Review And Assessment Of Malaria Epidemic Situation And Re-Transmission Risk In A Central City Of China, 1950-2019

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Abstract

Background: With characteristics of fast transmission and widespread, malaria was the most deadly parasite disease. In China, 13 ministries and commissions jointly issued the *Action Plan For Malaria Eradication*, which was aimed to reach malaria elimination by 2020. Scientific analysis of the epidemic situation and assessment of re-transmission risk of malaria in Changsha, an important city of central China, are of certain reference value for China to pass the World Health Organization malaria control assessment in 2020.

Method: The epidemic situation and control process of malaria in Changsha from 1950 to 2019 have been illustrated, and an adjusted assessment method was used to analyze the transmission risk index (MRI) of imported malaria in different districts of Changsha in recent years. All data were from Changsha Center for Disease Control and Prevention (CDC).

Results: (1) From 1950 to 2019, there were 282,394 incidences and 39 deaths of malaria in Changsha, the incidence rate has been controlled below 10/1,000,000 after 1990; The fatality rate of malaria in Changsha has always been at a low level, but it reached 10.28/1000 after 2010; (2) Before the year 1978, tertian was the major type of malaria in Changsha, which accounted for 92.71%, but the proportion of pernicious malaria gradually increased after 2000, which accounted for 69.3% since 2010. (3) From 1950 to 2009, the percentage of imported malaria cases in Changsha was only 2.93%; In April 2010, the last local case of malaria was reported in Liuyang, Changsha; After 2011, all cases of malaria in Changsha were imported cases, which were mainly from Africa and Southeast Asia. (4) The re-transmission risk of imported malaria in Changsha from high to low were Liuyang City, Yuelu District, Tianxin District, Yuhua District, Ningxiang County, Furong district, Wangcheng District, Changsha County and Kaifu District.

Conclusion: After 70 years, implemented three stages of prevention and control measures, Changsha has achieved the goal of malaria elimination. However, with the imported cases increased, the risk of re-transmission of malaria in Changsha still exists, especially in Liuyang and Yuelu district. Malaria control and prevention should still be taken seriously as an important preventive work in case of the secondary spread.

Background

Malaria, a vector disease caused by the bite of anopheles mosquitoes or the transfusion of blood of infected individuals, is distributed globally and mainly concentrated in some countries and regions like Southeast Asia, Africa, and South America. With its characteristics of fast transmission and widespread, malaria has become the most deadly parasite disease. According to the latest *World Malaria Report* [1] released in November 2018, there were 219 million malaria incidences and 435,000 malaria deaths in the world each year, which caused a large disease burden for human beings. The *Global Technical Strategy (GTS)for Malaria 2016–2030* [2], developed to accelerate progress towards malaria elimination, sets a target of reducing global malaria incidence and mortality rates by at least 90% by 2030 and countries in the world have kept fighting to achieve the goal of worldwide malaria elimination [3].

China used to be a malaria prone country. Before the foundation of the People's Republic of China in 1949, it was estimated that 30 million malaria cases occurred yearly and ranked the first among all kinds of infectious diseases, which jeopardized people's health and development of social and economy seriously [4]. Since then, organizations and scientific research for the control of malaria have been established and large-scale surveys have been carried out in China [5]. After 70 years of prevention and control, the number of malaria cases has declined to tens of thousands in the late 1990s, and its distribution has been greatly reduced [6]. To protect public health and achieve the global goal of malaria eradication, 13 ministries and commissions (including Ministry of Health) jointly issued the *Action Plan For Malaria Eradication In China (2010–2020)* in 2010, which was aimed to eradicate local cases (except the border of Yunnan province) by 2015 and reach malaria elimination nationwide by 2020 in China[7].

Changsha, located in the central south of China, is the center of politics, economy, culture, education, and business in Hunan province and an important hub of transportation and culture in China. From the year 1950, Changsha has made great achievements by gradually implementing various prevention and control measures to eliminate malaria. Since 1987, the incidence of malaria in Changsha has been controlled below 1/100,000; in 2010, the last local case of malaria was reported in Changsha; in 2016, Changsha has reached the malaria elimination standard at the municipal level. However, with the development of globalization, the number of imported malaria in Changsha was increasing. From 2010 to 2019, a total of 403 imported cases were reported in Changsha, which have caused a potential threat of re-transmission of malaria. In order to scientifically summarize the experience and adjust the future strategy, this paper illustrated the epidemic situation, control and elimination process of malaria in Changsha from 1950 to 2019, and assessed the local re-transmission risk of imported malaria in resent years, which may be useful for China to pass the World Health Organization's malaria elimination assessment in 2020 and achieving the goal of worldwide malaria elimination by 2030.

Methods

Study area

Changsha, covers a total area of 11,800 square kilometers, with 9 districts (or cities) and counties including 189 towns (or streets), and over 8 million permanent residents. Changsha is close to the Tropic of Cancer (111°53'–114°15'E, 27°51'–28°41'N) and subject to subtropical monsoon humid climate. Its average annual temperature is 17.2°C and the total annual precipitation is about 1361.6 mm. With the characteristics of distinct seasons, synchronization of high temperature and ample precipitation, abundant water resources, Changsha is suitable for breeding and safe wintering of mosquitoes and also conducive to the development and reproduction of sporozoites in mosquitoes, which may lead to the spread of malaria.

Data collection

The data of malaria was obtained from the National Malaria Surveillance System, reported by Changsha Center for Disease Control and Prevention (CDC). Malaria is a notifiable infectious disease in China, medical and health researches in both the public and private medical departments were required to report malaria cases directly online within 24 hours. Cases of malaria includes the clinically diagnosed and laboratory diagnosis cases [8], which are identified according to the unified diagnostic criteria issued by Ministry of Health in China. Clinically diagnosed cases were defined as patients with malaria related symptoms, like periodic onset of chills and fever, hyperhidrosis, anemia, splenomegaly,and most of all, the experience of living in or travelling to areas with malaria transmission. Laboratory diagnosis cases were defined as clinically diagnosed cases with malaria parasites confirmed by rapid diagnostic tests (RDTs), microscopy or polymerase chain reaction test.

The monitoring data of Anopheles vector was obtained from Changsha CDC. There were four monitoring points in Changsha, which were located in Changsha, Liuyang, Ningxiang and Wangcheng district. The light trap method and double net human trap method were used to monitor the population and density of Anopheles vector from June to October every year, once every half a month. From 2012 to 2018, 23133 Anopheles mosquitoes were captured by light trapping method and 6944 were captured by double net man trapping method, all captured Anopheles were identified as Anopheles sinensis by morphological identification.

The data of prevention and control ability were obtained from Changsha CDC. Since 2011, Changsha has set up malaria consultation points, distributed exceed 810000 copies of publicity materials and handbooks, received nearly 90000 people's consultation, held 14 training courses on malaria related knowledge, and trained nearly 900 people. From 2011 to November 2019, a total of 52884 blood samples were examined, and 2062 blood samples were reviewed. The missing rate of negative blood samples was 0, and the false detection rate of positive blood films decreased year by year. Since 2012, the reporting rate of malaria cases within 24 hours after diagnosis, the rate of malaria cases receiving laboratory examination, the rate of epidemiological case investigation, the rate of standardized treatment of malaria cases and the disposal rate of epidemic areas have all reached 100%. In 2016, the elimination measures, on-site assessment and safeguard measures of malaria control in 9 counties (cities, districts) under the jurisdiction of Changsha were scored above 85 points.

Risk assessment of re-transmission of imported malaria

On the basis of risk assessment index system for re-transmission of imported malaria established by Lei Lei and other researchers [9-15], Delphi expert consultation method was adopted to adjust the index weight and assignment score of nine districts (counties and cities) in Changsha according to the actual situation (Table 1). All experts worked in CDC or institutions of parasitic disease prevention and control, and were Mainly engaged in malaria control and prevention.

Two levels of risk index have been created. The first-level indexes comprised of three risk types included infection source, transmitting conditions and control capacity. The second-level indexes were expanded, detailed aspects of each of these first-level indexes. Then, the Transmission Potential Index (TPI), Intervention Capacity Index (ICI) and Malaria Risk Index (MRI) in different districts of Changsha in recent 10 years were calculated according to the weight and score of these index [9-15].

(1) TPI=ATI×MEI. ATI (Anopheles transmission index) is the malaria transmission risk index of Anopheles mosquitoes, which represents the risk of malaria transmission by the main local malaria vectors; MEI (Malaysia endemic index) represents the local malaria epidemic situation, MEI=NI+TI, NI is the number of imported malaria cases and TI is the type of imported malaria. (Table 1)

(2) ICI=$\sum$Ci*Wi. ICI include financial support, work execution (24-hour reporting rate and case investigation rate), diagnostic capacity, standardized treatment and assessment score of malaria elimination. Ci is the assigned score and wi is the weight coefficient of each index related to prevention and control capability. (Table 1)

(3) MRI=TPI/ICI. MRI was divided into four grades by percentile method, the higher the score, the higher the risk of re-transmission.

Statistical analysis

Data were input by Excel 2010 and analyzed by SPSS 23.0. Frequency, rate, constituent ratio, percentile chart and circle chart were used to describe the malaria surveillance data, and ArcGIS 10.2 was used to map the risk of malaria re-transmission, the darker the color, the higher the risk.

Results

Epidemic situation of malaria in Changsha from 1950 to 2019

From 1950 to 2019, there were 282,394 incidences and 39 deaths of malaria in Changsha and cases of malaria were reported every year. In the 1950s and 1960s, the incidence of malaria in Changsha fluctuated between 787.6/1,000,000 and 7202.5/1,000,000, with an average incidence of 2728.55/1,000,000 and 3782.02/1,000,000 respectively. In the 1970s, the incidence declined year by year and the reported incidence fluctuated between 84.4/1,000,000 and 3045.1/1,000,000, with an average incidence of 1166.33 /1,000,000. The three peaks of malaria epidemics occurred in 1955, 1964 and 1971(reported incidences were 6286.3/1,000,000, 7202.5/1,000,000 and 3045.1 /1,000,000, respectively). Since 1980, the epidemic in Changsha has been well controlled, with an average incidence of 30.61/1,000,000. After 1990, the incidence rate has been controlled below 10/1,000,000. In the 2000s, the incidence of malaria in Changsha has reached the lowest at 1.17/1,000,000. Although there was a brief rebound in 2010 (reported incidence was 12.5 /1,000,000), the reported incidence was kept in a decreasing trend from 2011, the average incidence of malaria reported in 2010s was 5.51/1,000,000. (Table 2).

The fatality rate of malaria in Changsha has always been at a low level, which were 0 in both1980s and 2000s. However, it reached 10.28/1000 after 2010. The three peaks of fatality rate occurred in the year 2011 (57.14/1000), 2014 (33.33/1000) and 1995 (25.00/1000). (Table 2)

Before the year 1978, tertian malaria was the major type of malaria in Changsha, which accounts for 92.71%. From the year 1978 to 1989, the proportion of tertian malaria dropped to 55.81% and the proportion of other types of malaria, including ovale malaria, quartan malaria, mixed malaria and unclassified malaria increased to 43.27%. From the year 1990 to 2000, the proportion of tertian malaria returned to 70.75%. However, the proportion of pernicious malaria gradually increased after 2000. In 2004, pernicious malaria accounted for 33.33%, which was in the same level of tertian malaria. In 2005 and 2007, the percentages of pernicious malaria (40% and 50% respectively) were higher than that of tertian malaria. With an average percentage of 69.3%, pernicious malaria was in the largest proportion in Changsha since 2010, among which the percentage of pernicious malaria has reached 86.67% in 2014 and 81.48% in 2017.Figure 1

Imported malaria case in Changsha

From 1950 to 2009, the percentage of imported malaria cases in Changsha was only 2.93%; In April 2010, the last local case of malaria was reported in Liuyang, Changsha; After 2011, all cases of malaria in Changsha were imported cases. From 2010 to 2019, a total of 403 imported malaria cases were reported in Changsha, which were mainly from Nigeria, Ghana, the Democratic Republic of the Congo, Uganda, Cameroon, and other African countries, some of them came from Indonesia, Myanmar and other southeast Asian countries.(Figure 2

Risk assessment of re-transmission of imported malaria from 2010 to 2019

The S-W normal distribution test showed that the risk index was non-normal distribution (Z=0.809, P<0.05). The percentile method was used to classify the risk level, with < P25 as level 1, P 25- P 50 as level 2, P 51- P 75 as level 3, and > P 75 as level 4. The higher the level, the greater the risk of re-transmission. The re-transmission risk of imported malaria in Changsha from high to low were Liuyang City, Yuelu District, Tianxin District, Yuhua District, Ningxiang County, Furong district, Wangcheng District, Changsha County and Kaifu District. Among them, Liuyang City and Yuelu District belonged to level 4. (Table 3, Figure 3)

Discussion

The control process of malaria in Changsha from 1950 to 2019 included three stages (Figure 4), which demonstrated the great changes of malaria from control to elimination.

The first stage, from 1950 to 1989, was a period of effective control of malaria. From 1950 to 1962, measures taken in this phase included actively treating the infectious sources, carrying out environmental improvement, training technical team and conducting malaria surveys; from 1963 to 1978, the leading group implemented the prevention and treatment strategy like prophylactic medication, radical cure malaria victim in resting phase, current illness and long-term recurrence, with the aim to narrow the epidemic areas and decrease incidences, which was the main phase of the whole process; from 1979 to 1989, the workgroup detected and eliminated the remaining infectious sources, strengthened the monitoring and management to consolidate previous achievements and prepared for the eradication of malaria.

The second stage, from 1990 to 2010, was a period of elimination of malaria. Malaria surveillance measures have been adopted to detect the remaining sources of infection and manage the floating population [16,17]. Firstly, hospitals at all levels should do malarial parasite examination for fever patients, register, classify, investigate and manage all malaria patients [18]. Secondly, the professional staff of Changsha CDC are supposed to carry out active investigations of the missed cases from the municipal, county and township hospitals every year. Except for using drug to kill mosquitoes, epidemiological investigation and treatment were carried out in the epidemic regions. Thirely, blood tests were taken on fever patients with history of travel or migrant population, students from high epidemic countries or areas of malaria in colleges should be registered and given preventive medicine [19,20].

The third stage, from 2011 to 2019, was a period of prevention of reintroduction. Changsha launched the *Action Plan for Malaria Eradication* in 2011 [14], established the leading group, and appointed Changsha First Hospital as the designated hospital for malaria treatment. Changsha CDC has set up a parasitic disease prevention and control department with 5 full-time staffs, and appointed commissioners in each district to ensure the orderly progress of malaria elimination. Measures like investigation and treatment of malaria cases, improvement of microscopy network, standard drug administration, strengthen mosquito monitoring have been implementated, the ability of scientific control for Malaria have been strengthen. More actions through media, radio, television, microblog, WeChat, Website and so on have been taken to strengthen health education and raise awareness of disease prevention. Since 2011, relevant personnel have been organized to participate in the training of provincial malaria prevention and treatment techniques every year and the knowledge of malaria prevention and treatment has been promoted throughout Changsha.

The results showed that before the year 1978, Changsha was the tertian malaria epidemic area with anopheles mosquito as the main transmitting vector; the incidence rate of malaria was at a high level, while the fatality rate was at a low level in Changsha. From 1979 to 1989, the incidence of malaria has decreased dramatically. In 1980s, cases of malaria was just 1542 and the fatality rate was 0; the epidemic of malaria in Changsha has been well controlled under the relevant prevention and control measures in the first stage, which have made full preparations for malaria eradication. After 1990, the incidence rate of malaria in Changsha has been controlled below 1/100,000, and in the 2000s, the incidence has reached the lowest to 1.17/1,000,000 which almost reached the standard of elimination. The last local case of malaria in Changsha was reported in April 2010, which means the elimination of malaria in Changsha has achieved a phased victory.

However, in recent years, with the acceleration of scientific, technological, economic and cultural globalization, especially the implementation the spirit of "*The Belt and Road*", labor, economic and trade exchanges between Changsha and high endemic areas of malaria has become increasingly frequent [21-25]. Since 2011, all malaria cases in Changsha were imported. As the sources of imported malaria were persistent existed, the vector of malaria was not completely eliminated and the risk of malaria reoccur in Changsha would still exist, which posed a great challenge to malaria elimination in the province. In addition, we found that, after 2010, the fatality rate of malaria in Changsha has reached the highest level in the past 70 years. Infection with different kinds of plasmodium usually results in different clinical outcomes in patients [26,27]. The most virulent and fatal type of malaria in the worldwide is caused by pernicious malaria [28], which is a major cause of death and neurological disease. In the past, the common malaria cases reported in Changsha were tertian malaria, while in recent years, with the increase of imported cases, a number of ovale, quartan and mixed infection malaria have been reported and the proportion of pernicious malaria has increased rapidly. After 2010, the proportion of pernicious malaria in Changsha was more than 50%, with a maximum of 86.67% in 2014. This may be the main reason for the high fatality rate of malaria after 2010, which made it more difficult for diagnosis and treatment [29].

In this study, an adjusted comprehensive assessment method was used to assess the risk of re-transmission of imported malaria in different districts of Changsha. The results showed that the risk level of re-transmission in Liuyang was the highest, which may be related to the large number of migrant workers to Africa or Southeast Asia. Most of them had low education level and did not fully understand the protection knowledge of malaria. In addition, the medical level of Africa and Southeast Asia were backward, the migrant workers generally did not have malaria related antibodies, and it took several weeks or even months to get sick after the first infection of Plasmodium, which led to widespread infection and transmission. The risk level of re-transmission in Yuelu district were relatively high, which may be related to the fact that this district is the political and cultural center of Changsha. Municipal government, Xiangjiang new area and many colleges and universities are here, which has attracted many experts, scholars and students from malaria endemic areas to visit, study and exchange here. Kaifu District and Changsha County had the lowest re-transmissi risk because of their strong prevention and control ability and few imported cases.

Great importance should be attached for prevention and control of imported malaria outbreaks, with the focus on monitoring people from high epidemic area of malaria and making accurate diagnosis and in-time treatment, once suspected cases were been found, they should be dealt with actively to cut off the source fundamentally [30,31]; It's better to enhance the professional training of clinicians, inspectors and information managers of infectious diseases to improve their skills in malaria prevention, microscopy, clinical diagnosis, treatment and prevention and control, especially for some basic health service organization or general hospitals with weak technology; Moreover, it is necessary to strengthen the health education of local residents and establish their awareness of malaria prevention. Finally, cooperation among the departments of public health, immigration, entry-exit inspection and quarantine services, police and the commercial sector would play an important role in the detection, prevention and management of imported malaria [32], it is necessary to strengthen the cooperation between various departments to ensure the implementation of prevention and control measures.

After 70 years efforts, Changsha has achieved the goal of malaria elimination. However, the risk of re-transmission still exists, especially in Liuyang and Yuelu district. In accordance with the provincial and municipal work arrangements and requirements, we should continue to take malaria control and prevention as an important preventive work and maintain the sustainability of malaria surveillance, effectively manage imported malaria cases, implement various prevention and control measures as required to prevent the secondary spread of scientifically and effectively [33,34].

Due to the capacity of malaria testing and the availability of medical facilities before the year 2000, some underreporting and misreporting of malaria cases may exist during the study period, in addition, our assessment approach did not include meteorological or socio-economic indicators, which is the limitation to this study.

Conclusions

After 70 years, implemented three stages of prevention and control measures, Changsha has achieved the goal of malaria elimination. However, with the increased imported cases, the proportion of pernicious malaria has risen and the fatality rate of malaria has reached a high level since 2011and the risk of re-transmission of malaria in Changsha still exists, especially in Liuyang and Yuelu district. Malaria control and prevention should still be taken as an important preventive work to prevent the secondary spread.

List Of Abbreviations

1. Global Technical Strategy (GTS)
2. World Health Organization (WHO)
3. Center for Disease Control and Prevention (CDC)
4. Rapid diagnostic tests (RDTs)
5. Transmission Potential Index (TPI)
6. Intervention Capacity Index (ICI)
7. Malaria Risk Index (MRI)
8. Anopheles transmission index (ATI)
9. Malaysia endemic index (MEI)

Declarations

Ethics and Consent to Participate

Not applicable

Consent to publish

All authors agreed to publish this article on Malaria Journal

Availability of data and materials

All data and material in our study were obtained from Changsha Center for Disease Control and Prevention.

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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The funder had in our study was the correspondence author (Yuan LV).

Authors' Contribution

W Z and G L mainly responsible for Writing - original draft, review & editing;

R F, Y L and N Z mainly responsible for Resources of data and Data curation;

M C, J L, X R and Y S mainly responsible for Methodology;

S Y mainly responsible for Formal analysis;

Y L mainly responsible for sponsorship of Funding acquisition and Supervision, review & editing.

All authors read and approved the final manuscript.

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Tables

Table 1
Grade assignment of re-transmission risk indicators of imported malaria

The first level indexes	The second-level indexes	Assessment content	Levels	Values
Infection source	Number of imported malaria cases(NI)	Number of imported malaria cases from 2010 to 2019	Imported malaria cases < 10	1
			Imported malaria cases 11 ~ 30	3
			Imported malaria cases 31 ~ 50	5
			Imported malaria cases > 50	7
	Type of imported malaria(TI)	Number of imported non- pernicious malaria cases from 2010 to 2019	Imported non-pernicious malaria cases = 0	1
			Imported non-pernicious malaria cases 1 ~ 7	3
			Imported non-pernicious malaria cases 8 ~ 15	5
			Imported non-pernicious malaria cases > 15	7
Transmitting conditions	Anopheles transmission index(ATI)	Main species of Anopheles in Changsha	Anopheles japonicus Riyuetan subspecies	5
			Anopheles minimus	4
			Anopheles anthropophagus	3
			Anopheles sinensis	2
Control capacity	Financial support	Special fund support	Yes	4
			No	6
	Work execution	24-hour reporting rate	Up to 100%	1
			Less than 100%	7
		Case investigation rate	Up to 100%	1
			Less than 100%	7
	Diagnostic capacity	Blood test an rechecking rate	Up to 100%	1
			Less than 100%	7
	Standardized treatment	Standardized treatment rate	Up to 100%	1
			Less than 100%	7
	Diagnosis and treatment skills of medical institutions	Assessment score of malaria elimination	80 ~ 85 scores	7
			85 ~ 90 scores	5
			90 ~ 95 scores	3
		Time of reaching the elimination standard	95 ~ 100 scores	1
			2013	2
			2014	3
			2015	4

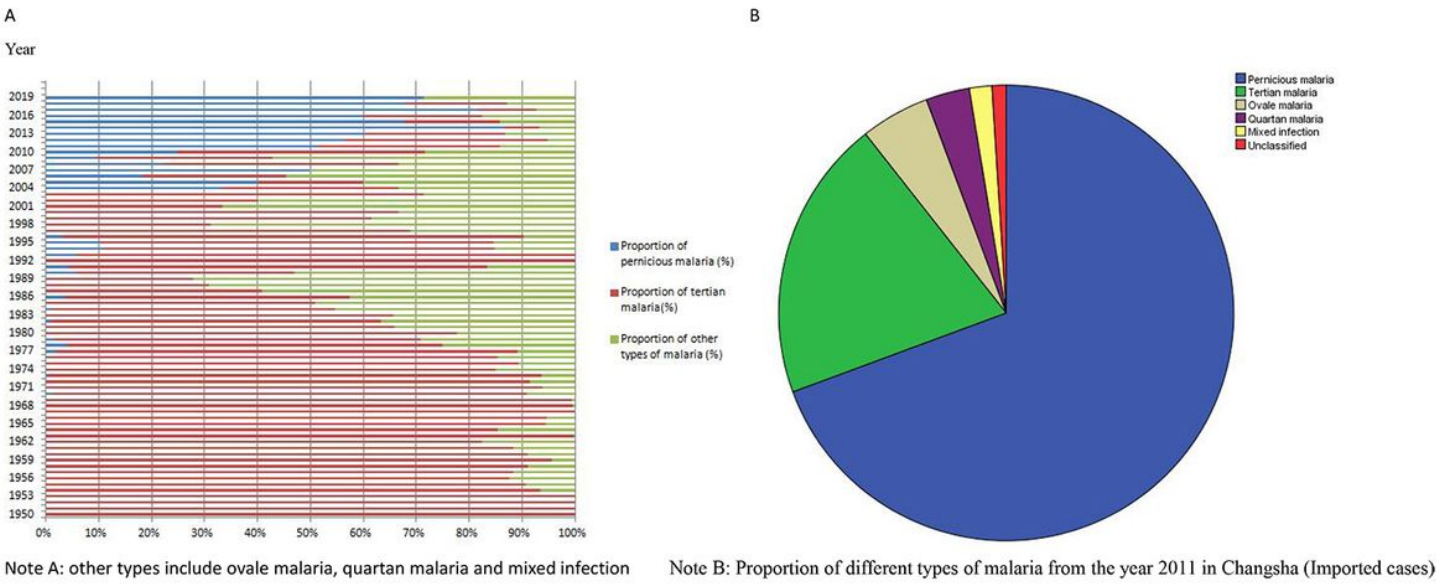
Table 2
Dynamic series of incidence and morbidity rate of malaria in different years in Changsha

Decade	Number of patients	Incidence rate(1/million)	Number of deaths	Morbidity rate (1/ thousand)	Absolute increase of patients		Speed of development of patients (%)		Speed of growth of patients (%)	
					Cumulative	Decade	Compared with the first decade	Compared with previous decade	Compared with the first decade	Compared with previous decade
1950s	91926	2728.55	13	0.37	0	0	100.00	100.00	100.00	100.00
1960s	137174	3782.02	20	0.14	45248	45248	149.22	149.22	49.22	49.22
1970s	50980	1166.33	1	0.02	-40946	-86194	55.46	37.16	-44.54	-62.84
1980s	1542	30.61	0	0.00	-90384	-49438	1.68	3.02	-98.32	-96.98
1990s	285	5.06	1	2.50	-91641	-1257	0.31	18.48	-99.69	-81.52
2000s	72	1.17	0	0.00	-91854	-213	0.08	23.12	-99.92	-76.88
2010s	415	5.51	4	10.28	-91511	343	0.45	576.39	-99.55	476.39

Table 3
The TPI, ICI and MRI of each district in Changsha

District	TPI	Levels	ICI	Levels	MRI	Levels
Kaifu	12	2	9.24	4	1.30	1
Changsha	12	2	9.24	4	1.30	1
Wangcheng	12	2	8.62	1	1.39	2
Furong	12	2	7.39	3	1.62	2
Ningxiang	20	3	8.01	2	2.50	3
Yuhua	24	3	9.24	1	2.60	3
Tianxin	20	4	7.39	4	2.71	3
Yuelu	24	4	8.62	3	2.78	4
Liuyang	28	4	8.62	3	3.25	4

Figures



Note A: other types include ovale malaria, quartan malaria and mixed infection

Note B: Proportion of different types of malaria from the year 2011 in Changsha (Imported cases)

Figure 1

Proportion of different types of malaria in different years in Changsha

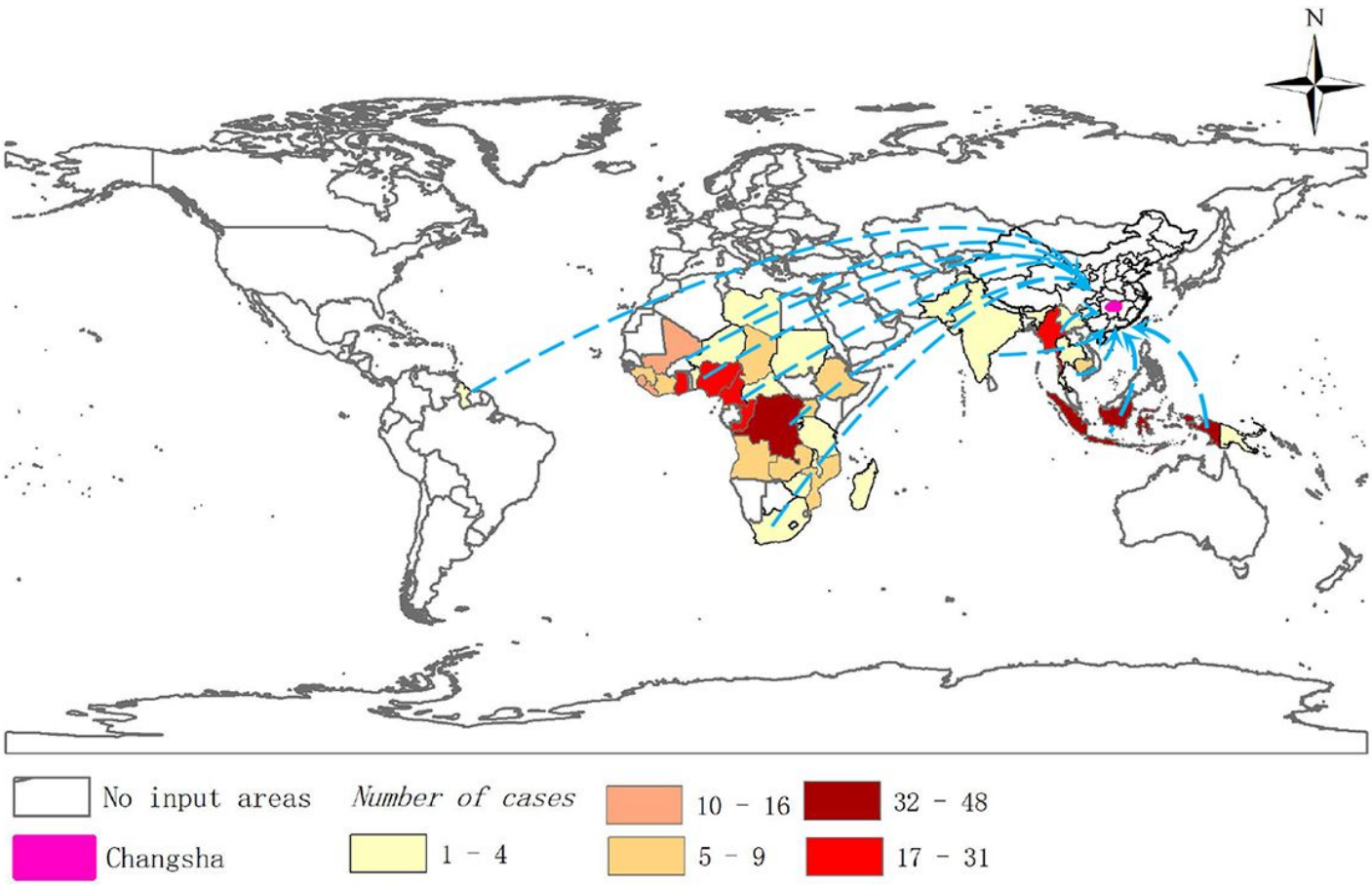


Figure 2

Distribution of imported malaria in Changsha after 2010. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

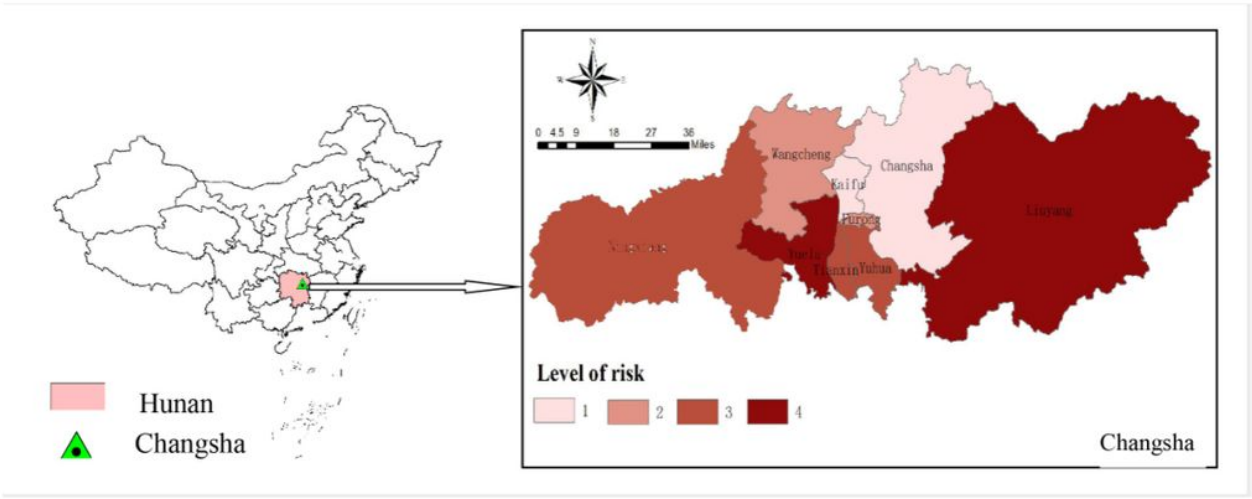


Figure 3

Classification map of re-transmission risk of imported malaria in Changsha. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

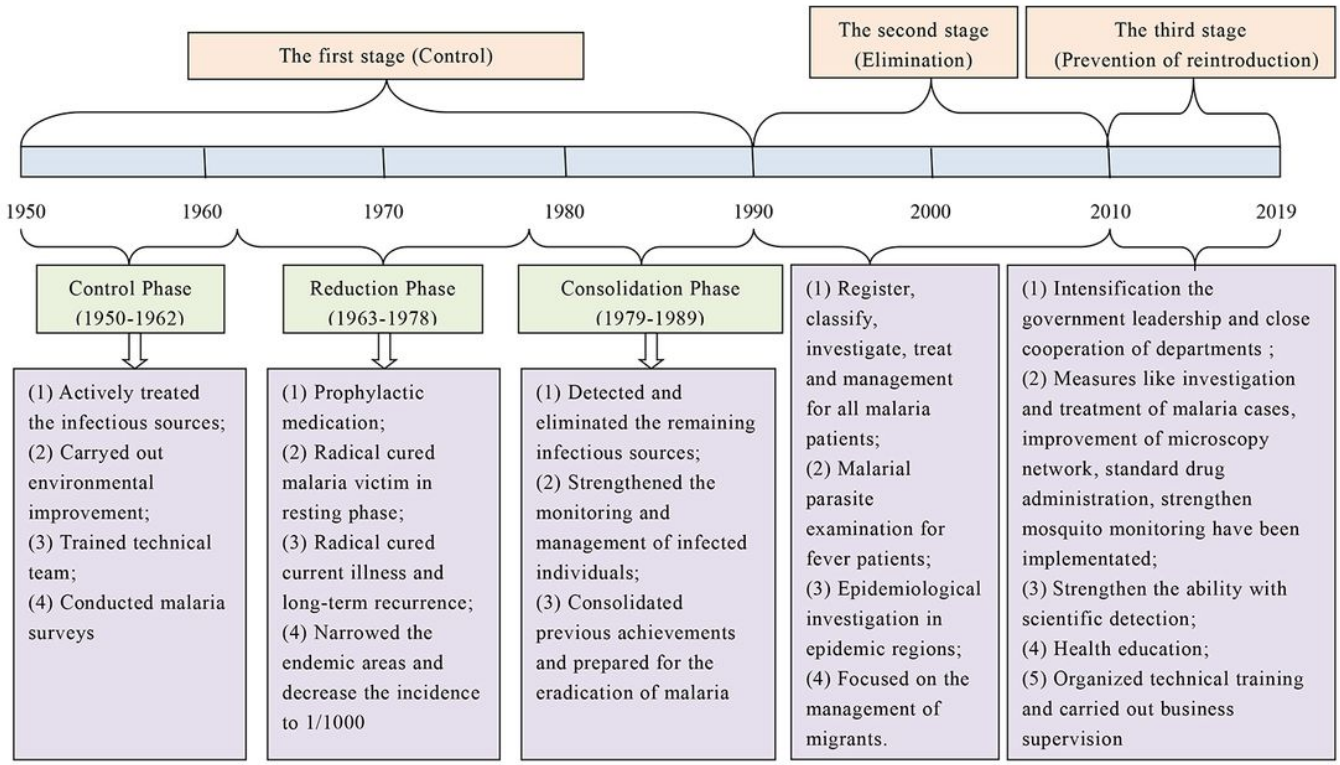


Figure 4

The process of control and elimination of malaria in Changsha