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CHAPTER FOUR

Surveillance and Response to Drive the National Malaria Elimination Program

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Abstract

The national action plan for malaria elimination in China (2010–2020) was issued by the Chinese Ministry of Health along with other 13 ministries and commissions in 2010. The ultimate goal of the national action plan was to eliminate local transmission of malaria by the end of 2020. Surveillance and response are the most important components driving the whole process of the national malaria elimination programme (NMEP), under the technical guidance used in NMEP. This chapter introduces the evolution of the surveillance from the control to the elimination stages and the current structure of national surveillance system in China. When the NMEP launched, both routine surveillance and sentinel surveillance played critical role in monitoring the process of NMEP. In addition, the current response strategy of NMEP was also reviewed, including the generally developed “1-3-7 Strategy”. More effective and sensitive risk assessment tools were introduced, which cannot only predict the trends of malaria, but also are important for the design and adjustment of the surveillance and response systems in the malaria elimination stage. Therefore, this review presents the landscape of malaria surveillance and response in China as well as their contribution to the NMEP, with a focus on activities for early detection of malaria cases, timely control of malaria foci and epidemics, and risk prediction. Furthermore, challenges and recommendations for accelerating NMEP through surveillance are put forward.

1. INTRODUCTION

Currently, malaria is prevalent in 97 countries or regions, with about 3.4 billion people at risk and 470,000–800,000 deaths due to malaria (World Health Organisation (WHO, 2013)). Malaria was also one of major tropical diseases that exerted a great burden on people’s health, as well as the social and economic development in the People’s Republic of China (P.R. China), particularly in the period from 1950 to 1970s, when annual malaria cases numbered around several millions. Therefore, the government of P.R. China has paid great attention to malaria control during the last six decades. Since the 1980s, the annual incidence rate of malaria has been reduced significantly, with the social economic development in P.R. China. Through efforts at all levels in the country, active prevention and treatment were successfully implemented. The number of counties with annual incidence rate over than 1 per 10,000 was only 75 (3.4%) out of 2189 malaria endemic counties in 2009. Indigenous cases were few and limited to focal localities, which was an initiative basis of the national malaria elimination programme (NMEP) in 2010. The goal of the NMEP is to eliminate malaria in the whole country by 2020 (Ministry of Health, 2010).

Annual malaria incidence further declined with the implementation of the NMEP. Although malaria importation from other countries has
increased, with a proportion of 93.3%, only 182 indigenous cases were found among the total 2718 cases in all 31 provinces of P.R. China in 2012 (Xia et al., 2013). Moreover, indigenous cases were focally distributed in limited countries and provinces in the southern and central parts of China, which implies that China has actually stepped into the pre-elimination phase of World Health Organization (WHO) classification, if only malaria incidence is considered (Diouf et al., 2014; Yin et al., 2013). Different from the malaria control stage, with an objective of morbidity and mortality reduction, the elimination programme pursues surveillance and response to all malaria infections and ultimately aims to stop malaria transmission (WHO, 2013). Thus, the main strategies in the pre-elimination require to sensitively identify and clear malaria foci, including residual foci, and to prevent reintroduction of malaria (Guo et al., 2013; Li et al., 2013; Smith et al., 2013). As for the prevention of reintroduction, more attention needs to be paid to particular areas where malaria transmission has been interrupted due to the following reasons: (1) the transmission factors in different types of endemic areas have not fundamentally changed; (2) a rapid increase of the mobile population has resulted in the spread and accumulation of sources of infection (Zhou et al., 2007); and (3) an eco-environmental change has caused climate warming, which can change the composition and density of the vector Anopheles spp. population and affect drug resistance of Plasmodium falciparum (Guan et al., 2005; Huang et al., 2012a,b; Yang et al., 2007).

2. BACKGROUND

The surveillance and response system is well integrated within the public health system in P.R. China, and all effective and prompt malaria response measures depend on timely and accurate information provided by the surveillance system (Duan et al., 2012; Kelly et al., 2013; Zhou et al., 2013). The relevant information is filtered, verified, stored on dedicated web-based platforms, and then disseminated and analysed by end-users (Barboza et al., 2014; Corberan-Vallet and Lawson, 2014). Depending on epidemic data, vector data and other relevant data acquired through surveillance system, the malaria response system is capable of completing the investigation and verification of individual cases (Chokejindachai and Conway, 2009), screening surrounding populations (Sanders et al., 2014) and implementing relevant vector control strategies (Abeyasinghe et al., 2012; van Bortel et al., 2010).
2.1 WHO requirements for surveillance in the malaria elimination stage

At present, the number of malaria cases detected and reported through the global malaria surveillance system only accounts for a small proportion of the total malaria cases. Therefore, WHO urged malaria-endemic countries to strengthen disease surveillance (WHO, 2013), medical and health information and vital registration systems, since the data generated through such systems are critical for assessing and improving the effectiveness of health interventions. In April 2012, to help endemic countries strengthen their malaria surveillance systems, WHO released two operational manuals: Disease surveillance for malaria control: an operational manual (WHO, 2012a) and Disease surveillance for malaria elimination: an operational manual (WHO, 2012b). These manuals respectively introduced general principles for malaria surveillance in different periods, and gave recommended case definition, key indicators, data recording procedures and guidelines for the establishment of surveillance systems. In addition, these manuals also included templates for recording, reporting and investigating malaria cases.

According to WHO’s Disease surveillance for malaria elimination: an operational manual, in the malaria elimination stage, the main objectives of surveillance are to find malaria infections (either symptomatic or asymptomatic infections), and to ensure the radical cure of *P. vivax* cases without relapses. In this regard, the implementation of a higher-standard surveillance during the malaria elimination stage is proposed, including examination of malaria parasites for all suspected cases, quality control of the examination, timely and complete case reports, and a comprehensive survey of cases and foci. All the data from examinations and surveys are saved, so that the data can be used for the final assessment and certification of malaria elimination.

2.2 Malaria surveillance and response in other countries

Since the United Nations Millennium Declaration was signed by 189 countries in 2000, many countries have continuously put forward plans to eliminate malaria, including Sri Lanka (Dias et al., 2013; Gunawardena et al., 2014), Turkey (Aydin and Sahin, 2013), Solomon, Vanuatu (Kelly et al., 2013), Botswana (Simon et al., 2013), and South Africa (Maharaj et al., 2012). There are 39 countries that are either planning to eliminate malaria or have entered the elimination or pre-elimination stage (Richard et al., 2009).

Worldwide, disease surveillance mainly relies on the passive surveillance system based on case reports. The surveillance systems cannot monitor all cases and various countries have different surveillance ranges, surveillance
indicators, constitutions and sensitivity of surveillance system. In the United States, there are two systems to collect and report malaria cases: the National Malaria Surveillance System and the National Notifiable Diseases Surveillance System. In addition, the Armed Forces Health Surveillance Center also provides relevant information of malaria cases in the military, and usually this information would not be reported to the national health department (CDC, 2013). Such a multichannel reporting system can increase the coverage of malaria cases. In Canada, the surveillance system of infectious diseases was established in 1929; however, the current federal surveillance system only reports information including age and gender of the cases, *Plasmodium* species, mortality rate and possible infections. Thus, it has been suggested to further strengthen the malaria surveillance system in Canada to deal with information of the imported malaria cases (MacLean et al., 2004). In Turkey, Sri Lanka and other countries that are moving towards malaria elimination, case-oriented malaria surveillance systems have been established. Cases detection through doctors or laboratory examinations and vector surveillance were conducted at the same time. Even in some countries where malaria has been eliminated or will be eliminated, the recurrence or outbreak of malaria is possible to roll back after elimination (Galappaththy et al., 2013; Kamat 2000; Pascual et al., 2006; Sainz-Elipe et al., 2010). Hence, it is particularly important to establish an intensive malaria surveillance system and find imported cases as early as possible to reduce the risk of malaria transmission or outbreaks to a low level. Unfortunately, the current surveillance system is very weak in some African countries that suffer from a high malaria burden (Antonio-Nkondjio et al., 2012; Karimuribo et al., 2012; Kunene et al., 2011; Overgaard et al., 2012; Owusu-Ofori and Bates, 2012).

### 2.3 Malaria surveillance and response in the control and elimination stages in P.R. China

In P.R. China, the national malaria surveillance was established in the beginning of the national malaria control programme in the 1950s, and further intensified with an official document issued by Ministry of Health in 2005. At that time, the country was in the malaria control stage, with the objective to reduce malaria incidence and mortality. According to a survey in 2003 supported by the Global Fund, the malaria incidence in the whole country amounted to 740,000 of cases, and hundreds of millions of people were at risk of malaria infection in 907 counties/cities/prefectures in 18 provinces/autonomous regions/municipalities (P/A/M) (Zhou et al., 2005). Based on the epidemic situation of malaria at that time and the nationwide routine surveillance
results, a total of 62 surveillance sites were set up in 2005, covering in 18 P/A/M of the country where conducting surveillance in key monitoring areas.

Since 2010, when the country declared it was entering the malaria elimination stage, the epidemiological features have changed significantly. Under the NMEP, not only the target but also the strategies and measures in the elimination stage are significantly different from those in the control stage (Cao et al., 2014; Yin et al., 2013; Xia et al., 2013; Zheng et al., 2013). The surveillance and response to individual cases and foci are the vital strategies and key interventions in the elimination stage. Consequently, the country initiated the national surveillance system for NMEP in 2012, which consists of both routine surveillance and sentinel surveillance. Sentinel surveillance sites were selected based on malaria incidence and entomological considerations, categorized into two types of sites: sites with more local cases and sites with more imported cases (Cao et al., 2014; Xia et al., 2013; Xiong et al., 2010).

3. SURVEILLANCE IN THE NATIONAL MALARIA ELIMINATION PROGRAMME

3.1 Malaria surveillance system

China’s surveillance system for malaria elimination comprises routine surveillance and sentinel surveillance at three administrative levels: (1) the national level, conducting by the National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention (CDC); (2) the provincial level performing by provincial disease control and prevention agencies; and (3) the county level, implementing through the county CDC where the surveillance site is located. The routine surveillance that covers the whole country includes daily case reporting, checkup and case investigation of malaria cases, including specific activities such as case verification, active case detection, blood examination and missing report investigations at regular intervals (China CDC, 2012). Sentinel surveillance is focused on those activities that cannot covered by the routine surveillance system in all counties, such as entomological surveillance (species, density), drug resistance monitoring and insecticide resistance surveillance.

The national malaria elimination surveillance sites (hereinafter referred to as the national surveillance sites) cover 25 P/A/M. A total of 49 national malaria surveillance sites have been set up by county/city/district as a unit and divided into two categories according to their degree of malaria prevalence and characteristics (Figure 4.1). One category is for areas with more local malaria cases, including the following eight P/A/M: Anhui
(Gao et al., 2012; Zhou et al., 2005), Guizhou (Li et al., 2005), Hainan (Xiao et al., 2012), Henan (Liu et al., 2006), Yunnan (Xu and Liu, 2012), Hubei (Li et al., 2013; Tian et al., 2013), Tibet (Huang et al., 2011) and Jiangsu (Cao et al., 2013). Twenty-nine counties/cities/districts with relatively higher local malaria incidence in the most recent 3 years were selected as surveillance sites. The other category is for areas with more imported malaria cases, including Beijing, Shanghai, Zhejiang (Lu et al., 2013), Fujian (Wang, 2013), Shandong (Xing et al., 2013), Liaoning (Geng et al., 2012), Guangxi (Guo et al., 2013), Guangdong, Henan, Hunan, Jiangsu, Anhui, Sichuan, Zhongqing, Hebei, Shanxi, Jiangxi, Shaanxi, Gansu and Xinjiang (Xia et al., 2013). Twenty counties/cities/districts with relatively more imported malaria cases in the most recent 3 years were selected as surveillance sites.

The nationwide routine surveillance mainly includes five activities: case reporting, diagnosis checkup, case investigation, active case detection and blood examination of unexplained fever cases. Sentinel surveillance consists of two scenarios: one scenario is focused on local transmission; the activities
involved include blood examination of unexplained fever cases, serological antibody test, entomological surveillance, insecticide-resistance surveillance and drug-resistance surveillance of \( P. falciparum \). The other scenario is targeted to malaria importation, in which the surveillance activities comprise sentinel hospital surveillance, returned overseas screening and drug-resistance surveillance of imported \( P. falciparum \). Data collection is through an internet-based system, namely the Parasitic Diseases Management Information System Network, and an annual surveillance report is released to the public in the form of white books or online papers (Xia et al., 2013; Zhou et al., 2005).

### 3.2 Malaria surveillance activities

#### 3.2.1 Routine surveillance

**3.2.1.1 Case reporting and case management**

Various medical institutions, CDCs, inspection and quarantine agencies, blood collection agencies at all levels as well as the village doctors fill in the infectious disease report card and make report through the network of the national disease surveillance information report management system within 24 h once they find suspected, clinically diagnosed and confirmed malaria cases. Those without direct reporting network conditions send the infectious disease report card to their local county CDC within 24 h after diagnosis, and the county CDC makes a network direct report within 2 h after receiving the infectious disease report card. When a sudden malaria epidemic occurs, a special report would be made immediately through the national public health emergency management information system, according to the relevant regulations in the malaria epidemic emergency preparedness plan (Figure 4.2).

At least one staff member in the county CDC is responsible for browsing the national disease surveillance information report management systems on a daily basis. Once a suspected, clinically diagnosed, or confirmed malaria case is reported, that staff member would immediately contact the reporting unit to check on the blood smear of the reported case. If the diagnosis of the case is changed, it would be immediately revised in the disease surveillance information report management system. Staff from county CDC would make a case investigation on each malaria case within 3 days after receiving the case reporting. The investigation includes basic information, epidemiological history, treatment history, and the diagnosis and treatment of this onset. After the completion of treatment (normally 8 days), more detailed information is collected by a well-designed questionnaire within 1 week.
At the primary medical agencies, the main diagnostic test is a microscopic examination or rapid diagnostic test (RDT). Case confirmation is conducted using microscopic examination, RDT or polymerase chain reaction in the above institution, and finally qualified assurance and qualified control (QA/QC) at provincial or national CDCs.

Taking 2013 as an example, a total of 4,146 malaria cases were reported from 31 P/A/M in P.R. China. Among them, 1,745 were reported by 49 surveillance sites. All cases were reported within 24 h after diagnosis. A total of 4,085 (98.58%) reported cases were checked through laboratory examination, and 4,024 were laboratory confirmed as malaria with an accordance rate of 97.10%. A total of 4,065 cases (98.05%) were case investigated within 3 days.

3.2.1.2 Blood examination of fever cases
Active case detection is a key strategy in the surveillance system of NMEP as a complement to passive case detection. The specific approaches of active case detection for malaria elimination in P.R. China are as follows. Within 1 week after receiving a case report, the county CDC will organize a case screening around a passively detected case with active or inactive foci. Blood specimens also are collected from cases with a fever history in the past 2 weeks. If two or
more locally acquired malaria cases or asymptomatic carriers are found, the screening expands to all the residents in the focus. Case investigations are also conducted for all screened cases and reported in the system.

Still taking 2013 as an example, 26 provinces provided data for blood examination in unexplained fever cases. A total of 4,109 out of 4,662,690 examinations were tested for malaria, with a positive rate of 0.09%. In sentinel surveillance sites, 220,813 unexplained fever cases were examined; 1767 were confirmed as malaria, with a positive rate of 0.80%. Active case detection was carried out in seven provinces (including Anhui, Yunnan, Jiangsu, Zhejiang, Hebei, Jiangxi, Shanxi) and 20 surveillance sites. Among a total of 12,436 subjects, only one imported malaria case was screened by active case detection in Jiangsu Province (Table 4.1).

### 3.2.2 Sentinel surveillance

#### 3.2.2.1 Entomological surveillance

Entomological surveillance and vector control not only play an important role in interrupting malaria transmission, but they also weaken the vectorial capacity to the critical level for malaria elimination through effective vector control strategies. Effective vector control strategies must be formulated on the basis of understanding the bionomics, habits, and population distribution of the vectors. Different strategies should be adopted in areas with different epidemic situations and particular vectors. In addition, personal protection and related education should be conducted in areas at risk of malaria transmission.

Entomological surveillance on Anopheles includes species, density, and bionomics and habits. In China, light traps are used to collect Anopheles specimens to identify species, and estimate the populations and density of mosquitoes in one natural village or community. Surveillance activities are mainly conducted in June through October, using a serological test twice a month in those consecutive 5 months of the year.

A total of 16 provinces carried out entomological surveillance in 2013. A total of 34,043 anopheline mosquitoes were caught, with the majority of An. sinensis accounting for 83.56% of cases, along with nine An. anthropophagus and 18 An. minimus. For example, entomological surveillance was carried out in June–October in Anhui Province, catching 11,282 anopheline mosquitoes, and the anopheline mosquito density was the highest in the second half of June and first half of July, reaching 12/light-night and 14.2/light-night. In Sichuan Province, a total of 1441 An. sinensis were caught; the peak of An. sinensis population and density was in late May, late July and early August, while lowest
### Table 4.1 Summary of nationwide blood examination of unexplained fever cases in the malaria elimination surveillance sites in 2013

<table>
<thead>
<tr>
<th>Province / Autonomous regions/ Municipality</th>
<th>Number of surveillance sites</th>
<th>Number of blood examinations of unexplained fever cases in whole province</th>
<th>Number of blood examinations of unexplained fever cases in whole province</th>
<th>Number of blood examinations of unexplained fever cases in surveillance sites</th>
<th>Number of blood examinations of unexplained fever cases in surveillance sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhui</td>
<td>8</td>
<td>581,792</td>
<td>177</td>
<td>8,350</td>
<td>0</td>
</tr>
<tr>
<td>Guizhou</td>
<td>6</td>
<td>204,350</td>
<td>12</td>
<td>4,065</td>
<td>0</td>
</tr>
<tr>
<td>Yunnan</td>
<td>6</td>
<td>449,163</td>
<td>578</td>
<td>67,419</td>
<td>371</td>
</tr>
<tr>
<td>Henan</td>
<td>4</td>
<td>1,206,034</td>
<td>197</td>
<td>68,298</td>
<td>65</td>
</tr>
<tr>
<td>Hainan</td>
<td>3</td>
<td>120,000</td>
<td>16</td>
<td>26,705</td>
<td>7</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>2</td>
<td>503,593</td>
<td>341</td>
<td>11,175</td>
<td>45</td>
</tr>
<tr>
<td>Hubei</td>
<td>2</td>
<td>407,522</td>
<td>129</td>
<td>2,105</td>
<td>0</td>
</tr>
<tr>
<td>Tibet</td>
<td>1</td>
<td>11,50</td>
<td>4</td>
<td>1105</td>
<td>1</td>
</tr>
<tr>
<td>Fujian</td>
<td>1</td>
<td>26,619</td>
<td>76</td>
<td>650</td>
<td>22</td>
</tr>
<tr>
<td>Guangdong</td>
<td>1</td>
<td>21,759</td>
<td>148</td>
<td>3,909</td>
<td>18</td>
</tr>
<tr>
<td>Guangxi</td>
<td>1</td>
<td>218,237</td>
<td>1,251</td>
<td>5,708</td>
<td>1,052</td>
</tr>
<tr>
<td>Hunan</td>
<td>1</td>
<td>62,814</td>
<td>196</td>
<td>510</td>
<td>7</td>
</tr>
<tr>
<td>Liaoning</td>
<td>1</td>
<td>105,692</td>
<td>45</td>
<td>1,760</td>
<td>0</td>
</tr>
<tr>
<td>Shandong</td>
<td>1</td>
<td>202,000</td>
<td>131</td>
<td>5,93</td>
<td>0</td>
</tr>
<tr>
<td>Beijing</td>
<td>1</td>
<td>45,268</td>
<td>113</td>
<td>–</td>
<td>1,100</td>
</tr>
<tr>
<td>Shanghai</td>
<td>1</td>
<td>107,768</td>
<td>73</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>Sichuan</td>
<td>1</td>
<td>521,902</td>
<td>228</td>
<td>12,018</td>
<td>5</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>1</td>
<td>158,217</td>
<td>210</td>
<td>–</td>
<td>34</td>
</tr>
<tr>
<td>Hebei</td>
<td>1</td>
<td>43,932</td>
<td>35</td>
<td>344</td>
<td>17</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>1</td>
<td>43,429</td>
<td>45</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Shaanxi</td>
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<td>59,864</td>
<td>47</td>
<td>1,059</td>
<td>0</td>
</tr>
<tr>
<td>Gansu</td>
<td>1</td>
<td>–</td>
<td>16</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>1</td>
<td>19,093</td>
<td>5</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Shanxi</td>
<td>1</td>
<td>10,817</td>
<td>5</td>
<td>238</td>
<td>3</td>
</tr>
<tr>
<td>Chongqing</td>
<td>1</td>
<td>45,268</td>
<td>31</td>
<td>4,752</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>4,662,690</td>
<td>4,109</td>
<td>220,813</td>
<td>1,767</td>
</tr>
</tbody>
</table>
in September and October. The average density of *An. sinensis* was 144/light-night. Among them, indoor density was 35.2/light-night, outdoor 35.2/light-night and cattle shed 83.8/light-night. The highest density was at cattle sheds (Figure 4.3).

When a vector population in a certain area was found at an abnormal pattern by the surveillance system, there must be a clear understanding about the insecticide resistance of vectors in this area before insecticide-based vector control strategies are employed. Surveillance of insecticide resistance of vectors in the malaria elimination stage began in 2012. The surveillance sites adopting mosquito control with insecticides were selected, and the provincial disease control and prevention agencies were responsible for conducting surveillance once every 2 years.

In 2013, two provinces submitted surveillance data of insecticide resistance for anopheline mosquitoes. Some insecticide resistance evidence was found. For example, Jiangsu province collected adult *An. sinensis* in the field of Tiangang Lake, Sihong County in July, and used the WHO-recommended adult mosquito contact tube method to determine the insecticide resistance of its filial 1 (F1) 3- to 5-day-old female mosquitoes. The results showed that the death rate of mosquitoes in 24 h after contacting 0.05%
deltamethrin for 1 h was 5%. The resistance degree was “R”, indicating that \textit{An. sinensis} in this area had developed relatively strong resistance to deltamethrin. In Hainan Province, resistance of \textit{An. sinensis} to four kinds of insecticides was determined in Changjiang, Ledong and Qiongzhong cities/counties. The results showed that resistance occurred in all cities/counties with exception for Qiongzhong county, where drug resistance to deltamethrin was found but it is still sensitive to malathion.

3.2.2.2 Drug resistance surveillance
According to the requirements of the current surveillance program, in areas with relatively more number of the local malaria cases, one site was selected for conducting drug resistance surveillance in Yunnan Province. The provincial disease control and prevention agency was responsible for the surveillance and carried it out in the transmission season every year, using \textit{in vivo} 4-week tests and \textit{in vitro} microtechniques to determine the sensitivity of \textit{P. falciparum} to compound artemisinin derivatives (e.g. dihydroartemisinin and piperaquine). Clear evidence has shown the resistance of \textit{P. falciparum} parasites to artemisinin derivatives. While in areas with more number of the imported malaria cases, this surveillance was done in Jiangsu Province, using the same methods as carried out in Yunnan Province. They found that all 4 cases determined by \textit{in vivo} 4-week tests showed sensitivity. In the other 20 cases, approximately 1, 5, 3 and 2 persons had resistance to each drug of artesunate, chloroquine, mefloquine and piperaquine, respectively, as determined by \textit{in vitro} microtechnique.

3.2.2.3 Surveillance on population at risk
The guidelines specify that in surveillance sites with more number of the imported cases, one county-level hospital with more admission of malaria cases is chosen as a sentinel hospital to carry out the routine surveillance, and special attention is paid to the imported malaria cases from other countries. The clinicians at the sentinel hospital should ask all the febrile cases admitted about their epidemiological history abroad, collect blood samples from the febrile cases who have recent travel history in foreign countries for microscopic examination or RDT detection, and immediately report to the county CDC when the suspected malaria case found. For the imported malaria case detected, the county CDC should undertake case investigation and make timely report. At the same time, the county CDC is responsible for malaria screening of all of the companions (persons who travelled...
with them) of the imported malaria cases, undertaking blood test or RDT for all of the companions with fever symptoms and 10% of the companions without fever symptoms. In addition, there should be follow-up surveys of other acquaintances, and the results of investigation will enter into the questionnaire form of the national malaria surveillance site for febrile cases and asymptomatic returnees from abroad.

In 2013, sentinel surveillance was carried out in Anhui, Henan, Zhejiang and Shaanxi provinces, where there were relatively more number of the imported malaria cases, with a total of 167 individuals. Among them, a total of 23 falciparum malaria cases, three cases were mixed infection and one ovale malaria were found. At the same time, the screening of the returnees from abroad were performed in the surveillance sites of other 13 provinces, as a result, a total of 4358 persons were screened, and 737 cases were found.

4. RESPONSE STRATEGY IN THE NATIONAL MALARIA ELIMINATION PROGRAMME

4.1 1-3-7 strategy

The response strategy defined as a 1-3-7 approach were used in the NMEP (Cao et al., 2014). In the strategy, the term of “1” means case reporting, by which medical and health institutions at all levels should report cases detected including suspected cases within 1 day (24 h) through the disease surveillance information report management system of China CDC. The term of “3” means to investigate the cases and epidemiological surveys, more specifically, the county-level disease control agency should make a laboratory confirmation for all cases reported in its administrative area within 3 days, after conducting epidemiological case survey and identifying the Plasmodium species and sources of infection of the confirmed cases. The term of “7” refers to active surveillance and focus response, more specifically, the county CDC makes a judgement to address the questions if there is risk of transmission in places where the malaria cases reside after the active surveillance and then take appropriate response activities, such as providing preventive chemotherapy to the at-risk population and indoor residual spraying in at-risk houses (Cao et al., 2014).

Early detection and timely reporting of the cases are the most important aspects of the 1-3-7 strategy. Not only the laboratory-confirmed cases but also the clinically-diagnosed cases with laboratory-negative should be reported directly through the information management network within the specified time. The intent of the strategy is to raise the sensitivity of the surveillance system as much as possible and reduce local transmission due to
a missed diagnosis or delayed diagnosis and treatment (Ministry of Health of the People’s Republic of China, 2012).

All malaria cases submitted for the web-based reporting system have to be laboratory confirmed finally, since the identification of parasite species and source of infection are used as the basis for evaluation of transmission risk. Therefore, during the malaria elimination stage, not only the laboratory-confirmed cases by blood smear test and the clinically diagnosed cases need to be reconfirmed by professionals from CDCs at up level after submitted to the web-based reporting system, but also molecular biology techniques must be used for further examination of those clinically diagnosed cases with negative results in the blood smear test, as well as those with difficulty for *Plasmodium* species identification. At the same time, the source of infection of the reconfirmed cases needs epidemiological case investigation, so as to provide a basis for further conducting focus active surveillance and response against resurgence.

In the malaria elimination stage of P.R. China, “focus” is defined as the natural village or community, residential area or construction site where malaria cases occur. Therefore, interventions of NMEP including the timely report, investigation of the clue cases or the first case, focus investigation, and quick response, are the core strategies for malaria elimination surveillance and response in P.R. China (Cao et al., 2013; Yang et al., 2012; Zhou et al., 2013). By timely focus investigation of types of focus and their transmission risk as well as various appropriate disposal measures, interruption of every possible local transmission is guaranteed (Sheng et al., 2003).

Focus investigation includes the activities in three aspects, such as recording basic information of focus, surveying vector anopheline species population and screening infections of malaria by blood smear test. Focus response includes the following three activities:

1. Health education is performed together with malaria case screening of the residents in the focus, especially educating the residents about malaria symptoms and the need to seek medical diagnosis and treatment as early as possible. In active and inactive focus, knowledge to enhance self-protection awareness by avoiding outdoor sleeping as well as promoting the use of mosquito nets, screen doors, screen windows and other mosquito-proofing facilities to reduce mosquito-biting is also disseminated.

2. Expanded treatment is performed in active focus. If missing reported malaria cases or parasite carriers are found, treatment should be expanded to the whole family of the malaria case, parasite-carrier and their neighborhood residents with the same antimalaria treatment scheme, so as to clear away the possible source of infection.
3. Vector control is undertaken in active focus. Indoor residual spraying of pyrethroid insecticides is used to reduce the density of malaria-transmitting vectors and block transmission of malaria. The range of spraying covers the patient’s houses and neighbours.

If two or more missing reported cases or parasite-carriers are found through screening, the range of spraying should be expanded to the entire focus. In focus where the coverage of using long-lasting mosquito nets or insecticide-impregnated mosquito nets has reached more than 85%, insecticide spraying is not necessary.

In the first quarter of 2014, for instance, a total of 642 malaria cases were reported in the whole country. The reporting rate within 24 h after diagnosis of the cases was 100%. These cases include 631 imported cases, 10 local cases, and 1 case without detailed information. Among these cases, the laboratory examination rate was 99.69%, the laboratory confirmation rate was 97.35%, the completion rate of epidemiological case investigation within 3 days and the disposal rate of focus within 7 days were all above 99%, and no secondary case occurred. Based on these statistics, the implementation of the 1–3–7 strategy achieved successful results (Figure 4.4).

**Figure 4.4** Workflow under the 1-3-7 strategy for malaria elimination in China (from Cao, et al., 2014).
4.2 Risk assessment

The surveillance system in the control stage relied on passive surveillance to collect case information in time and other monitoring data. Such data were only a temporary description of the time and spatial characteristics of some surveillance sites, without any prospective and predictive information. There are several potential risk factors affecting transmission patterns of malaria, such as changes in the distribution of vector species population (Basilua Kanza et al., 2013; Bugoro et al., 2011; Linton et al., 2005; Sahu et al., 2014), environmental changes (Confalonieri et al., 2014), global warming (Alonso et al., 2011; Aoun et al., 2010), and population movements (Osorio et al., 2007; Trung et al., 2004). If we can conduct an effective risk assessment in advance, an effective and timely prediction or warning can be achieved, the intensity of malaria transmission could be potentially reduced. A comprehensive understanding of malaria risk factors (Neuberger et al., 2010; Taliisuna et al., 2012; Woyessa et al., 2013) cannot only help predict the malaria trends, but it also is very important for designing and adjustment of the surveillance and response systems in the malaria elimination stage to make them more effective and sensitive. Currently in the malaria elimination stage in China (Yin et al., 2013; Zheng et al., 2013; Zhou et al., 2013), the risks of increasing proportion of the imported cases, development of drug resistance of vectors and malaria parasites, as well as environmental changes, all bring enormous pressures and threats to the achievement of malaria elimination in P.R. China. An appropriate and effective risk assessment strategy is not only important for promoting malaria elimination in P.R. China by 2020, but also for the prevention of reemergence of malaria epidemics in the late stage of malaria elimination, particularly by providing timely warning and response strategies for some vulnerable population or areas at risk (Lin et al., 2009; Yang et al., 2010).

Malaria risk assessment can be analysed from multiple perspectives and levels. For example, international scholars regard tourists visiting family and friends as a risk factor for malaria infection (Angell and Behrens, 2005). Also, a model based on health behaviour theory that was established in the light of the geographic and cultural diversity of people provides a relatively good reference for related clinical control (Angell and Behrens, 2005; Ye et al., 2007). Furthermore, according to quantitative risk assessment based on three indicators, including vectorial capacity, vector susceptibility, and imported source of infection, it is considered that the first two indicators of entomological risk are relatively practical and closely correlated with the risk of malaria transmission (Kazembe et al., 2006; Poncon et al., 2008; Yang et al., 2010).
The risk assessments of malaria re-emergence have been extensively investigated, both in the malaria control stage and elimination stage in China (Xia et al., 2003; Xiao et al., 2010; Xiong et al., 2010; Yang et al., 2010; Zhou et al., 2010). The following are five major progresses.

Firstly, a high correlation between malaria outbreak and the rise of vectorial capacity in the central part of China was demonstrated by a survey of vectorial capacity of An. sinensis, which is the main risk factor affecting malaria transmission (Pan et al., 2012). The results demonstrated an increase of transmission risk in the central part of China. The reason may be the sharp drop in the number of livestock and changes in animals’ behaviour, which leads to a lack of traditional biological barriers and increased risk of people and malaria vector contact.

Secondly, based on an understanding of global climate changes and biological drives, a statistic model has been developed to predict the spatiotemporal patterns of transmission of P. vivax and P. falciparum malaria in P.R. China, taking temperature and relative humidity as the most important environmental factors. The results of this study indicate that areas with malaria transmission year round are still limited to the southern and southeastern provinces of P.R. China, such as Yunnan, Guangdong, Guangxi and Hainan, and the endemic areas of P. falciparum malaria are still restricted within Yunnan and Hainan provinces (Yang et al., 2012). Control strategies for different potential endemic areas have been suggested, such as adopting appropriate surveillance and response systems in the climate-sensitive areas in the central part of the country, while strengthening surveillance and warning systems in the northeast part (Figure 4.5).

Thirdly, studies on the influence of multiple factors, including geographic, meteorological and vector, and the correlation among these complex factors and the re-emergence of malaria epidemics in the plains regions of P.R. China since 2001, indicated that the distribution of water bodies around the malaria cases, changing climate factors, the increase of vectorial capacity of An. sinensis and its basic reproductive rate were important risk factors causing malaria epidemics (Zhou et al., 2010).

Fourthly, taking malaria knowledge and personal protection level as an indicator to investigate the influence of factors related to the border areas of P.R. China on malaria control (Moore et al., 2008), a study found that among ethnic minorities, lack of malaria knowledge and weak personal protection consciousness are still the potential risk factors for malaria transmission in this area.

Fifthly, the imported malaria risk assessment index system was established and different risk assessment indicators were defined according to the transmission mechanism and epidemiological characteristics of imported malaria. Four risk levels were set up according to risk assessment of the
indicator system (Zeng and Yu, 2006). According to the four risk levels, recommendations were developed to implement different health and quarantine control measures in each level.

In summary, malaria risk assessment has been implemented in P.R. China for the analysis of the influence of risk factors on a single characteristic of malaria transmission, and also to integrate multiple risk factors in a mathematical model to predict overall malaria transmission trends. Different research perspectives have been used to predict malaria transmission trends by using different risk assessment methods, so as to further strengthen and improve malaria surveillance and response strategies.

4.3 Case study: imported malaria cases in Shanglin

During June 2013, several hundred imported malaria cases were reported through the surveillance system in Shanglin county, Guangxi (Xia et al., 2013). The main reason for this rapid emergence of the imported malaria cases was due to the return of thousands of Chinese gold miners from Ghana. It was declared as a public health emergency by local government, and a rapid response was carried out to effectively prevent local transmission from the imported cases, and to provide prompt treatment to patients according
to an emergency work plan formulated by an expert group, which consisted of three steps described below (Figure 4.6).

First, a working mechanism of “one day, one report” was implemented in Shanglin county, based on the guiding principle of the national malaria surveillance and response system. As a result, detailed information on returnees’ status, case diagnosis and treatment were reported from each township or town to the special coordinating office of the county government every day. The confirmed malaria cases were reported by medical institutions at various levels within 24 h. Second, the epidemiological case investigation was performed by technical personnel from local CDCs within 3 days after receiving the case report. A total of 1052 imported cases were reported in Shanglin during 2013, of which 6.59% (69 cases) were vivax malaria, 91.35% (961 cases) were falciparum malaria, 0.29% (3 cases) were quartan malaria, 1.05% (11 cases) were ovale malaria, and 0.76% (8 cases) were mixed infections. The coverage rate of case investigation was 100% within 3 days. Third, local CDC personnel completed the focus investigation and foci treatments within 7 days in collaboration with relevant departments of the local government, such as health, public security and education departments, as well as village committee in Shanglin. Insecticide spraying for mosquito control was conducted covering 26,954 m² in all foci identified areas and covered a total of 3939 persons. Vector surveys were carried out 32 times in six sites in three townships. In addition, a total of 751 *An. sinensis* mosquitos were caught. No other anopheline species were found, and no any sporozoite-positive mosquito was found among 31 dissected *An. sinensis*. 

![Figure 4.6 Reported malaria in Shanglin and Guangxi in 2013.](Image)
Thanks to the quick response, including case reporting, epidemiological investigation, vector surveillance and timely focus disposal, the occurrence of secondary malaria cases was strictly prevented. The 1-3-7 surveillance and response strategy was implemented successfully through multisectoral collaboration, resulting in zero local transmissions, no death cases and no secondary malaria case (Cao et al., 2014; Xia et al., 2013).

5. CHALLENGES

5.1 The sensitivity of surveillance systems needs to be improved

Health and medical institutions are numerous at different levels of China, including village clinics, township health centres, county hospitals, prefectural or city hospitals, CDCs of the provinces, cities and counties, individual clinics, and some private hospitals. These agencies are conducting malaria parasite examinations for all the febrile cases who seek treatment. There is broad coverage, and surveillance is performed throughout the year. In this way, the continuity of surveillance is maintained. However, the effectiveness of surveillance is affected by the number of cases seeking treatment and the malaria diagnosis abilities of the different medical institutions (Figure 4.7).

For a number of reasons, such as the decreasing local infections year by year and relatively high mobility of grassroots laboratory technicians, in some areas the registered data and the registration forms for blood examination are incomplete (Sun et al., 2012). Therefore, the task of blood examination for febrile cases has met greater pressure (Guo et al., 2013). In hypoendemic areas of malaria, a shortage of testing equipment in medical institutions seriously affects the quality and efficiency of microscopic examinations of blood smears. In addition, although malaria RDTs can be used for quick, easy and stable diagnosis of malaria parasite infection in primary health care units of remote areas, there is still reliance on further applications of molecular detection methods, particularly for the examination of asymptomatic infected persons with low density (Adhin et al., 2013; Brown et al., 2012; Ojurongbe et al., 2010; Zakeri et al., 2010).

5.2 More techniques for surveillance on the imported cases need to be developed

At present, surveillance of imported cases mainly relies on the passive surveillance system in existing medical and health systems. By the time the imported case is discovered, the infected individual may be far away, for
instance, from the ports of entry to his home. During this time, the threat may include: (1) deterioration in health status, which in the most serious cases may lead to death; (2) during the trip and after returning home, the infected individual may be a mobile source of infection, and in the presence of a malaria-transmitting vector, pose a risk of secondary transmission. Therefore, the improved techniques for surveillance on the imported cases need to be developed (Smith et al., 2013; Tatem et al., 2014).

5.3 Response mechanism needs to be improved

In the malaria control stage in P.R. China, the Global Fund provided tremendous support for malaria control efforts, and malaria incidence decreased to the historically lowest level. However, when the Global Fund stopped funding programmes in the country, it had just entered the malaria elimination stage. A surveillance and response system is a large undertaking integrating manpower, equipment, organizational management, statistical analysis, and many
other aspects. A well-operated and effective surveillance system certainly needs strong economic support (Doroshenko et al., 2005; Reis et al., 2007). However, the currently available surveillance funding is not sufficient for the malaria elimination stage. Furthermore, funding will be needed for necessary adjustments for new technological approaches as they become available.

6. CONCLUSIONS AND RECOMMENDATIONS

At present, China has established a nationwide malaria surveillance system for NMEP. It relies on a real-time reporting network system and is capable of submitting timely reports of various surveillance indicators. Based on the analysis in this chapter, it appears that the national system can make quick, purposeful and planned responses for different malaria epidemics, such as control future malaria outbreaks.

In the malaria elimination stage in P.R. China, the nationwide surveillance system based on the 1-3-7 strategy is designed to ensure the timely detection, monitoring and treatment of every malaria case, as well as determine its source of infection and transmission route, and prevent potential spread. The establishment of a surveillance site system offsets the deficiency of routine surveillance, recognizes the results of special surveillance in key areas, and provides a strong basis for tailoring malaria elimination strategies and epidemic responses into local settings. In addition, the application of risk assessment for predicting malaria transmission patterns also further strengthens and improves malaria surveillance and response strategies which is an essential component of NMEP.

Malaria surveillance and response is highly public, social and technical, requiring close coordination and collaboration within the whole society (Troppy et al., 2014; Velasco et al., 2014). Especially for NMEP, we must first establish a strong malaria surveillance management system and formulate practical and feasible rules and regulations, then establish a surveillance system fit for the current capacities and local settings (Tambo et al., 2014). The surveillance capacity at different levels should be strengthened in the meantime. In addition, it is necessary to further enhance the application of surveillance and warning approaches in the fields (Gorman, 2013; Zhou et al., 2013).

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