Observational Study

Medicine

OPEN

Analysis of epidemiological changes and elimination effects for malaria in Handan city, the north China

Shuang Liang, Dr[a,b], Ruiling Guo, MM[c], Jing Zhuang, BM[c], Penghui Li, Dr[a,b], Zhongzheng Chang, BM[a,b], Wangdong Zhu, Dr[a,b], Zengjun Jin, PhD[a,b,c,*]

Abstract

The elimination of malaria requires high-quality surveillance data to quickly detect and respond to individual cases. This study aims to analyze the epidemiological characteristics of malaria and ascertain the long-term epidemic trends of malaria by 2020 in Handan China. Case-level data for the period 2011 to 2020 were extracted from Chinese Information System for Disease Control and Prevention. The lamp trap method was used to capture mosquitoes so that the characteristics of mosquitoes can be analyzed. The incidence, accuracy, and timeliness of malaria case diagnosis, reporting and investigation were evaluated at the elimination stage (2011–2020) in Handan City, China. Between 2011 and 2020, 94 malaria cases were reported in Handan City, of which 93 malaria cases were male and all of which were imported from abroad. The annual average incidence decreased from 622.33/100,000 to 0.11/100,000 in the elimination stage. Since the initiation of the National Malaria Elimination Program in 2010, malaria cases have been consistent with the increase in overseas export channels and labor personnel service. There is a need to strengthen malaria surveillance of returning workers from Africa and to conduct timely blood tests to diagnose and treat imported infections. Local authorities ensure that imported malaria cases can be timely diagnosed, reported, treated and investigated at local level.

Abbreviation: CDC = center for disease control and prevention.

Keywords: elimination, evaluation, imported malaria, malaria, surveillance

1. Introduction

Malaria is considered one of the most significant health problems for humans with a substantial disease burden in tropical areas. Malaria results from a vector borne plasmodial infection with single-celled parasites belonging to the Plasmodium genus and transmitted via the bites of the female Anopheles mosquito.[1] In 2020, there were approximately 241 million cases of malaria responsible for about 627,000 deaths, the majority on the African. Outstanding progress has been made in malaria control over the past decade.[2–5] More and more countries are progressing to elimination. As of December 2017, of the 106 countries with sustained transmission of malaria in 2000, 19 countries attained zero indigenous cases for 3 years or more; 16 of these countries that eliminated malaria between 2007 and 2017. To achieve the goal of eliminating malaria, a sustainable and well-functioning malaria monitoring system is considered as a key measure.[6] World Health Organization launched a new initiative on global malaria programme 3T, Test, Treatment and Track in 2012, which depends on the provision of timely and accurate monitoring data to monitor performance and identify threats to malaria control and elimination.[7]

In the past, especially in the last 30 to 40 years after the founding of the People's Republic of China, China has suffered from severe malaria epidemics.[8] From 1949 to 2020, the transmission of the malaria can be primarily divided into 5 phases: transmission; outbreak; pandemic transmission; decline with sporadic distribution; and the elimination phase.[9] A national malaria elimination programme was launched in China in 2010, which supported to achieve zero indigenous case of malaria within the 2020 timeline.[10] The elimination phase was different from the control phase, and needs to monitor and respond to each malaria infection, and to eventually stop local malaria transmission. China had developed a case-based malaria surveillance system to gather

This study was supported by the Doctoral Research Foundation of Hebei University of Engineering, Hebei Provincial Centre for Disease Control and Prevention, the Special Research Foundation of Hebei University of Engineering (SJ2101003157 and SJ220100329), and Handan Municipal Science & Technology Commission (19422083007 and 20312904044), Handan Municipal Social Sciences Association (2022168).

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] School of Medicine, Hebei University of Engineering, Handan, China, [b] Handan Key Laboratory of Integrated Medical and Industrial Application in Basic Medicine, Handan, China, [c] Handan Municipal Centre for Disease Control and Prevention, Handan, China.

** Correspondence: Zengjun Jin, School of Medicine, Hebei University of Engineering, Handan, Hebei 056038, China (e-mail: jinzengjun@hebeu.edu.cn).*

How to cite this article: Liang S, Guo R, Zhuang J, Li P, Chang Z, Zhu W, Jin Z. Analysis of epidemiological changes and elimination effects for malaria in Handan city, the north China. Medicine 2022;101:50(e31722).

Received: 21 July 2022 / Received in final form: 19 October 2022 / Accepted: 19 October 2022

http://dx.doi.org/10.1097/MD.0000000000031722

information needed for diagnosis and investigation, and to promote a rapid response to individual cases.[11,12] In order to eliminate malaria, the strengths and limitations of the program must be understood by quantitatively evaluating the performance and efficiency of national malaria elimination programme.[13,14]

Compared to 2019, the global number of malaria cases and deaths has increased by 14 million and 69,000 cases, respectively, in 2020. At the same time, increasing labor service and travel to malaria-endemic areas in recent decades had resulted in a steady increase in the number of imported cases in non-endemic countries.[15] Malaria posed a serious health hazard to travelers to local areas. Imported malaria was an infection acquired abroad and brought into the regional territory.[16] Cases imported-malaria into non-endemic countries tended to lead to delayed diagnosis, expensive treatment, and sometimes, secondary local transmission.[17] During 2017 to 2019, China had achieved interruption of indigenous malaria transmission. Still, malaria was the imported disease with the highest number of notifications in China, between 2500 and 10,000 malaria cases were imported into China from 2002 to 2017.[10]

Given an example, Handan city (2018 population 9.52 million), a typical northern city with a long history in North China. Based on literature records and data analysis, the last local malaria case in Handan was occurred before 2005. In the last decades, notified malaria infections had been entirely imported. There were no documented cases by autochthonous transmission, and it mainly related to the improvement of public health care and a strong sense of personal health. Although there is a partial distribution of the potential vector of this species, it is considered that the current risk of introduced malaria is very low.[18] In order to improve knowledge about malaria-imported cases characteristics, the epidemiological and clinical characteristics of patients diagnosed with malaria in North China were assessed.

In this study, a longitudinal population-based surveillance study of every malaria case from 1990 to 2020 in North China was conducted. We have a systematic analysis of the key components of malaria surveillance, including trends in malaria prevalence, the origin of imported malaria, the Plasmodium species, and prevention effects of malaria.

2. Materials and Methods

2.1. Study site

Handan city is located in the southern end of Hebei Province and in the northern part of China, laying between latitudes 36°20′ and 36°40′N, and longitude 114°03′ and 114°40′E. The total area is 12,047 square kilometers, including 4460 square kilometers in mountainous areas and 7587 square kilometers in plain areas. It has a population of >9.5 million and includes 18 counties. Handan belongs to the southeast monsoon climate region, which is a continental monsoon climate transiting from the semi-humid zone of warm zone to the semi-arid zone. It has abundant sunshine, the same period of rain and heat, the same period of dry and cold, and the 4 seasons are alternating obviously. The main cash crops are wheat, maize, cotton, millet, rice and soybean. This variety in climate, environment, and ecology makes the area favorable for mosquito development.

2.2. Study design

This is a longitudinal population-based surveillance study. The data were extracted from the Chinese Information System for Disease Control and Prevention between 2004 and 2020. The other data were collected from digital monthly reports between 1990 and 2003.

2.3. Fever patient blood smear microscopy

Since 2010, microscopic examinations on "triple fever" patients (clinically diagnosed as having malaria, suspected malaria or unexplained fever) had been carried out each year and blood tests had been conducted for malaria parasites.

2.4. Mosquito collection and species identification

The lamp trap method was used. According to the characteristics of mosquito breeding and distribution, 4 representative areas with different habitats were selected in residential areas, parks, hospitals, rural houses and cattle sheds in 3 urban districts and rural suburbs of Handan. The survey was conducted twice a month from May to October every year. The captured adult mosquitoes were brought back to the laboratory and smoked with ether for classification and identification.

The mosquitoes were morphologically divided into *Anopheles*, *Culex*, *Aedes*, and other subfamilies or genera. The species of *Anopheles* were further classified by morphology.[19]

2.5. Data analysis

All data analysis was conducted by the Statistical Package for Social Sciences software (version 25.0; SPSS Inc., IL).

2.6. Ethics approval and consent to participate

The experimental research reported in the current study was performed with the approval of the Ethics Committee of the Handan Municipal Centre for Disease Control and Prevention (CDC) and the Ethics Committee of Hebei University of Engineering (BER-YXY-2019046). Human research was performed in compliance with the Declaration of Helsinki and its later amendments. All participants provided their written informed consent to participate in this research.

3. Results

3.1. Descriptive analysis of the malaria cases

3.1.1. Occurrence of cases. During 1990 to 2010, 47 cases of malaria were reported in the early malaria elimination phase. The highest incidence rate was 2010 (0.06/100,000), and no malaria cases were reported in 1990, 1991, 1996, 2000 and 2006. In the elimination phase between 2011 and 2020, a total of 94 imported cases of malaria were reported (Fig. 1). After 2009, there was an increase in fluctuation of malaria cases imported from other countries.

3.1.2. Determination/judgement of the final indigenous case. All 94 malaria cases reported in Handan City from 2011 to 2020 had detailed epidemiological records, and all of them had a detailed history of living in high malaria areas abroad, which could rule out the possibility of local infection.

From 2005 to 2010, there were 17 cases of malaria in Handan city, 5 cases of *plasmodium falciparum* malaria, 2 cases of *plasmodium vivax* malaria, 1 case of mixed infection of *P vivax* and *P falciparum* malaria, and 9 cases of unclassified malaria. Due to the history of *P vivax* malaria epidemic area in our city, there is no *P falciparum* vector, we determined that the *P falciparum* cases were imported cases. A retrospective investigation was conducted on the outward travel history of 2 cases of *P vivax* malaria and 9 cases of unclassified malaria. The survey confirmed they all had experience of working in malaria-infected areas in south China or abroad. According to the above investigation results, it can be concluded that the last indigenous case in Handan city occurred before 2005.

3.2. Plasmodium species composition

From 1990 to 2020, 4 species of *plasmodium* (*P vivax*, *P falciparum*, *Plasmodium ovale* and *Plasmodium malariae*) were identified in 141 malaria cases. From 1990 to 2010, a total of 47 cases of malaria have been reported, of which 33 cases were *P vivax*, 6 cases were *P falciparum* and 8 cases were unclassified *Plasmodium* infections. From 2011 to 2020, 64 cases of *P falciparum* accounted for 71.3% of the total malaria infections. In addition, 3 cases of *P ovale* infection and one case of *P malariae* infection was identified during this period. Furthermore, there were nine unclassified *plasmodium* infections (Table 1).

3.3. Patterns of imported case in malaria elimination stage

3.3.1. General epidemiologic profile. Among the 94 cases, there were 15 cases of *P vivax*, 64 cases of *P falciparum*, 6 cases of *P ovale*, 7 cases of *P falciparum* and *P ovale* mixed infection, 1 case of *P malariae*, and 1 case of unclassified *Plasmodium* infection during 2011 to 2020 (Fig. 2). Of these, 45 cases were reported locally and 49 were reported from other cities. The demographic features of imported cases in 2011 to 2020 was shown in Table 2. 93 imported malaria cases were male. The 21 to 50 age group had the most malaria cases, accounting for 91.5% of the total 94 cases. The remaining age groups of 20 years or less and 51 years or more included only a small number of cases, 1 and 7, respectively. The proportion of farmers, oversea laborers and workers was the highest, accounting for 37.2% (35/94), 35.1% (33/94) and 17.0% (16/94) of the total occupation distribution, respectively.

The onset time of imported malaria was not related to the season. Cases reported in every month during 2011 to 2020. There were 10 cases in January, 10 cases in July and 16 cases in September, and 4 to 9 cases in other months, which was consistent with the time of overseas return of the cases (Fig. 3). In addition, the 10-year cases analysis displayed that most of these cases were recorded in the counties of Chengan, Linzhang, Weixian and the main city zone of Handan, which reported 45, 8, 5, and 9 cases of imported malaria, respectively, which accounted for 71.3% of the total number of cases. All the imported cases had work experience abroad before their onset. Among them, 25 cases were from Nigeria and 22 cases from Congo, accounting for 47.9%. Angola, Pakistan, and Myanmar followed with 5, 6, and 5 cases, respectively. The results of epidemiological investigation showed that all the cases were imported from abroad.

3.3.2. Case investigations. All 45 locally reported cases were investigated by malaria control personnel of the disease control institutions in their jurisdiction, and the samples of cases were rechecked by county, city and provincial CDC. After a laboratory confirmed malaria case, the municipal CDC provides the patient with antimalarial drugs. The clinician is responsible for the treatment of the patient, and the malaria control personnel in the district are responsible for the follow-up of the treatment progress and results of the case. In view of the historical prevalence of *P vivax* in our city, and the occasional capture of *Anopheles sinensis* (*An sinensis*) in mosquito density monitoring in recent years, we determined the living places of these 9 *P vivax* cases to be the epidemic sites with the possibility of transmission, and carried out key treatment according to the disposal requirements. *An sinensis* and other malaria mosquitoes were not found by vector investigation, and no suspicious cases were found in active screening of fever cases. The standard disposal rate of the epidemic site was 100%, and no imported secondary cases of locally infected malaria were detected.

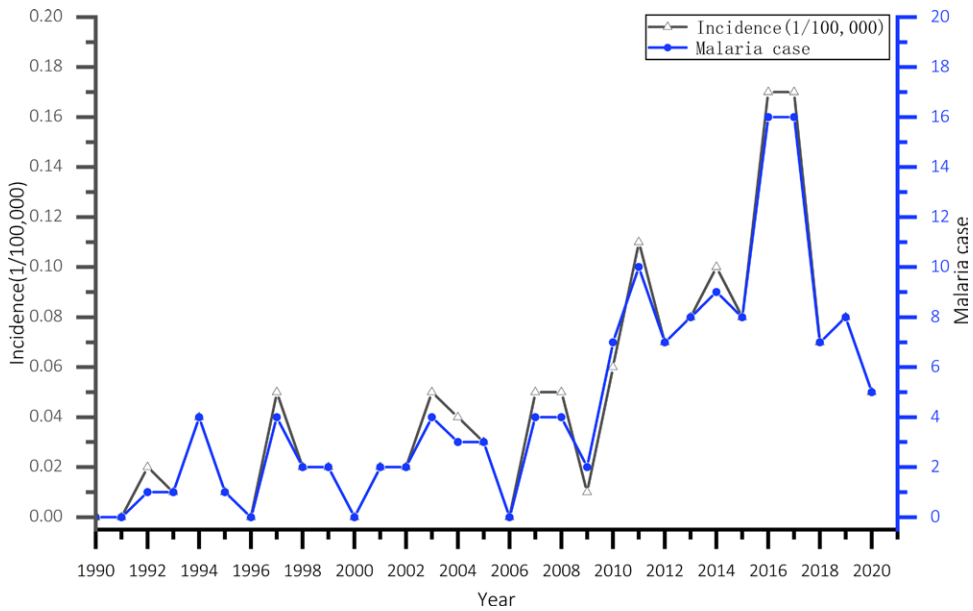

Figure 1. Malaria incidence and cases reported in Handan, Hebei Province from 1990 to 2020.

Table 1

***Plasmodium* species in Handan city, 1990 to 2020.**

Year	*Plasmodium vivax*	*Plasmodium falciparum*	*Plasmodium ovale*	*Plasmodium malariae*	Mixed infection	Unclassified infection	Total
1990–2010	33	6	0	0	0	8	47
2011–2020	15	64	6	1	7	1	94
Total	48	70	6	1	7	9	141

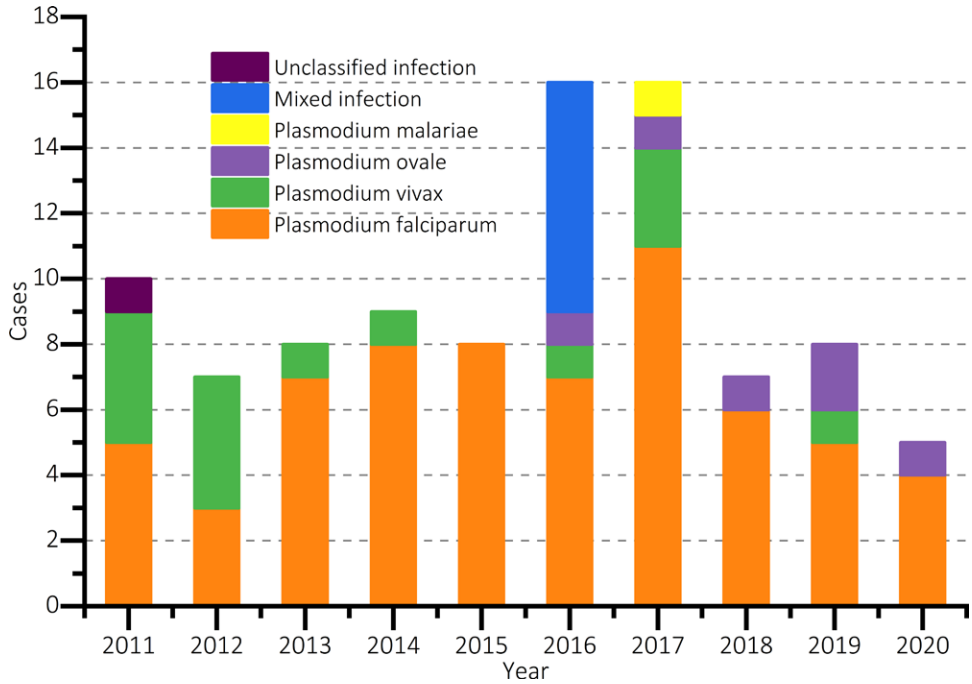

Figure 2. Species type distribution of imported malaria in Handan city from 2011 to 2020.

Table 2

Demographic characteristic of malaria cases in Handan city between 2011 and 2020.

Variables	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Female	0	0	0	0	0	0	0	0	0	1	1
Male	10	7	8	9	8	16	16	7	8	4	93
≤20	0	0	1	0	0	0	0	0	0	0	1
21–50	10	7	7	9	7	15	14	5	7	5	86
≥51	0	0	0	0	1	1	2	2	1	0	7
Farmers	1	1	5	5	3	11	9	0	0	0	35
Oversea laborers	8	3	0	2	3	3	1	0	8	5	33
Workers	1	0	1	1	1	1	4	7	0	0	16
Houseworker	0	1	2	0	1	0		0	0	0	4
Businessmen	0	1	0	1	0	1		0	0	0	3
Others	0	1	0	0	0	0	2	0	0	0	3

*Others include cadres, individual worker, for example.

3.3.3. Fever patient blood tests. According to province program requirements, the number of blood fever patients between 2011 and 2020 was higher than blood tests required. Except for 2011, the completion rate of blood tests was more than 100%, and the proportion of blood tests in the transmission season reached 50%. Since 2010, Handan has been actively managing patients who are currently ill. 94 malaria cases were treated, including 45 locally reported imported cases, and all cases were in good condition after treatment (Table 3).

3.4. Vector investigations

During the malaria epidemic in the 20th century, all the malaria cases in Hebei province were *P vivax*, and *An sinensis* was the only malaria vector. Traceable vector monitoring data in Handan city began in the 1950s. There were 18 species of adult mosquitoes from3 genera and 18 species of larvae. Except *An sinensis*, no other species of malaria vector were found. The main breeding places of *An sinensis* are concentrated in rice fields and its irrigation systems. According to the number of *An sinensis* specimens and the date and place of collection, *An sinensis* is a common mosquito species in Handan City. Before the year of 1993, rice cultivation area in the Fu River and Qing Zhang River basin was large. With the rapid social development, rice cultivation has been greatly reduced since 2003. Now, there are almost no paddy fields, but mainly wheat and corn.

Since 1993, mosquito vector monitoring has been carried out continuously in the main urban area of Handan, the annual mosquito density fluctuates greatly, but the overall trend is decreasing, and it is related to the annual precipitation (Fig. 4). In 1996, during the flood disaster in Handan City, the highest number of *An sinensis* mosquitoes were captured, with a density of 251.3 mosquitoes per night lamp, accounting for 37.6% of the captured mosquitoes. After that, both the density and proportion of *Anopheles* mosquitoes showed a decreasing trend. According to the monitoring results from 2003 to 2015, the composition ratio and capture number of *An sinensis* have decreased significantly since 2010. The density of mosquitoes, the density of *Anopheles* and the proportion of *Anopheles* increased slightly during the floods in Handan City in the summer of 2016. Subsequently, *An sinensis* was not caught from 2017 to 2020.

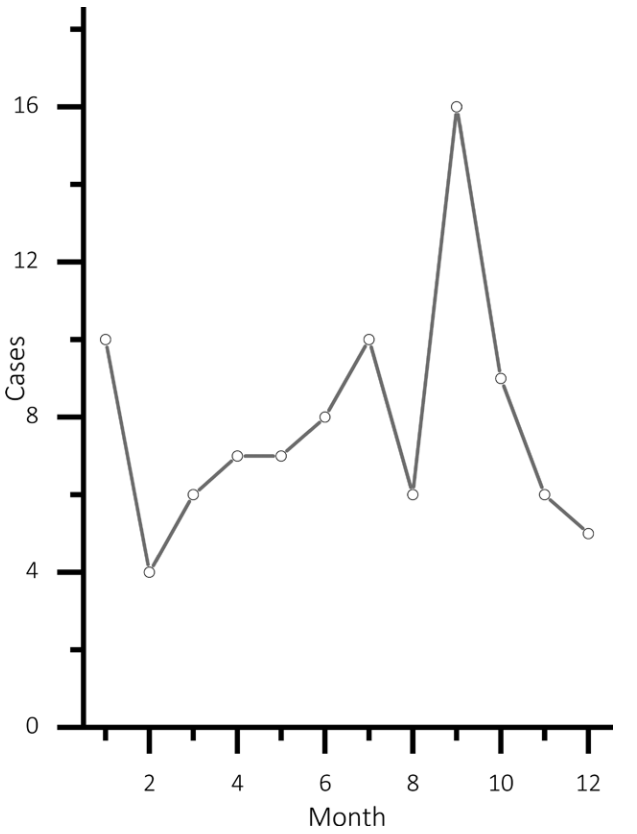

Figure 3. Monthly distribution of imported malaria in Handan city during the period of 2011 to 2020.

Table 3

The number of blood tests and patient treated in Handan city, 2011 to 2020.

Year	Blood tests required	Completed blood tests	Complete percentage (%)	Percentage (%) in 5–10 mo	Check consistency (%)	Case number
2011	16,387	13,391	81.7	61.7	100	8
2012	4213	4689	111.3	79.1	100	3
2013	4389	5302	120.8	83.3	100	1
2014	4389	5378	122.5	82.4	100	4
2015	4389	5172	117.84	81.4	100	3
2016	950	1073	113.0	50.0	100	7
2017	900	1046	116.2	53.4	100	8
2018	900	1214	134.9	62.3	100	3
2019	900	1050	116.7	51.1	100	4
2020	900	1110	123.3	56.2	100	4
Total	38,317	39,425				45

4. Discussion

Handan used to be an area of high prevalence of *P vivax*, with *An sinensis* as the single vector. The rivers in Handan are Ming River in the north, Fuyang River in the middle and Zhang River in the south. At present, Fuyang River has water all the year round, and Ming River and Zhang River are in a dry period. However, tributaries with reeds, irrigation ditches, ponds and drains around villages are the best breeding grounds for *An sinensis*. And people who live nearby are more likely to get bitten by mosquitoes during peak biting times, which can lead to malaria. In Handan City, corn and wheat are the main crops. In the 1970s, Fuyang River basin began to introduce rice planting and formed a scale of water field; with the reduction of surface water resources and ecological environment control, water field has been basically disappeared by the end of the 1990s. This is also a good fit with the malaria epidemic trend in our city.

During the epidemic stage (1956–1985), the incidence of malaria in Handan was obviously seasonal, with high incidence from May to September. From 1960 to 1979, Handan city in North China experienced widespread malaria outbreaks, in line with provincial and national epidemic patterns.[20] With the increase of national efforts to prevent and control infectious diseases and the improvement of the environment, the incidence of malaria dropped to sporadic levels in the late 1980s. The incidence was non-seasonal, and cases were reported even in winter and spring when mosquitoes were not active. From 1989 to 2004, a total of 27 malaria cases were reported. Due to the lack of relevant epidemiological data, it is impossible to verify whether the malaria cases reported during this period were locally infected.

A total of 20 malaria cases were reported in 2005 to 2010. According to the case information, there was a clear history of living in areas with high malaria in foreign countries and they were imported cases.[20] From 2011 to 2020, 94 cases were reported, all of which had detailed epidemiological investigation information and were imported from abroad. The number of imported malaria cases increased during this period, which was consistent with the increase of export channels and personnel of labor services abroad. In this period, malaria elimination efforts will focus on the management of malaria patients, the maintenance of blood testing capacity for malaria parasites in patients with fever, and the screening and investigation of people traveling to and from areas with high malaria levels.

Since the implementation of the malaria elimination work in our city, the malaria prevention and control work has achieved remarkable results, which has improved the people's knowledge of malaria and self-prevention ability, and greatly enhanced the medical institutions' ability to treat malaria cases. The indicators reached the standard of eliminating malaria. To maintain this goal, the following points need to be noted.

With socio-economic development, urban expansion has accelerated and regional ecological changes have resulted in a decrease in malaria cases and the elimination of indigenous cases, this point was confirmed in the study of Wang et al. Wang et al[21] reported that malaria prevention and control measures and local fiscal revenue increases were related to the decrease of malaria incidence in Hainan.

In 2017, China reported zero indigenous malaria case for the first time. In addition, zero indigenous malaria case was reported in the Chinese mainland for 3 consecutive years from 2017 to 2019.[10] However, malaria cases imported from Africa and Southeast Asia are still occurring in China because of overseas labor.[22,23] Therefore, country-led efforts are regional and intersectoral cooperation and ongoing monitoring and evaluation. Meanwhile, some works must be done consistently, such as the maintenance of non-transmission status, the diagnosis, treatment and management of imported malaria cases, the implementation of business training, technical guidance, quality control and supervision and inspection, through multi-sectoral collaboration.[24,25]

Maintaining the microscopic capability of primary health inspectors is also a challenge in achieving and sustaining malaria elimination.[26] In 2011, the completion rate of blood tests was 81.7% (13,391/16,387), and there were nine unclassified *plasmodium* infections during 2007 to 2020, some of these cases may be due to *Plasmodium knowlesi* (discover only in 2010) which is currently found in South-East Asia countries (like Myanmar). Hence, the skills of microscopists for the preparation and interpretation of blood smears should be strengthened. In order to keep the elimination of malaria sustainable, we will take precise measures at different levels and areas. One point here is not to be ignored, it is definitively not easy to maintain a reasonable level of skills for microscopists for the preparation

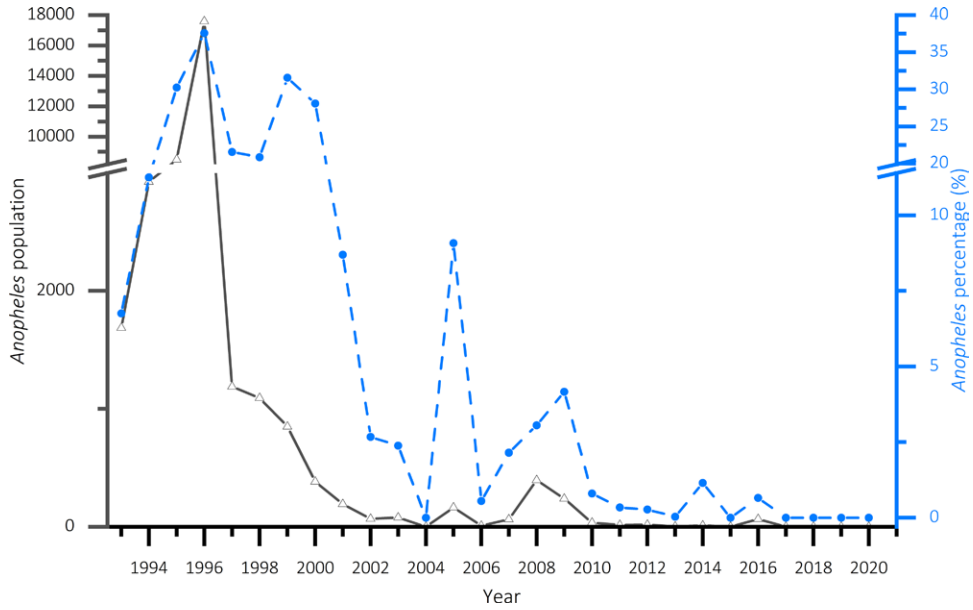

Figure 4. *Anopheles* number and *Anopheles* percentage accounting for the captured mosquitoes in Handan, Hebei Province in the 1993 to 2020 period.

and interpretation of blood smears when the number of analysis asked is low. The potential contribution of using molecular identification of *Plasmodium* species is vital important (more expensive but more suitable for country with few malaria diagnostic demand). The Internet and other technological means should be used to enhance the level of information technology and improve the effectiveness of the prevention.[27]

5. Conclusions

Our study found that the source of malaria case detection has changed greatly from the control to elimination stage, and imported malaria cases occur throughout the year, so managing imported malaria cases is a major local priority in Handan, North China. Medical laboratory staff should also be better trained in the diagnosis and detection of imported malaria. In the long term, systematic vector surveillance to control adult mosquito density to less harmful levels is also an important part of the post-elimination phase of malaria. However, Handan still faces many challenges, including epidemiological changes in malaria cases among the international migrant workers.

Acknowledgement

We thank Xiaowei Li for the data collection of imported malaria cases (2009-2010).

Author contributions

RG and ZJ conducted the study design and study implementation. SL, RG, and ZJ performed the data analyses and draft the manuscript. JZ, PL, ZC, and WZ provided public health insight for analyzing the results. All authors read, edited and approved the final manuscript.

Conceptualization: Ruiling Guo, Zengjun Jin.
Data curation: Jing Zhuang.
Formal analysis: Penghui Li.
Funding acquisition: Shuang Liang, Ruiling Guo, Wangdong Zhu, Zengjun Jin.
Investigation: Shuang Liang, Ruiling Guo, Zhongzheng Chang.
Methodology: Ruiling Guo, Zhongzheng Chang.
Resources: Jing Zhuang.
Software: Penghui Li.
Supervision: Zengjun Jin.
Validation: Wangdong Zhu.
Visualization: Penghui Li.
Writing – original draft: Penghui Li, Zengjun Jin.
Writing – review & editing: Penghui Li, Zengjun Jin.

References

[1] Zofou D, Nyasa RB, Nsagha DS, et al. Control of malaria and other vector-borne protozoan diseases in the tropics: enduring challenges despite considerable progress and achievements. Infect Dis Poverty. 2014;3:1.
[2] Lai S, Sun J, Ruktanonchai NW, et al. Changing epidemiology and challenges of malaria in China towards elimination. Malar J. 2019;18:107.
[3] Rossati A, Bargiacchi O, Kroumova V, et al. Climate, environment and transmission of malaria. Infez Med. 2016;24:93–104.
[4] Cotter C, Sturrock HJ, Hsiang MS, et al. The changing epidemiology of malaria elimination: new strategies for new challenges. Lancet. 2013;382:900–11.
[5] Monroe A, Williams NA, Ogoma S, et al. Reflections on the 2021 World Malaria Report and the future of malaria control. Malar J. 2022;21:154.
[6] Lu G, Zhou S, Horstick O, et al. Malaria outbreaks in China (1990-2013): a systematic review. Malar J. 2014;13:269.
[7] Ndong IC, Okyere D, Enos JY, et al. Challenges and perceptions of implementing mass testing, treatment and tracking in malaria control: a qualitative study in Pakro sub-district of Ghana. BMC Public Health. 2019;19:695.
[8] Zhou ZJ. The malaria situation in the People's Republic of China. Bull World Health Organ. 1981;59:931–6.
[9] Yin J-H, Zhou S-S, Xia Z-G, et al. Chapter one – historical patterns of malaria transmission in China. In: Zhou XN, Kramer R, Yang WZ, eds. Advances in Parasitology. San Diego, CA: Academic Press; 2014:1–19.
[10] Feng J, Zhang L, Huang F, et al. Ready for malaria elimination: zero indigenous case reported in the People's Republic of China. Malar J. 2018;17:315.
[11] Cao J, Sturrock HJW, Cotter C, et al. Communicating and monitoring surveillance and response activities for malaria elimination: China's "1-3-7" strategy. PLoS Med. 2014;11:e1001642.
[12] Feng X-Y, Xia Z-G, Vong S, et al. Chapter four – surveillance and response to drive the national malaria elimination program. In: Zhou XN, Kramer R, Yang WZ, eds. Advances in Parasitology. San Diego, CA: Academic Press; 2014:81–108.
[13] Zhou X-N, Bergquist R, Tanner M. Elimination of tropical disease through surveillance and response. Infect Dis Poverty. 2013;2:1.

[14] Malone JB, Bergquist R, Martins M, et al. Use of geospatial surveillance and response systems for vector-borne diseases in the elimination phase. Trop Med Infect Dis. 2019;4:15.
[15] Vatandoost H, Raeisi A, Saghafipour A, et al. Malaria situation in Iran: 2002-2017. Malar J. 2019;18:200.
[16] Huang Q, Hu L, Liao Q-B, et al. Spatiotemporal analysis of the malaria epidemic in Mainland China, 2004-2014. Am J Trop Med Hyg. 2017;97:504–13.
[17] Tatem AJ, Jia P, Ordanovich D, et al. The geography of imported malaria to non-endemic countries: a meta-analysis of nationally reported statistics. Lancet Infect Dis. 2017;17:98–107.
[18] Herrador Z, Fernandez-Martinez B, Quesada-Cubo V, et al. Imported cases of malaria in Spain: observational study using nationally reported statistics and surveillance data, 2002-2015. Malar J. 2019;18:230.
[19] Zhang S-S, Zhou S-S, Zhou Z-B, et al. Monitoring of malaria vectors at the China-Myanmar border while approaching malaria elimination. Parasit Vectors. 2018;11:511.
[20] Ding C, Huang C, Zhou Y, et al. Malaria in China: a longitudinal population-based surveillance study. Epidemiol Infect. 2020;148:e37.
[21] Wang S-Q, Li Y-C, Zhang Z-M, et al. Prevention measures and socio-economic development result in a decrease in malaria in Hainan, China. Malar J. 2014;13:362.
[22] Kounnavong S, Gopinath D, Hongvanthong B, et al. Malaria elimination in Lao PDR: the challenges associated with population mobility. Infect Dis Poverty. 2017;6:81.
[23] Wang D, Li S, Cheng Z, et al. Transmission risk from imported plasmodium vivax malaria in the China-Myanmar border region. Emerg Infect Dis. 2015;21:1861–4.
[24] Zhang X, Yao L, Sun J, et al. Malaria in Southeastern China from 2012 to 2016: analysis of imported cases. Am J Trop Med Hyg. 2018;98:1107–12.
[25] Zhou S, Li Z, Cotter C, et al. Trends of imported malaria in China 2010-2014: analysis of surveillance data. Malar J. 2016;15:39.
[26] Ding G, Zhu G, Cao C, et al. The challenge of maintaining microscopist capacity at basic levels for malaria elimination in Jiangsu Province, China. BMC Public Health. 2018;18:489.
[27] Sahu M, Tediosi F, Noor AM, et al. Health systems and global progress towards malaria elimination, 2000-2016. Malar J. 2020;19:141.