Distribution of malaria patients seeking care in different types of health facilities during the implementation of National Malaria Elimination Program

Gang Li

Huazhong University of Science and Technology

Donglan Zhang

University System of Georgia

Zhuo Chen

University System of Georgia

Da Feng

Huazhong University of Science and Technology

Xiaoyu Chen

Huazhong University of Science and Technology

Shangfeng Tang

Huazhong University of Science and Technology

Heejung Son

University System of Georgia

Zhenhua Wang

University System of Georgia

Yuanhang Xi

University System of Georgia

Zhanchun Feng (✉ zcfeng@hust.edu.cn)

School of Medicine and Health Management, Tongji Medical College, Huazhong University of Science and Technology
<https://orcid.org/0000-0002-6513-2907>

Research

Keywords: Geographic variation; Care-seeking behavior; Geospatial distribution; Medical treatment preference

Posted Date: March 18th, 2020

DOI: <https://doi.org/10.21203/rs.2.18503/v3>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Version of Record: A version of this preprint was published at Malaria Journal on March 30th, 2020. See the published version at <https://doi.org/10.1186/s12936-020-03205-9>.

Abstract

Background: China launched the National Malaria Elimination Program (NMEP) in 2010 that set the goal that all health facilities had the ability to diagnose malaria along with the hospitals at all levels had the ability to treat malaria by 2015. To provide a reference for the control of imported malaria, we conducted a study on the distribution of malaria patients seeking care in different types of health facilities.

Methods: There were two data source. One was obtained through the Infectious Diseases Information Reporting Management System (IDIRMS), which only contained the name of health facilities and the number of cases. The other was obtained through multistage stratified cluster sampling. Descriptive statistical analysis was used to investigate the distribution of malaria patients attending different types of health facilities (hospitals, township hospitals and CDCs), hospital tiers (county-level, prefecture-level or provincial-level) and hospital levels (primary, secondary or tertiary), and the Chi-square test was used to compare the proportions of patients seeking care outside their current residence region between different types of hospitals. Point maps were drawn to visualize the spatial distribution of hospitals reporting malaria cases, and flow maps were created to show spatial flow of malaria patients by using the ArcGIS software.

Results: The proportions of malaria patients who sought care in hospitals, township hospitals, and Centers for Disease Control and Prevention (CDCs) were 81.7%, 14.7% and 3.6%, respectively. For those who sought care in hospitals, the percentages who sought care in provincial-level, prefecture-level and county-level hospitals were 17.4%, 60.5% and 22.1%, correspondingly; the proportions of malaria patients who sought care in tertiary hospitals, secondary hospitals, and primary hospitals were 59.8%, 39.9% and 0.3%, respectively. Moreover, the proportions of patients seeking care in hospitals within county and prefectural administrative area were 18.2%, 63.4%, respectively.

Conclusion: During the implementation of NMEP, malaria patients tended to seek care in tertiary hospitals and prefecture-level hospitals, and more than half of patients could be treated in hospitals in prefecture-level areas. In the current phase, it is necessary to establish referral system from county-level hospitals to higher-level hospitals for malaria treatment.

Background

Malaria is one of the most prevalent mosquito-borne infectious diseases in the world, which can easily cause a damaging impact on society and the economy[1-3]. In recent years, malaria cases have been increasing globally. According to the latest available data, an estimated of 228 million malaria cases occurred worldwide, and 405,000 deaths associated with malaria were reported in 2018[4, 5]. Malaria had been prevalent since the foundation of the People's Republic of China[6]. After the Chinese government put a great deal of efforts into the control of malaria epidemics, the morbidity and mortality rates of malaria had reached their lowest level historically in the late 20th Century[7]. However, after 2000, a malaria resurgence occurred in China, and peaked in 2006 with approximately 64,178 malaria cases reported[8-10]. China immediately launched the National Malaria Control Program (NMCP) (2006-2015) with the partnership of the Global Fund project[11, 12]. With the effective implementation of measures such as multi-sectorial cooperation and communication strategy, the incidence of autochthonous malaria cases had declined sharply during the period 2006-2010 in China [13-15].

After 2010, the epidemiology of malaria was different from that in the past. Almost all cases were imported cases due to the increasing number of immigrant workers and foreign travelers[16]. At the same time, the area where malaria transmission was occurring during this period in China had expanded from 24 traditional malaria-endemic provinces to 31 provinces across the country. Most patients suffering from malaria were low-literacy labors from rural areas, and their awareness of being infected with malaria was low. Despite they were suffering from malaria, the initial symptoms of these patients were fever, chills, and sweating[17]. And they always sought care at a grassroots medical institution nearby with cold. Some previous studies also reported deaths from malaria patients who developed severe illnesses due to misdiagnosis by grassroots medical institutions[18, 19]. In order to enable malaria patients to receive timely treatment within the county area and reduce delays, Chinese government also had launched the National Malaria Elimination Program (NMEP) (2010–2020)

in 2010[3, 8, 20]. Through this action plan, the government had strengthened the training of malaria diagnosis and treatment for clinicians in health facilities at all levels (clinics, township hospitals, hospitals and CDCs) to achieve the goal that all health facilities had the ability to diagnose malaria along with the hospitals at all levels had the ability to treat malaria by 2015[21, 22]. In China, the CDCs provides malaria diagnostic services and free antimalarial medications; clinics, township hospitals and hospitals at all levels perform both diagnostic and treatment services[23]. If the township hospital failed to treat malaria patients after making an exact diagnosis, patients would be referred to county-level or higher-level hospitals[24].

As a category B notifiable infectious disease in China, health facilities at all levels have the responsibility to report malaria cases within 24 hours after diagnosis according to the law on the Prevention and Control of Infectious Diseases[25]. In a way, if patients were diagnosed as malaria, their visits to health facilities would be recorded. And some studies have also described the distribution of malaria patients seeking care in different types of health facilities based the reporting data[26]. However, to our knowledge, there are few studies focus on the proportions of malaria patients seeking care in hospitals with county-level or prefecture-level areas. To address this knowledge gap, this study intends to describe the distribution of malaria patients in different types of health facilities, and the proportions of patients seeking care in hospitals within county and prefectural administrative area in the context of the eradication phase of malaria.

Methods

Brief profile of study area

Two provinces with the highest incidence of malaria were selected in each region of Eastern, Central and Western China[11, 27], which were Zhejiang and Jiangsu provinces in Eastern China; Henan and Anhui provinces in Central China; Yunnan and Sichuan provinces in Western China (Fig. 1). The population of Zhejiang stands at 57 million, and Jiangsu is the fifth most populous and the most densely populated nationally during the 2019 census. Both of them have a humid subtropical climate. Anhui and Henan are landlocked province in Central China, with the population of 63 million and 96 million in 2019, respectively. Most of their cities have a continental monsoon humid climate. Sichuan adjoins the Tibetan Plateau in the west, with the third largest population in China. Yunnan, a mountain and plateau region on the southwestern border of China, with a subtropical climate. Both Jiangsu and Zhejiang ranked top fifth in Gross Domestic Product (GDP), followed by Henan, Sichuan, and Anhui, while Yunnan's economy ranked behind in 2019. Compared with the provinces of Western China, the provinces of Eastern and Central China have well-developed transportation[28]. During 2014-2016, the average annual malaria incidence rates in Zhejiang, Jiangsu, Anhui, Henan, Sichuan, and Yunnan were 3.1, 3.0, 1.9, 1.3, 2.5, and 7.5 per million population, respectively.

Data source

There were two data source. One was obtained through the Infectious Diseases Information Reporting Management System (IDIRMS) with the help of the National Health Commission of the People's Republic of China. And the number of malaria cases reported by each health facility between January 2014 and December 2016 in sample provinces was collected, which was used to analyze the distribution of malaria patients in different types of health facilities. Due to the data obtained from IDIRMS lacked patients residential address information, it could not be used directly for the analysis of the proportions of patients seeking care in hospitals within county and prefectural administrative areas. So we used the multistage stratified cluster sampling method to select two provincial-level hospitals, five prefecture-level hospitals, ten county-level hospitals with most malaria cases in each sample province. And all patients' medical records in each hospital selected were collected (Fig. 2). Variables collected from the medical record included patient demographics, patient residential address, hospital course. According to the number of cases reported in 102 hospitals selected, a total of 1,868 cases from 102 hospitals should be investigated. In fact, we collected 1,633 cases from 63 hospitals. The actual cases investigated accounted for 87.4% of the cases reported in 102 selected hospitals. The actual cases investigated accounted for 54.2% of the total 3,011

cases reported in all hospital. Except Anhui Province had the most samples by default, samples from other provinces had a good representative.

Variables and definition

The basic characteristics of hospitals (including address, hospital tier) were obtained from the National Medical Institution Inquiry System[29, 30]. The patient's address was derived from the medical records. Each patient had two residences in the medical record, one was permanent home residence and the other was current residence. The current residence was used in our study, which usually referred to the place where the patients who had been living and working in the past three months, including the patients who were long-term migrants living and working in one location. The address used for analysis only needs to be accurate to the county level, so for patients who lacked detailed address information, we used the county government address of the county where he currently lived to replace his current residence. Then we geocoded the address using Baidu Map Application Programming Interface (API).

Within county patients meant that patients sought care within the same county as their current residence. Within city patients meant that patients sought care within the same prefecture-level area as their current residence. A province could be divided into several prefecture-level areas, and each prefecture-level areas could be divided into one city and several counties in China. A more detailed terms description of within county and within city patients was shown in Figure 3. The data we collected was based on cases reported by health facilities in sample province. There may be some patients in the sample provinces seeking care in other provinces. In this study we assumed that the number of patients who flowed in was equal to the number of patients who flowed out. Patients from other provinces seeking care in the sample province were counted as patients in the sample province. And we defined as (a) Proportion of within county patients in A province = Number of within county patients / Total cases reported in A province. And the principle of calculating the proportion of within city patients, the proportion of within province patients was the same as mentioned above.

China's hospital system was administrated by governments at the provincial-level, prefecture-level and county-level, so hospitals can be classified into provincial-level hospitals, prefecture-level hospitals and county-level hospitals. Hospitals of higher administrative level tend to have better medical resources. In a county-level region, clinics, township hospitals and county-level hospitals belong to grassroots medical institutions which provide basic medical services. Hospital levels are rated by hospital size and treatment level. Generally, the treatment level of the tertiary hospital is higher than that of the secondary hospital. Almost county-level hospitals belong to secondary hospitals, and most provincial-level hospitals and prefecture-level hospitals belong to tertiary hospitals in China. Usually provincial-level hospitals are located in the provincial capital city and prefecture-level hospitals are located in the city.

Data analysis and mapping

Paper medical records were double entered into the Microsoft Excel 2016 (Microsoft Corporation, USA) and then were merged to electronic record data, and a descriptive analysis was conducted. Point maps were created to visualize the spatial distribution of hospitals reporting malaria cases using the ArcGIS software version 10.7 (ESRI, USA)[31]. Patient data was aggregated to county-level to describe the flow from different counties of residence to specific facilities. And flow maps were created to illustrate the patient spatial flow using the "XY To Line" analyst tool in ArcGIS.

Ethical approval

The study was approved by of the Ethics Committee of the Tongji Medical College of Huazhong University of Science and Technology (IORG0003571). Permission was granted by the National Health Commission of People's Republic China and the manager of each hospital. Patient information was anonymised and deidentified before analysis.

Results

Distribution of malaria patients in different health facilities

A total of 3,686 malaria patients sought care in 616 health facilities (township hospitals, hospitals and CDCs) in six sample province during the period from 2014 to 2016. Overall, provinces in Western China had the largest number of malaria cases, followed by the Eastern and Central China.

The proportions of patients seeking care in hospitals, township hospitals and CDCs were 81.7% ($n=3,011$), 14.7% ($n=542$) and 3.6% ($n=133$), respectively (Table 1). The proportions of patients seeking care in hospitals in most provinces had exceeded 90%, except for Zhejiang and Yunnan province. While the proportion of patients seeking care in township hospitals in Yunnan was over 40%, which was much higher than that in other provinces.

Distribution of malaria patients in different type hospitals

The proportions of patients seeking care in provincial-level, prefecture-level and county-level hospitals were 17.4% ($n=524$), 60.5% ($n=1,822$) and 22.1% ($n=665$) (Table 2). The proportions of patients seeking care in tertiary hospitals, secondary hospitals and primary hospitals were 59.8% ($n=1,801$), 39.9% ($n=1,202$) and 0.3% ($n=8$). The proportions of patients seeking care in tertiary hospitals in Zhejiang, Anhui, and Henan were relatively high, which were 73.1%, 69.2%, and 84.6%, respectively. The proportions of patients seeking care in provincial hospitals in Henan and Anhui were much higher than in other provinces, which were 45.1% and 58.2%, respectively.

Geographical distribution of hospitals for treating malaria cases

Figure 1 showed the spatial distribution of hospitals reporting malaria cases, which included 3,011 cases in 467 hospitals. The bigger dots represent large number of cases and the smaller dots represent small number of cases treated in hospitals. We could see that the hospitals located in each provincial capital city treated most malaria cases. Hospitals located in few certain cities in central and western China treated most cases. In a prefecture-level area, usually hospitals located in the city treated more cases than that in the county.

Spatial flow analysis of malaria patients who sought medical care in hospitals

Spatial flow refers to the path from a patient's current residence to the hospital where he visited. According to our actual sampling results, 10 provincial hospitals, 25 prefecture-level hospitals and 28 county-level hospitals were investigated, and a total of 1,633 patients were surveyed. The proportions of patients seeking care in hospitals within provincial-level, prefecture-level and county-level administrative area were 96.1% ($n=1,569$), 63.4% ($n=1,036$) and 18.2% ($n=297$), respectively (Table 3). The proportions of patients seeking care within county area varied greatly among different provinces. Among these provinces, Jiangsu had the highest proportions of patients seeking care within county-level area, at 47.7%. The proportions of patients seeking care within county-level area in most provinces was less 10%. The proportions of patients seeking care within prefecture-level area also varied greatly among different provinces. Among these provinces, Jiangsu had the highest proportions of patients seeking care within prefecture-level area, at 90.9%. The proportions of patients seeking care within prefecture-level area in most provinces was around 60%. We also could see that the hospitals located in the provincial capital city in most provinces had treated a lot of patients from other cities (Fig. 4). In each prefecture-level areas, hospitals located in the city had treated many patients from other counties.

The proportions of patients seeking care within prefecture-level area in secondary and tertiary hospitals were 41.7% ($n=156$) and 35.0% ($n=441$), respectively, which varied substantially from province to province. There was a significant difference in the proportions of patients seeking care within prefecture-level area between the second and tertiary hospitals in Zhejiang, Henan, Sichuan, and Yunnan provinces.

Discussion

This study presents the distribution of malaria patients seeking care in different types of health facilities and most patients seeking care in provincial-level and prefecture-level hospitals were from areas where they lived far away from hospitals they visiting. In our study, we found that most malaria patients sought care in hospitals, followed by township hospitals and CDCs. This may be due to the fact that most patients were imported *falciparum* during post-stage of malaria elimination[32]. Patients with *falciparum* were often in poor health and needed timely medical first aid so hospitals were playing an increasingly important role in the reporting, diagnosis and treatment for them[33]. Compared with other provinces, the proportion of patients seeking care in township hospitals was slightly lower than that in hospitals in Yunnan, at 43.3%, which was much higher than that in other provinces. Yunnan province has international borders with Myanmar, Vietnam and Laos where malaria had been endemic. Most cases in Yunnan had been imported from these countries. And the number of malaria cases in Yunnan once ranked first historically[34, 35]. Because malaria was a common disease in Yunnan, clinicians at local township hospitals had experience in treating malaria.

For patients seeking care in hospitals, we could see that proportions of patients seeking care in tertiary hospitals were much higher than any other two types of hospitals in most provinces except Yunnan province. We were also wondering whether it was because these patients had easier access to tertiary hospitals that led to a higher proportion of that. We found that the proportion of within county patients in tertiary hospitals in Yunnan was only 13.6%, which meant that most patients in tertiary hospitals were came from other counties where far away from the tertiary hospitals. In China, each county in China generally has one or more county-level hospitals, and these hospitals usually belong to secondary hospitals. Why didn't they go to the secondary hospital? There were maybe two reasons. One reason was that maybe clinicians in secondary hospitals failed to make an exact diagnosis as malaria, and then they referred patients to a higher-level hospital. Another reason was that patients may think that tertiary hospitals could provide better treatment services, and they would like to seek care in tertiary hospitals directly[36, 37]. We could not deny the fact that there would be many patients who would seek care in tertiary hospitals directly. However, the proportions of patients seeking care in hospitals within county-level areas were so low. So we speculated that maybe clinicians in secondary hospitals could not make a malaria diagnosis and treatment[38].

However, the proportions of patients seeking care within prefecture-level areas were relatively high in most provinces. It seemed that most malaria cases could be treated in prefecture-level areas. Compared with patients who sought care outside their prefecture-level areas, patients who sought care within prefecture-level areas would save time and prevent the delay and deterioration of the disease[39]. In the post-malaria eradication phase, may be it is necessary to designate a hospital for malaria treatment in each prefecture-level area[40].

The characteristics of distribution of patients seeking care in different types of hospitals between provinces varied greatly. As for Jiangsu province, both the proportions of patients seeking care with county-level areas and the proportions of patients seeking care with prefecture-level areas were much higher than that in other provinces. This meant that most malaria patients could be treated in hospitals within the prefecture-level and county-level areas, which was the goal that NMEP set. The measures taken by Jiangsu province to control the malaria epidemic were unique. The number of imported malaria cases in Jiangsu had been ranked third nationwide, and the number of *falciparum* malaria cases ranked first in the nation[41, 42]. The Jiangsu government put great importance to the elimination of malaria, and Jiangsu took the lead in putting forward the “1-3-7” approach: case reporting within one day, case investigation within three days, and case investigation and disposal of the epidemic within seven days[43]. Meanwhile various forms of technical training were carried out annually, and almost all staffs in various health facilities mastered the malaria Rapid Diagnostic Tests (RDTs)[44-46]. As a result, patients could be diagnosed and treated within county-level areas and prefecture-level areas.

Limitations of the study

This study has at least three limitations. First, when selecting a sample hospital, we considered the number of cases reported by the sample hospital, the location of the sample hospital. Hospitals with small number of reported malaria cases was not be prioritized for inclusion. Second, the actual sample cases was lower than expected due to the reluctance of sampled hospital staff or the loss of cases due to the renewal of the electronic case system. For example, we only collected 41 cases

in Anhui Province, this would lead to unstable analysis results in Anhui. Third, when we analyzed the patients flow, we paid more attention to the direct path of patients from their current residence to the hospital. May be some patients sought care in one more hospitals firstly, and he finally was diagnosed in the hospitals we studied.

Conclusions

This study described the distribution of malaria patients in different types of health facilities, and the proportions of patients seeking care in hospitals within county and prefectural administrative areas during the implementation of National Malaria Elimination Program. During the implementation of the NMEP, malaria patients tended to seek care in tertiary hospitals and prefecture-level hospitals, and most patients could be treated in hospitals in prefecture-level areas. A lower proportion of patients seeking care within county level areas reminded that the diagnosis and treatment capacity of county-level hospitals may be insufficient, which may lead to delays in malaria treatment, resulting in life-threatening and huge economic burden. In the elimination stage of malaria, the scope and extent of the malaria epidemic has fallen to its lowest level in history. Local governments should formulate corresponding prevention and control strategies according to their own regional realities. It is necessary to continue to strengthen the monitoring of fever symptoms in people entering the epidemic areas[47], and consolidate the ability of clinicians in grassroots medical institutions to carry out RDTs and microscopic examination, and establish referral system from grassroots medical institutions to hospitals designated for malaria treatment.

Declarations

Acknowledgements

We would like to acknowledge Disease Prevention and Control Bureau, National Health Commission of the People's Republic of China for their strong support of this study. The data collection also was conducted with the help of Center for Diseases Control and Prevention in Zhejiang, Jiangsu, Anhui, Henan, Yunnan and Sichuan. The authors would like to thank all the respondents for data collection and the staff in CDCs and health administrative department for their assistance.

Authors' contributions

GL, ZCF and DLZ conceived and planed the study, SFT, GL and CYC collected the data, GL, ZC and XYC conducted the data analysis, GL and DLZ wrote the paper. ZC, SFT, DF, HS, ZHW and YHX commented and revised drafts of the manuscript. All authors read and approved the final manuscript.

Funding

This study was supported by the National Health Commission of PRC Project "Malaria Elimination Assessment and Malaria Policy Analysis" and National Natural Science Foundation of China (grant no. 71673098).

Availability of data and materials

The datasets used in the current study are available from the corresponding author and will also be presented as an attachment in the article.

Ethics approval and consent to participate

Ethical approval was obtained from the Ethics Committee of Tongji Medical College,

Huazhong University of Science & Technology (IORG No: IORG0003571). Permission was taken from National Health Commission of People's Republic China and from the manager of each hospital.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

¹School of Medicine and Health Management, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, 430030, China. ²Department of Health Policy and Management, College of Public Health, University of Georgia, Athens, GA 30602, USA. ³School of Economics, University of Nottingham Ningbo China, Ningbo, Zhejiang, 531200, China. ⁴School of Pharmacy, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, 430030, China. ⁵Department of Mathematics, University of Georgia, Athens, GA 30602, USA.

Abbreviations

WHO, World Health Organization; NMEP, National Malaria Elimination Program; Rapid Diagnostic Tests (RDTs); CDCs, Centers for Disease Control and Prevention; IDIRMS, Infectious Diseases Information Reporting Management System; GDP, Gross Domestic Product.

References

1. Ghani AC. Can improving access to care help to eliminate malaria? *Lancet*. 2018;391:1870-1871.
2. Plewes K, Leopold SJ, Kingston HWF, Dondorp AM. Malaria: What's New in the Management of Malaria? *Infect Dis Clin North Am*. 2019;33:39-60.
3. Chen I, Cooney R, Feachem RGA, Lal A, Mpanju-Shumbusho W. The Lancet Commission on malaria eradication. *Lancet*. 2018;391:1556-1558.
4. World Health Organization. World malaria report 2018. 2019. <https://www.who.int/news-room/fact-sheets/detail/malaria>. Accessed 4 Jan 2020.
5. Lover AA, Coker RJ. The challenges of malaria elimination. *The Lancet*. 2013; 382:1699-1700.
6. Zhou ZJ. The malaria situation in the People's Republic of China. *Bull World Health Organ*. 1981;59:931-936.
7. Feng J, Zhang L, Huang F, Yin JH, Tu H, Xia ZG, Zhou SS, Xiao N, Zhou XN. Ready for malaria elimination: zero indigenous case reported in the People's Republic of China. *Malar J*. 2018;17:315.
8. Wang RB, Zhang QF, Zheng B, Xia ZG, Zhou SS, Tang LH, Gao Q, Wang LY, Wang RR. Transition from control to elimination: impact of the 10-year global fund project on malaria control and elimination in China. *Adv Parasitol*. 2014;86:289-318.
9. Huang Q, Hu L, Liao QB, Xia J, Wang QR, Peng HJ. Spatiotemporal Analysis of the Malaria Epidemic in Mainland China, 2004-2014. *Am J Trop Med Hyg*. 2017;97:504-513.
10. Newby G, Larson E, Shretta R, Bennett A, Phillips AA. Chinese action towards global malaria eradication Reply. *Lancet*. 2016;388:959-960.
11. Zheng Q, Vanderslott S, Jiang B, Xu LL, Liu CS, Huo LL, Duan LP, Wu NB, Li SZ, Xia ZG, et al. Research gaps for three main tropical diseases in the People's Republic of China. *Infect Dis Poverty*. 2013;2:15.
12. Moonen B, Cohen JM, Snow RW, Slutsker L, Drakeley C, Smith DL, Abeyasinghe RR, Rodriguez MH, Maharaj R, Tanner M, Targett G. Operational strategies to achieve and maintain malaria elimination. *The Lancet*. 2010;376:1592-1603.
13. Hu T, Liu YB, Zhang SS, Xia ZG, Zhou SS, Yan J, Cao J, Feng ZC. Shrinking the malaria map in China: measuring the progress of the National Malaria Elimination Programme. *Infect Dis Poverty*. 2016;5:52.

14. Zhou SS, Wang Y, Xia ZG. Malaria situation in the People's Republic Of China in 2009. *Zhongguo Ji Sheng Chong Xue Yu Ji Sheng Chong Bing Za Zhi*. 2011;29:1-3 **(in Chinese)**.
15. Zhou SS, Wang Y, Li Y. Malaria situation in the People's Republic of China in 2010. *Zhongguo Ji Sheng Chong Xue Yu Ji Sheng Chong Bing Za Zhi*. 2011;29:401-403 **(in Chinese)**.
16. Lai S, Sun J, Ruktanonchai NW, Zhou S, Yu J, Routledge I, Wang L, Zheng Y, Tatem AJ, Li Z. Changing epidemiology and challenges of malaria in China towards elimination. *Malar J*. 2019;18:107.
17. Demissie Y, Ketema T. Complicated malaria symptoms associated with *Plasmodium vivax* among patients visiting health facilities in Mendi town, Northwest Ethiopia. *Bmc Infectious Diseases*. 2016;16:436.
18. Wangdi K, Gatton ML, Kelly GC, Banwell C, Dev V, Clements ACA. Malaria elimination in India and regional implications. *The Lancet Infectious Diseases*. 2016;16:e214-e224.
19. Romay-Barja M, Cano J, Ncogo P, Nseng G, Santana-Morales MA, Valladares B, Riloha M, Benito A. Determinants of delay in malaria care-seeking behaviour for children 15 years and under in Bata district, Equatorial Guinea. *Malar J*. 2016;15:187.
20. National Health Commission of the People's Republic of China: Action Plan of China Malaria Elimination (2010–2020). 2010. <http://www.nhc.gov.cn/jkj/s5873/201005/f84f1c4b0f32420990d23b65a88e2d87.shtml>. Accessed 1 October 2019.
21. Lu GY, Liu YB, Beiersmann C, Feng Y, Cao J, Muller O. Operational challenges to the 1-3-7 surveillance strategy for malaria elimination in China: a qualitative study. *Lancet*. 2016;388:15-15.
22. Wang R, Tang S, Yang J, Shao T, Shao P, Liu C, Feng D, Fu H, Chen X, Hu T, Feng Z. Improving local health workers' knowledge of malaria in the elimination phase-determinants and strategies: a cross-sectional study in rural China. *Malar J*. 2017;16:210.
23. Li X, Lu J, Hu S, Cheng KK, De Maeseneer J, Meng Q, Mossialos E, Xu DR, Yip W, Zhang H, et al. The primary health-care system in China. *Lancet*. 2017;390:2584-2594.
24. Wang XL, Cao JB, Li DD, Guo DX, Zhang CD, Wang X, Li DK, Zhao QL, Huang XW, Zhang WD. Management of imported malaria cases and healthcare institutions in central China, 2012-2017: application of decision tree analysis. *Malaria J*. 2019;18:429.
25. Yin JH, Yan H, Huang F, Li M, Xiao HH, Zhou SS, Xia ZG. Establishing a China malaria diagnosis reference laboratory network for malaria elimination. *Malaria J*. 2015;14:40.
26. Fu H, Hu T, Wang J, Feng D, Fang H, Wang M, Tang S, Yuan F, Feng Z. A bibliometric analysis of malaria research in China during 2004-2014. *Malar J*. 2015;14:195.
27. Lin HL, Lu L, Tian LW, Zhou SS, Wu HX, Bi Y, Ho SC, Liu QY. Spatial and temporal distribution of falciparum malaria in China. *Malaria J*. 2009;8:9.
28. Liu Y, Zhang HW, Zhou RM, Yang CY, Qian D, Zhao YL, Xu BL. First imported relapse case of *Plasmodium vivax* malaria and analysis of its origin by CSP sequencing in Henan Province, China. *Malaria J*. 2014;13:448.
29. National Health Commission of the People's Republic of China: National medical institution inquiry system. <http://61.49.18.120:9090/unit/index> . Accessed 10 Oct 2019.
30. National Geomatics Center of China: National Geospatial Information system. <https://www.webmap.cn/store.do?method=store&storeId=2>. Accessed 19 Oct 2019.
31. Newby G, Bennett A, Larson E, Cotter C, Shretta R, Phillips AA, Feachem RGA. The path to eradication: a progress report on the malaria-eliminating countries. *Lancet*. 2016;387:1775-1784.
32. Li ZJ, Zhang Q, Zheng CJ, Zhou S, Sun JL, Zhang ZK, Geng QB, Zhang HL, Wang LP, Lai SJ, et al. Epidemiologic features of overseas imported malaria in the People's Republic of China. *Malaria J*. 2016;15:141.
33. Feachem RGA, Phillips AA, Hwang J, Cotter C, Wielgosz B, Greenwood BM, Sabot O, Rodriguez MH, Abeyasinghe RR, Ghebreyesus TA, Snow RW. Shrinking the malaria map: progress and prospects. *The Lancet*. 2010;376:1566-1578.

34. Clements ACA, Barnett AG, Cheng ZW, Snow RW, Zhou HN. Space-time variation of malaria incidence in Yunnan province, China. *Malaria J.* 2009;8:12.
35. Zhou SS, Huang F, Wang JJ, Zhang SS, Su YP, Tang LH. Geographical, meteorological and vectorial factors related to malaria re-emergence in Huang-Huai River of central China. *Malaria J.* 2010;9:9.
36. Tang S, Feng D, Wang R, Ghose B, Hu T, Ji L, Wu T, Fu H, Huang Y, Feng Z. Economic burden of malaria inpatients during National Malaria Elimination Programme: estimation of hospitalization cost and its inter-province variation. *Malar J.* 2017;16:291.
37. Tang S, Ji L, Hu T, Wang R, Fu H, Shao T, Liu C, Shao P, He Z, Li G, Feng Z. Public awareness of malaria in the middle stage of national malaria elimination programme: a cross-sectional survey in rural areas of malaria-endemic counties, China. *Malar J.* 2016;15:373.
38. Wang XL, Cao JB, Li DD, Guo DX, Zhang CD, Wang X, Li DK, Zhao QL, Huang XW, Zhang WD. Management of imported malaria cases and healthcare institutions in central China, 2012-2017: application of decision tree analysis. *Malar J.* 2019;18:429.
39. Lynch M, Korenromp E, Eisele T, Newby H, Steketee R, Kachur SP, Nahlen B, Yoon S, MacArthur J, Newman R, Cibulskis R. New global estimates of malaria deaths. *Lancet.* 2012; 380:559-559.
40. Lubell Y. Cost-effective use of prereferral treatment for severe malaria. *Lancet.* 2010;376:1880-1881.
41. Cao YY, Wang WM, Liu YB, Cotter C, Zhou HY, Zhu GD, Tang JX, Tang F, Lu F, Xu S, et al. The increasing importance of *Plasmodium ovale* and *Plasmodium malariae* in a malaria elimination setting: an observational study of imported cases in Jiangsu Province, China, 2011-2014. *Malaria J.* 2016;15:459.
42. Liu YB, Hsiang MS, Zhou HY, Wang WM, Cao YY, Gosling RD, Cao J, Gao Q. Malaria in overseas labourers returning to China: an analysis of imported malaria in Jiangsu Province, 2001-2011. *Malaria J.* 2014;13:29.
43. Cao J, Sturrock HJ, Cotter C, Zhou S, Zhou H, Liu Y, Tang L, Gosling RD, Feachem RG, Gao Q. Communicating and monitoring surveillance and response activities for malaria elimination: China's "1-3-7" strategy. *PLoS Med.* 2014;11:e1001642.
44. Yuan-Yuan C, Hua-Yun Z, Guo-Ding Z, Wei-Ming W, Jia-Jie J, Wen-Ji Q, Jia-Yan H, Jun C. Challenges for maintaining achievements of malaria elimination in Jiangsu Province, China. *Zhongguo Xue Xi Chong Bing Fang Zhi Za Zhi.* 2018;30:460-464 (in Chinese).
45. Sabot O, Cohen JM, Hsiang MS, Kahn JG, Basu S, Tang L, Zheng B, Gao Q, Zou L, Tatarsky A, et al. Costs and financial feasibility of malaria elimination. *The Lancet.* 2010;376:1604-1615.
46. Hsiang MS, Hwang J, Tao AR, Liu YB, Bennett A, Shanks GD, Cao J, Kachur SP, Feachem RGA, Gosling RD, Gao Q. Mass drug administration for the control and elimination of *Plasmodium vivax* malaria: an ecological study from Jiangsu province, China. *Malaria J.* 2013;12:383.
47. Song YZ, Ge Y, Wang JF, Ren ZP, Liao YL, Peng JH. Spatial distribution estimation of malaria in northern China and its scenarios in 2020, 2030, 2040 and 2050. *Malaria J.* 2016;15:345.

Tables

Table 1 Distribution of malaria patients seeking care in different types of health facilities

Type of medical institution	Total n=3686	Eastern China		Central China		Western China	
		Zhejiang n=517	Jiangsu n=709	Anhui n=341	Henan n=432	Sichuan n=622	Yunnan n=1065
Hospitals	3011(81.7%)	458(88.6%)	667(94.1%)	315(92.4%)	421(97.5%)	581(93.4%)	569(53.4%)
Township hospital	542(14.7%)	13(2.5%)	24(3.4%)	22(6.5%)	2(0.46%)	20(3.2%)	461(43.3%)
CDCs	133(3.6%)	46(8.9%)	18(2.5%)	4(1.2%)	9(2.08%)	21(3.4%)	35(3.3%)

Table 2 Distribution of malaria patients seeking care in different types of hospitals

Hospital type	Total n=3011	Eastern China		Central China		Western China	
		Zhejiang n=458	Jiangsu n=667	Anhui n=315	Henan n=421	Sichuan n=581	Yunnan n=569
Hospital tier							
Provincial	524(17.4%)	65(14.2%)	22(3.3%)	142(45.1%)	245(58.2%)	43(7.4%)	7(1.2%)
Prefecture-level	1822(60.5%)	279(60.9%)	484(72.6%)	87(27.6%)	162(38.5%)	396(68.2%)	414(72.8%)
County	665(22.1%)	114(24.9%)	161(24.1%)	86(27.3%)	14(3.2%)	142(24.4%)	148(26.0%)
Hospital level							
Tertiary	1801(59.8%)	335(73.1%)	402(60.3%)	218(69.2%)	356(84.6%)	329(56.6%)	161(28.3%)
Secondary	1202(39.9%)	123(26.9%)	258(38.7%)	97(30.8%)	65(15.4%)	252(43.4%)	407(71.5%)
Primary	8(0.3%)	0(0.0%)	7(1.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(0.2%)

Table 3 Characteristics of proportions of patients seeking care within county or within city in different types of hospitals

Province	Flow type	n	%	Hospital tier		P	Hospital level			P
				Secondary	Tertiary		Provincial	Prefecture	County	
Zhejiang	Within county	4	3.10%	1(10.0%)	3(2.6%)	0.196	1(1.9%)	0(0.0%)	3(33.3%)	0.510
n=127	Within city	82	64.60%	10(100.0%)	72(61.5%)	0.015	26(50.0%)	48(72.7%)	8(88.9%)	0.011
Jiangsu	Within county	199	47.70%	83(92.2%)	116(35.5%)	0.000	0(0.0%)	53(20.7%)	146(96.7%)	0.000
n=417	Within city	379	90.90%	84(93.3%)	295(90.2%)	0.363	5(50.0%)	228(89.1%)	146(96.7%)	0.000
Anhui	Within county	19	46.30%	17(65.4%)	2(13.3%)	0.001	0(0.0%)	0(0.0%)	19(100.0%)	0.000
n=41	Within city	33	80.50%	22(84.6%)	11(73.3%)	0.380	7(70.0%)	7(58.3%)	19(100.0%)	0.011
Henan	Within county	38	9.00%	21(31.8%)	17(4.8%)	0.000	15(5.4%)	20(14.6%)	3(37.5%)	0.000
n=421	Within city	224	53.20%	65(98.5%)	159(44.8%)	0.000	87(31.5%)	131(95.6%)	6(75.0%)	0.000
Sichuan	Within county	13	3.40%	0(0.0%)	13(4.0%)	0.113	6(19.4%)	7(2.7%)	0(0.0%)	0.000
n=387	Within city	236	61.00%	24(39.3%)	212(65.0%)	0.000	25(80.6%)	158(61.7%)	53(53.0%)	0.021
Yunnan	Within county	24	10.00%	4(3.3%)	20(16.8%)	0.000	1(16.7%)	19(16.7%)	4(3.3%)	0.003
n=240	Within city	82	34.20%	13(10.7%)	69(58.0%)	0.000	3(50.0%)	75(65.8%)	4(3.3%)	0.000
Total	Within county	297	18.20%	126(33.7%)	171(13.6%)	0.000	23(6.0%)	99(11.8%)	175(43.0%)	0.000
n=1633	Within city	1036	63.40%	218(58.3%)	818(65.0%)	0.018	153(39.7%)	647(76.9%)	236(58.%)	0.000

Note: The meaning of 'within' designation was the same as the caption in Figure 3

Figures

Figure 1

Spatial distribution of hospitals for malaria treatment. 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 2

Study design and flow chart of the observations selection. Note: The alphabet a represents that these data were used to analyze the distribution of malaria patients in different health facilities; the alphabet b represents that these data were used to analyze the distribution of malaria patients in different type hospitals; and the alphabet c represents that these data were used for spatial flow analysis of malaria patients who sought medical care in hospitals

Figure 3

Illustration of terms related to patient flow

Figure 4

Flow maps of malaria patients seeking care from current residency to hospitals. Note: Dots represent the location of hospitals where patients sought care, and starting points of the lines from dots represent the current residency of patients