yearly are shown in Figure 1.

The median interval (the subtraction of the latter date from the former date) from onset to the first diagnosis was 1 day (maximum: 186 days) between 2017 and 2018 nationwide and 1 day (maximum: 112 days) from the first diagnosis to confirmed diagnosis. However, 46.9% (2,596/5,539) of cases were first diagnosed 2 days after onset, and 33.3% (1,844/5,539) of cases were confirmed more than 2 days after the first diagnosis. The median intervals from onset to the first diagnosis in the health facilities at township and below, county, prefectural, provincial and other unspecified levels were 1 day (maximum: 47 days), 1 day (maximum: 90 days), 2 days (maximum: 186 days), 1 day (maximum: 89 days), and 1 day (maximum: 25 days), respectively. The corresponding intervals from the first diagnosis to confirmed diagnosis were 0 days (maximum: 11 days), 1 day (maximum: 65 days), 1 day (maximum: 71 days), 1 day (maximum: 112 days) and 1 day (maximum: 57 days), respectively. The proportion of cases receiving the first diagnosis and confirmed diagnosis at different intervals is shown in Figure 2.

All the reported cases (except 9 cases in 2017 and 5 cases in 2018 which were initially clinically diagnosed) were verified by the provincial labs, but only 76.1% (2,169/2,852) in 2017 and 73.7% (1,971/2,673) in 2018 were diagnosed as malaria on the first visit. In addition, 89.4% (4,942/5,525) of the verified cases were consistent with their original confirmation results. Agreements of 95.9% (328/342), 91.0% (1,711/1,881), 88.9% (2,088/2,350), 85.3% (797/934), and 87.5% (28/32) were found (χ^2=37.3, p<0.001) in health facilities at township and below, county, prefectural, provincial, and other unspecified levels, respectively. In addition, 5.0% (180/3,587) of *P. falciparum*, 7.2% (70/970) of *P. vivax*, 24.7% (37/150) of *P. malariae*, 31.9% (232/728) of *P. ovale*, 75.3% (67/89) of the mixed and 100% (1/1) of *P.*

TABLE 1. Malaria cases diagnosed first and confirmed in various health facilities nationwide according to the Parasitic Diseases Information Reporting Management System of China (2017–2018).

Item	First diagnosis			Confirmed diagnosis		
	2017	2018	Total	2017	2018	Total
Individual clinics	114	124	238	1	0	1
Village clinics	119	123	242	1	1	2
Township Health Center	319	207	526	213	126	339
County medical institutions	745	706	1,451	667	591	1,258
County CDCs	278	224	502	339	284	623
Prefectural medical institutions	863	868	1,731	1,100	1,119	2,219
Prefectural CDCs	35	14	49	58	36	94
Provincial medical institutions	298	332	630	396	471	867
Provincial CDCs	7	4	11	25	16	41
Prefectural EIQs	22	17	39	25	12	37
Provincial EIQs	14	14	28	14	12	26
Unspecified	47	45	92	22	10	32
Total	2,861	2,678	5,539	2,861	2,678	5,539

Abbreviations: EIQ=Entry-Exit Inspection and Quarantine, CDC=centers for disease control and prevention.

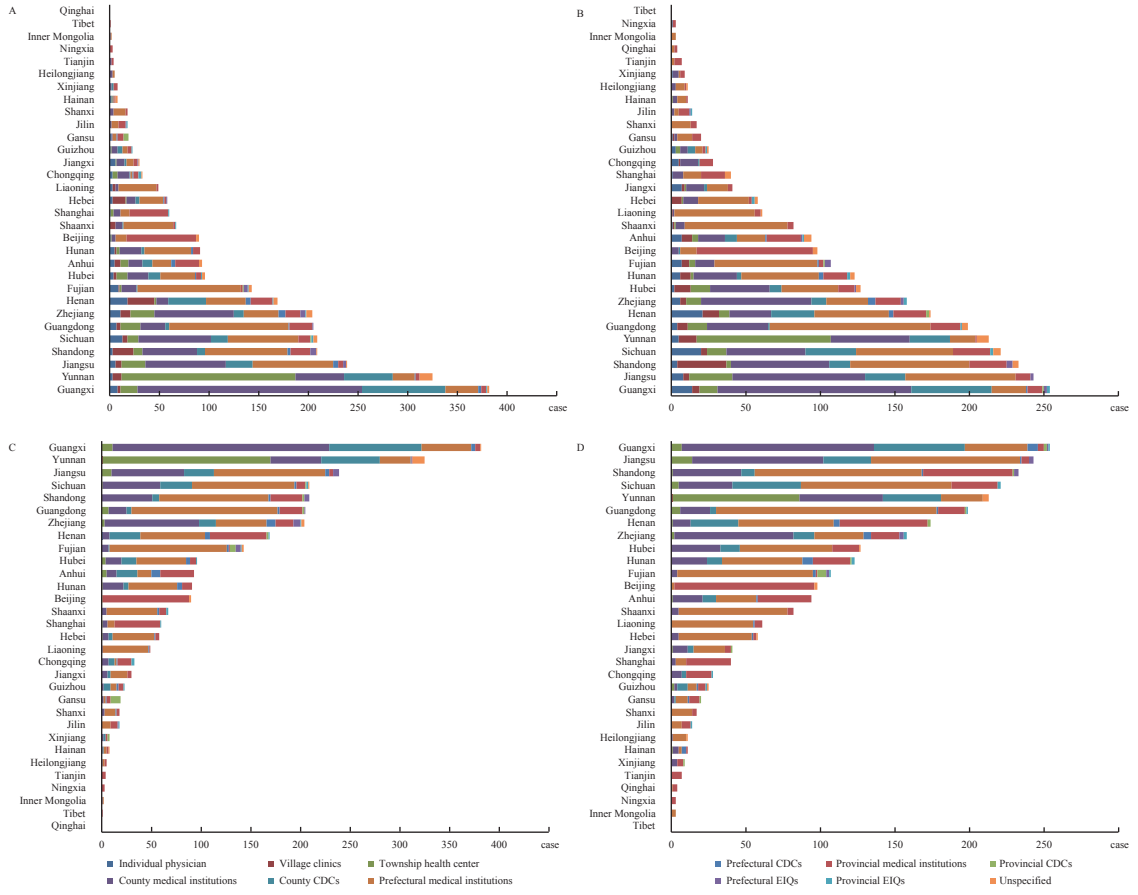

FIGURE 1. Malaria cases diagnosed first and confirmed in various health facilities in each provincial-level administrative division (PLAD) according to the Parasitic Diseases Information Reporting Management System of China (2017–2018). (A) Malaria cases diagnosed first in 2017; (B) Malaria cases diagnosed first in 2018; (C) Malaria cases confirmed in 2017; (D) Malaria cases confirmed in 2018.

knowlesi infections were inconsistent with their originally confirmed diagnosis (χ^2=908.0, p<0.001).

DISCUSSION

The accomplishment of zero indigenous malaria cases since 2017 in China is still facing challenges from reintroduction by imported cases mainly from Africa and Southeast Asia (*1–2*). This is even more challenging for formerly malaria-endemic areas where mosquitoes are still receptive for transmission. Several cases of malaria reintroduction have occurred in different countries (*7*).

To prevent reintroduction, current malaria surveillance and vigilance systems should be improved (*8*) starting from malaria awareness among the public, especially in travelers to or from malaria transmission areas. Public awareness of malaria in the beginning and middle stages of the national malaria elimination program in China did not meet the goal of malaria elimination (*9–10*). This study found that a considerable number of patients sought health care and were diagnosed 2 days after illness onset. Delayed detection by the health system will greatly increase the risk of transmission and poor prognosis of the patient. As health education and promotion have an important contribution to malaria control, prevention, and elimination, different targeted malaria awareness campaigns should be tailored to improve people's knowledge regarding malaria and improve the timeliness of their doctor visits.

In addition, it becomes even more crucial to ensure the provision of continuous, quality early diagnosis and treatment to save lives and prevent reintroduction in the malaria post-elimination phase. However, only approximately three-quarters of cases could be diagnosed as malaria on their first visits, and the capacity of malaria diagnosis was not sufficient at below provincial levels where the number of patients is most concentrated, specifically the species identification of *P. ovale*, *P. malariae*, and mixed

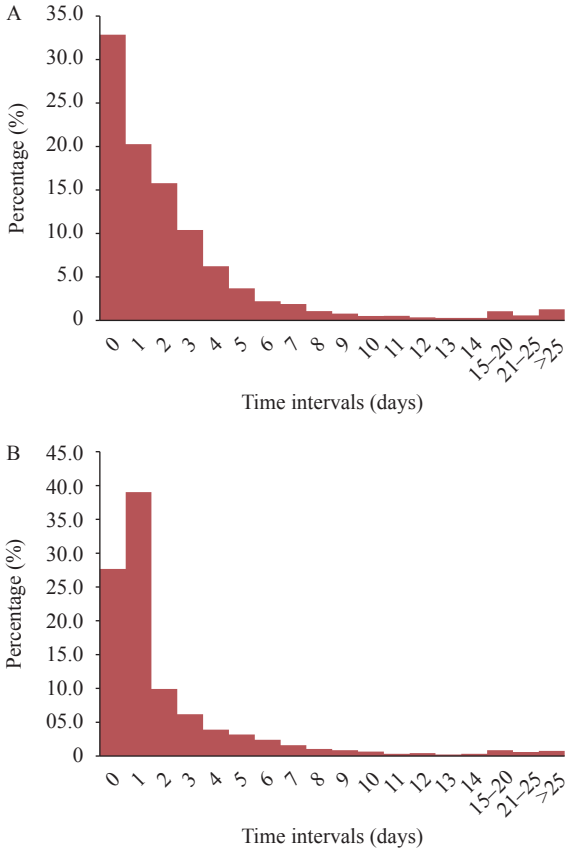

FIGURE 2. Time interval from onset to the first diagnosis (A) and then to confirmed diagnosis (B) between 2017 and 2018 according to the Parasitic Diseases Information Reporting Management System of China

infections (*6*). As a result, the global malaria epidemiological status, careful questioning of patient travel history, and skills in malaria diagnosis and treatment should also be taught to target health professionals periodically to improve their watchfulness and capacity for any malaria cases.

In conclusion, a systematic review of malaria cases was conducted that showed good performance in the diagnosis of *P. falciparum* malaria and *P. vivax* malaria cases, which were the highest number of cases between 2017 and 2018 in China. Furthermore, the findings indicate that it is necessary to increase the public awareness of potential risk of malaria, help health professionals improve watchfulness for any malaria cases, intensify the establishment and operation of NMDRLN, hold more training courses on malaria diagnostic techniques for medical institutions, and to prevent malaria reintroduction in the elimination and post-elimination phases.

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Preplanned Studies

The "1-3-7" Approach to Malaria Surveillance and Response — Henan Province, China, 2012–2018

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Summary

What is already known about this topic?

The "1-3-7" approach to malaria surveillance and response was a key measure for malaria elimination in China and was first introduced into the World Health Organization (WHO) as an international guideline for malaria surveillance and response in 2018.

What is added by this report?

The "1-3-7" approach was well implemented in Henan Province from 2012–2018. Over this study period, a total of 1,294 malaria cases were detected and reported, and all cases were diagnosed and reported within 1 day with 99.23% (1,284/1,294) of cases were investigated within 3 days. In addition, 93.7% (1,212/1,294) of foci were investigated and vector control was implemented within 7 days at all residual non-active foci to prevent further spread.

What are the implications for public health practice?

The "1-3-7" controlling pattern would be an effective and approachable method for implementation especially in malaria-eliminating countries and regions, but the interval from symptom onset to diagnosis cannot be ignored. Thus, the roles and responsibilities that all actors involved in the health sector must be specified too.

The "1-3-7" approach to malaria surveillance and response was a key measure for malaria elimination in China that aims to have all cases of malaria reported within 1 day, case investigation conducted within 3 days, and an in-depth investigation conducted within 7 days. The study aimed to assess the interventions and measure the impact they may have on malaria-related burden to guide malaria programming. Data from the National Notifiable Disease Reporting System (NNDRS) and the Parasitic Diseases Information Reporting Management System (PDIRMS) from 2012 to 2018 were collected and analyzed to evaluate the implementation of the "1-3-7" approach. Additionally, the interval time from the onset of fever symptoms to diagnosis of cases were also analyzed. A total of 1,294 malaria cases were reported in Henan and all cases were reported to NNDRS within 1 day after confirmed with 99.2% (1,284/1,294) were investigated within 3 days after diagnosis. In addition, 93.7% (1,212/1,294) of foci were investigated within 7 days, 13.1% (170/1,294) of malaria cases were definitively diagnosed within 24 hours after onset, and the median onset-to-diagnosis time was 3 days. The "1-3-7" approach was well implemented around the province, but onset-to-diagnosis time is another important indicator that cannot be ignored. To shorten this time, the roles and responsibilities of all actors involved in the health sector need to be specified.

Henan Province is located in the middle eastern region of China and the middle and lower reaches of the Yellow River. Natural climate conditions here were suitable for malaria transmission, which had seriously affected the physical health and social and economic development of the whole province since the Yin and Shang Dynasties 4,000 years ago. *Plasmodium vivax* was endemic all over the province and *Plasmodium falciparum* was endemic in the area south of 33° N before 1987 (*1*). The remarkable feature of the malaria epidemic in Henan Province was the alternation between local outbreaks and widespread epidemics. There were three countrywide epidemics in the 1950s, 1960s, and early 1970s, and in 1970, the incidence of malaria in Henan Province reached as high as 1,694.44 / 10,000 (*2*). However, after the collective work and efforts of several generations, no indigenous cases have been reported since 2012, and recently with the increase of investment abroad and international communication, people who participated in international activities also increased, which resulted in an increase of imported malaria cases in Henan (*3*). Therefore, strict malaria control measures were of importance to the populations who returned to China.

In order to avoid local reintroduction of malaria, Henan Province implemented the "1-3-7" approach.

The "1-3-7" approach to malaria surveillance and response was a key measure for malaria elimination in China that referred to the reporting of malaria cases to local health facilities within 1 day, further investigation of index cases and detection of other cases in households by case investigation teams within 3 days, and expanded case detection and entomological, ecological, and intervention assessments by focus investigation teams within 7 days (*4*). It is important to periodically assess the key malaria interventions and measure the impact they may have on malaria-related burden to guide malaria programming, and thus, the implementation of the "1-3-7" approach and the onset-to-diagnosis time of malaria cases between 2012 and 2018 were analyzed. The results showed that key malaria interventions were conducted well, but another problem was exposed: the median number of days for the onset-to-diagnosis time was 3 days, but 1/4 of the cases took 6 days and the longest took up to 31 days.

In this paper, we try to evaluate the implementation of the "1-3-7" approach, and the onset-diagnosis time of malaria cases. Data from the NNDRS and PDIRMS from 2012 to 2018 were collected and analyzed, which included date of onset, diagnosis and reporting, case investigation, focus investigation, and indoor residual spraying (IRS). Summary statistics and proportions were used and comparisons between groups were assessed using the chi-square test and/or the rank sum test. Level of significance was set at a $p \leq 0.05$.

During the 7 years period, a total of 1,294 malaria cases were reported in Henan and all of them were imported cases. There were 991 cases of *P. falciparum* malaria, 100 cases of *P. vivax*, 157 cases of *P. ovale*, 36 cases of *P. malariae*, 9 cases of mixed infection, and 1 case of *P. knowlesi* (Figure 1).

All malaria cases were reported to NNDRS within 1 day after confirmed, 99.2% (1,284/1,294) of cases were investigated within 3 days after diagnosis, 93.7% (1,212/1,294) of foci were investigated within 7 days, 4.7% (61/1,294) of foci were residual non-active foci with potential transmission, and 100% (61/61) were carried out vector control measures with 141,217 people being protected by the IRS (Table 1).

In 2012–2018, 13.14% (170/1,294) of malaria cases in Henan were definitively diagnosed within 24 hours after onset, and the median onset-to-diagnosis time was 3 days [inter quartile range (IQR), 1-6 days]. The longest interval was 31 days in 2012. There was a statistical difference in the onset-diagnosis time between 2018 and 2012 (Z=5.015, p<0.05) (Table 2).

DISCUSSION

The "1-3-7" approach played a crucial role in

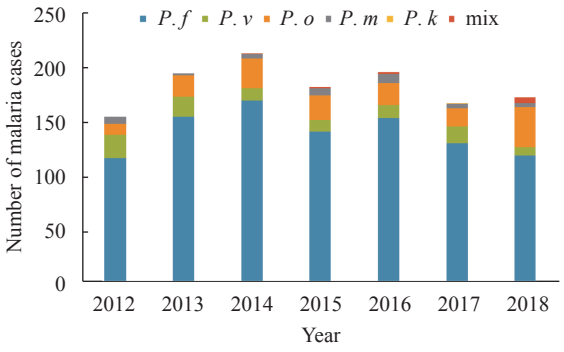

FIGURE 1. *Plasmodium* species of malaria cases in Henan Province, 2012–2018. Abbreviation: *P. f=Plasmodium falciparum*, *P. v=Plasmodium vivax*, *P. o=Plasmodium ovale*, *P. m=Plasmodium malariae*, *P. k=Plasmodium knowlesi*, mix=mixed infection.

TABLE 1. The "1-3-7" approach to malaria surveillance and response in Henan Province during 2012–2018.

Year	Total no. of cases	No. of case reported within 1 day (%)	No. of case investigated within 3 days (%) *	No. of foci investigated within 7 days (%)	No. of active foci (%)	No. of active foci treated by IRS (%)	No. of people protected by IRS
2012	156	156(100)	155(99.4)	156(100.0)	18(11.5)	18(100)	877
2013	197	197(100)	196(99.5)	197(100.0)	9(4.6)	9(100)	78,400
2014	216	216(100)	213(98.6)	216(100.0)	5(2.3)	5(100)	21,944
2015	184	184(100)	183(99.5)	184(100.0)	6(3.3)	6(100)	17,814
2016	198	198(100)	196(99.0)	198(100.0)	6(3.0)	6(100)	14,941
2017	169	169(100)	169(100.0)	96(56.8)	11(6.5)	11(100)	5,704
2018	174	174(100)	172(98.9)	165(94.8)	6(3.4)	6(100)	1,537
Total	1,294	1,294(100)	1,284(99.2)	1,212(93.7)	61(4.7)	61(100)	141,217

Abbreviations: IRS=indoor residual spraying.
* χ^2=3.195, p=0.784.

TABLE 2. The onset-diagnosis time of malaria cases in Henan Province during 2012–2018.

Year	Total no. of cases	No. of case diagnosed within 1 day (%) *	The onset-diagnosis time(day)		
			Median	IQR	The longest interval
2012	156	23(14.74)	3	(1−6)	31
2013	197	22(11.17)	3	(1−6)	29
2014	216	24(11.11)	3	(1−6)	27
2015	184	28(15.22)	3	(1−6)	29
2016	198	41(20.71)	3	(1−5)	30
2017	169	17(10.06)	3	(1−6)	30
2018	174	15(8.62)	3	(1−5)	30
Total	1,294	170(13.14)	3	(1−6)	31

Abbreviations: IQR=inter quartile range.
* Z=5.015, p<0.05.

malaria elimination in China, and this approach was therefore introduced by the World Health Organization (WHO) to be a guideline to instruct malaria control programs worldwide, especially in countries or regions where malaria is close to elimination (*5*). Henan Province launched a malaria elimination campaign in 2010 and strictly implemented the "1-3-7" approach across the whole province (*6*). As a result, the NNDRS benefitted heavily from the promptness of malaria reports, no indigenous cases have been found since 2012, and malaria elimination was achieved in 2019 (*7*). These experiences will pave the way for other malaria eliminating countries and areas to do the same.

All malaria cases that are diagnosed by health facilities at the provincial, district, and local levels can be reported promptly, and all *Plasmodium* species require reporting by law. In the era of big data, a well-defined health delivery process ensures availability of accurate, timely, and accessible health data, which is extremely important for the prevention and control of infectious diseases. While the overall treatment rate of foci within 7 days was 93.7% in 2012 to 2018, the rate was stable at 100% from 2012 to 2016 but dropped to 56.8% in 2017 before recovering to 94.8% in 2018 (*3*). This was likely due to the recording and statistical method being changed in 2017 where all foci were in fact disposed within 7 days, but some data were reported after 168 hours and could not be recognized by the system.

The "1-3-7" approach to malaria surveillance and response was well implemented but is limited to situations where malaria cases has just been detected. Although the implementation of the "1-3-7" approach is essential to prevent and control the reintroduction of malaria, the onset-to-diagnosis time cannot be ignored. The time before the "1" mentioned in the"1-3-7" method is not within the public health facilities' control, but it is essential for effective patient management. Malaria is generally treatable when effective treatment is commenced early, whereas delay in treatment may lead to serious consequences including death. Essentially all deaths caused by *P. falciparum* malaria were related to longer onset-to-diagnosis time.

While some achievements have been made during the study period, such as a decrease in the longest onset-to-diagnosis time by 2018, the onset-to-diagnosis time was still dissatisfactory and comparable to the difficult situations in Shanxi Province and along the China-Myanmar border (*8*–*9*). The exact reasons for delays in seeking care were unclear, but the roles and responsibilities of all actors involved in the health sector need to be specified. First, public awareness for malaria should be enhanced through community-based and school-based health education. Second, doctors should be trained to improve their capacity for case detection, diagnosis, and treatment to avoid the development of severe illness or unnecessary death. Finally, the entry-exit inspection and quarantine departments should oversee malaria health education over people entering and leaving China and people associated with the border ports. In addition, effective multi-sector cooperation and coordination mechanisms, particularly for CDCs and the entry-exit inspection and quarantine departments, should be strengthened to help facilitate information exchange and sharing.

However, the implementation of the "1-3-7" approach to malaria surveillance and response was subject to some challenges, such as the level of detail in epidemiological investigations, correct case

classifications, accurate foci assessments, suitable foci interventions, etc. (*10*), so securing the quality of the approach at all levels should be the goal for further malaria control.

This study is subject to some limitations. Although data covered a significant length of time and a large geographical area, the results are based on passively-reported data and may not fully represent the current situation. Furthermore, due to the nature of the study, the results presented may not be representative of the whole of China.

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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

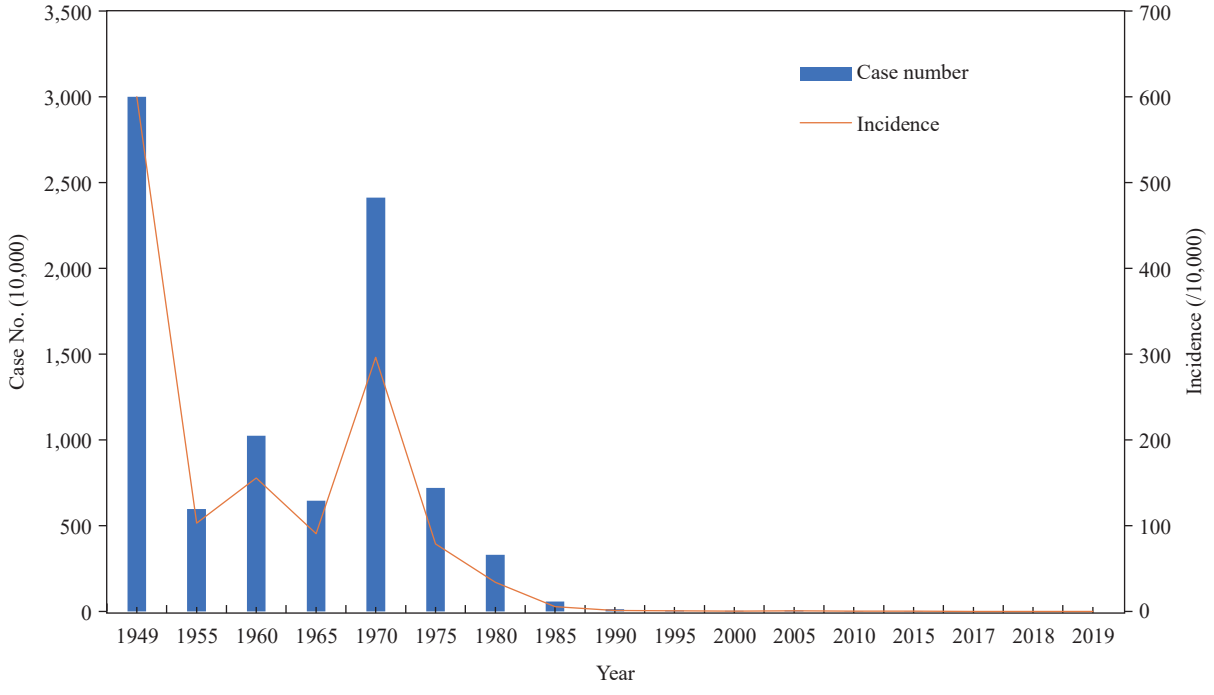

FIGURE 1. Trend of malaria case numbers and incidence in China from 1949 to 2019.

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

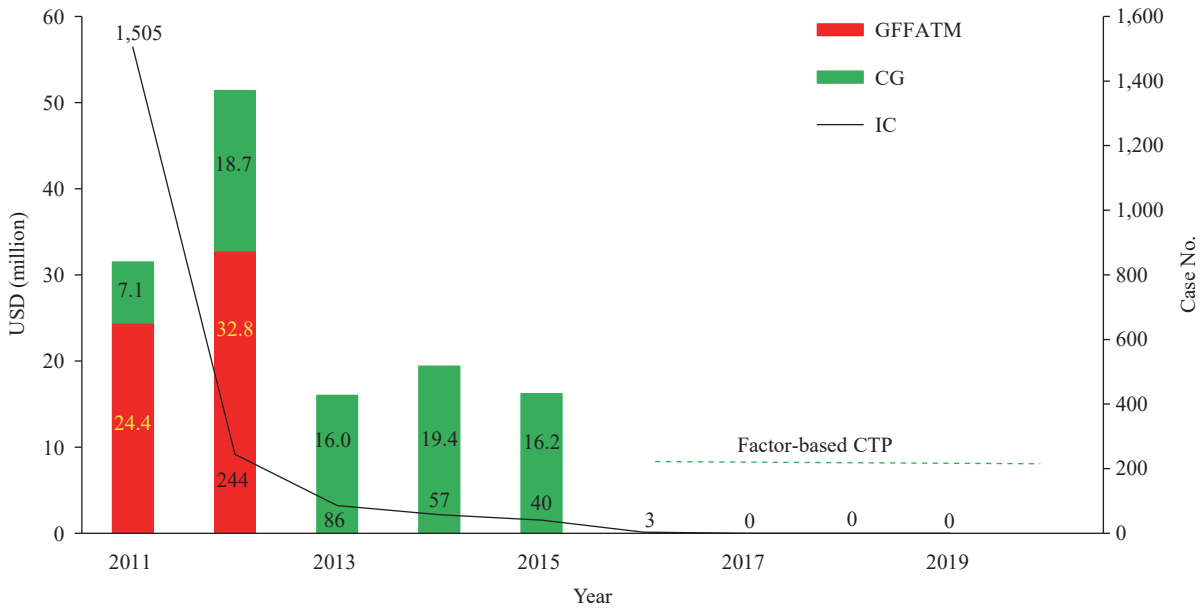

FIGURE 2. Trend of the investment and indigenous cases in China since 2011.

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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