

# Decades of Research Supporting Malaria Control and Elimination in China: A Bibliometric Analysis of Academic Articles Published in Chinese From 1980 to 2019

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## Research Article

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# Abstract

**Background:** China has accumulated a lot of experience on malaria control and elimination in the past few decades. Many research papers have been published in Chinese journals. This study intends to quantitatively analyze these local journals based on the bibliometric analysis to obtain the development path and experience of malaria control and elimination in China.

**Methods:** A long-term, multi-stage bibliometric analysis was implemented. Research articles published in Chinese journals from 1980 to 2019 were retrieved from Wanfang database and China National Knowledge Infrastructure (CNKI). Year of publication, journal name and keywords were extracted by the Bibliographic Items Co-occurrence Matrix Builder (BICOMB). We defined the K/A ratio (the percentage of a keyword frequency in the number of articles within a certain period) as an indicator for measuring the popularity of a keyword in different decades. And we used the software VOSviewer to make keyword co-occurrence network maps.

**Results:** A total of 16,290 articles were included. The overall trend of articles continues to rise. However, the articles published in the past three years had continued to decline. There are two kinds of trends of the keyword frequency between different decades. The K/A ratio of keywords such as '*Plasmodium falciparum*' continued to decline (17.05% in 1980s, 13.04% in 1990s, 9.86% in 2000s, 5.28% in 2010s), but 'imported case' and 'surveillance' continued to rise. Drug resistance always was a concern. The keyword co-occurrence network maps showed that the themes in malaria research were becoming more diverse, and the degree of multidisciplinary cooperation was gradually deepening.

**Conclusion:** This bibliometric analysis reveals the trends in malaria research in China over the past 40 years. The results suggest the high attention on the investigation, multidisciplinary participation and drug resistance for researchers and policymakers in malaria-epidemic areas. And the results also provided domestic experts with qualitative evidence for the summary of China's experience on malaria control and elimination.

## Background

From the foundation of the People's Republic of China in 1949 to reaching the goal of malaria free in 2020, the nationwide process of the elimination was be grouped into five phases by some researchers [1, 2]. Transmission not known (1949–1959): malaria investigations and pilot studies for control and treatment were being carried out in many province, and professional teams were formed. Outbreak and pandemic transmission (1960–1979) : mass drug administration and indoor residual spraying were conducted, the incidence of malaria was steeply reduced. Decline with sporadic distribution (1980–1999) : County classification based on epidemic was implemented, and different strategies were conducted according to local conditions. Low transmission with re-emergence in central China (2000–2009) : indigenous malaria cases were eliminated in most endemic counties, but outbreaks occurred in a few

areas. Elimination phase (2010–2020) : imported cases became the focus of prevention and control [3–6].

In different phases, prevention and control strategies are constantly being promoted, such as, joint malaria prevention and control that lasted more than half a century, '1-3-7' malaria surveillance and response strategy as key intervention to deal with imported cases [3, 4]. The continuous evolution of the strategies has ensured progress in the elimination. And these strategies are documented in the form of research publications.

In the last 40 years, a large number of research articles on malaria have been published in Chinese journals. Actually, it is necessary to systematically review the existing Chinese academic articles. The information and experiences contained in the academic research process would be a great reference to those areas that are still struggling with malaria, such as the trend of research hotspots. Although this information may not directly provide ready-made solutions or strategies for other countries, it can contribute for researchers and policy makers to predicting potential problems in the next phase, shortening the adjustment time of research direction, and reducing the trial and error cost in the development of strategies and technologies. In recent years, some researches tried to sum up the experience in this process and explore the value for other countries. But most of these researches focus on local epidemiological data, prevention measures and effects [7–13].

This research aims to analyze the articles published in Chinese journals, based on the a quantitative method, bibliometric analysis [14]. The bibliometric analysis is widely used in various research fields (food, medicine etc.) [15–17]. In malaria research field, this method is also accepted by researchers in many countries, such as, analyses of malaria researches in China, India, Malawi, worldwide malaria vector resistance and antimalaria drug resistance [18–22]. But all of these analyses, as conventional bibliometric analyses, tend to analyze the articles by static description (like taking a photo) rather than dynamic comparison (like taking photos and making stop motion animation). So there is few quantitative evidence that reveal the changing process between the decades.

To fill in this gap, this research conducted a long-term, multi-stage bibliometric analysis of the malaria-related academic articles published in the past 40 years to reveal the changes in the research themes and keyword hotspots in China, which may show more macro information than conventional bibliometric analysis.

## Methods

The methods involved in this study mainly is bibliometric analysis. The overall research framework and the software tools involved were showed in Fig. 1.

## Included and excluded standard

The search was conducted on 2 February 2020. Two major Chinese literature databases, Wanfang database and China National Knowledge Infrastructure (CNKI), were searched. The inclusion criteria were: Chinese articles were published in journals from 1980 to 2019; at least one of the following Chinese words, 'malaria', 'plasmodium', and 'anopheles', was included in the title or keywords [18, 19, 23]. Exclusion criteria were: articles without keyword; repetitive articles in two databases. The articles with the same publication year, title, and authors were defined as repetitive in this research. Software NoteExpress (Version 3.2, Aegean Technology Co., Ltd, Beijing, China) was used to manage and deduplicate the bibliography information.

## **Data extraction**

This study first analyzed all articles in the 40-year span as a whole and conducted a descriptive analysis according to the methods of conventional bibliometric analysis, including publication year, journal distribution, and highly cited articles. Then a comparative analysis was conducted between different decades. The 40-year span was divided into 4 stages, the first stage was from January 1, 1980 to December 31, 1989, the second stage (1990–1999), the third stage (2000–2009), the fourth stage (2010–2019). This time division followed the consensus of Chinese domestic malaria experts and the principle of the same time span [1, 2]. All the bibliographic information of articles included was exported into a format that can be used by the bibliometric analysis software according to the stage.

### **Keyword frequency analysis**

The Bibliographic Items Co-occurrence Matrix Builder (BICOMB) software (version 2.0, School of Medical Information, China Medical University, Shenyang, China) was used to extract and count the publication year, journal distribution, and keyword frequency [21]. It was a software developed by the Medical Information Department of China Medical University. It had good compatibility with Chinese journals. And it could replace the keywords with synonyms as one keyword we defined. For example, 'imported case' and 'imported patient' would be unified into 'imported case'.

This study defined 'K/A ratio' as the percentage of a keyword frequency in the number of articles within a certain period. The absolute frequencies of keywords in different stages could not be directly compared. The K/A ratio eliminated the impact of the difference in the total number of journal articles in different stages. It was used as an indicator to compare the popularity of the same keyword in different stages. For showing the top 100 keywords in each stage, the word clouds were built [24]. Microsoft Excel was used to calculate and display the change trend of the K/A ratio. A heat map was produced based on the rank of K/A ratio.

### **Keyword co-occurrence network and clustering**

VOSviewer (version 1.6.11, Centre for Science and Technology Studies, Leiden University, Leiden, Netherlands) was used to make four keyword co-occurrence network maps in different stages. It was a software tool for creating maps based on network data and for visualizing and exploring these maps [25]. This software can achieve the merger of keywords with synonyms and the replacement of Chinese to

English according to the 'thesaurus terms' file (a txt file in a specific format for VOSviewer), which was translated and reviewed by two researchers. For co-occurrence analysis, if keyword A and keyword B were the keywords of one articles, we defined this relationship between A and B as a co-occurrence [14]. The network developed based on such relationship was a keyword co-occurrence network. In a network map, a node represented a keyword, and its' size was related to the occurrence frequency of the keyword. The node color represented different cluster that they belonged to. Links represented co-occurrence relationships. For comparability among the network maps in different stages, the parameters in VOSviewer were set consistently as: the keywords with a frequency of more than 15 times were showed in maps; each cluster contained at least 5 keywords. Based on the setting, keywords were grouped into different clusters according to co-occurrence. Then the clusters in the network maps of four stages were compared with each other.

## Results

In this research, 14,963 articles were retrieved in the CNKI, and 9,950 articles were retrieved in Wanfang. A total of 24,913 articles were saved in NoteExpress for exclusion and deduplication. 1,082 articles without keyword were excluded. Most of them were notices, announcements and news on the topic of malaria published in academic journals. 7,752 articles were excluded due to repetitive (Fig. 2).

## Publication distribution

From January 1, 1980 to December 31, 2019, a total of 16,290 articles related to malaria research were published in Chinese academic journals. As shown in Fig. 3, in the 1980s and 1990s, the number of articles showed a volatile increase, from 2,768 to 4,786. In the 2000s, there was a gradual and slight decline from 2003 to 2010. In the last ten years, the number of articles showed a slight increase at first. But for the three consecutive years from 2017 to 2019, the annual decline exceeded 10%.

The top 15 journals with the most cumulative articles published in past 40 years were listed in Table 1. Articles related to malaria research were mainly published in professional journals in the fields of parasitic diseases, tropical diseases and infectious diseases.

**Table 1** Top 15 journals with the most publications

Rank	Journal	Records	% of total	Cumulative %
1	International Journal of Medical Parasitic Diseases	2126	13.22	13.22
2	Chinese Journal of Parasitology and Parasitic Diseases	1207	7.51	20.73
3	Journal of Parasitic Biology	1113	6.92	27.65
4	China Tropical Medicine	699	4.35	32.00
5	Chinese Journal of Schistosomiasis Control	462	2.87	34.87
6	Parasitoses and Infectious Diseases	433	2.69	37.56
7	Chinese Journal of Vector Biology and Control	275	1.71	39.27
8	Journal of Medical Pest Control	274	1.70	40.98
9	Chinese Journal of Zoonoses	240	1.49	42.47
10	Journal of Tropical Medicine	197	1.23	43.70
11	Henan Journal of Preventive Medicine	192	1.19	44.89
12	Hainan Medical Journal	166	1.03	45.92
13	Acta Parasitological et Medica Entomological Sinica	138	0.86	46.78
14	Chinese Journal of Public Health	131	0.81	47.60
15	Modern Preventive Medicine	126	0.78	48.38

Note: International Journal of Medical Parasitic Diseases was suspended in 2015

## High-cited articles

The highly cited articles in each stage that counted by CNKI database were showed in additional file [see Additional file 1]. The deadline for citation counting was February 2, 2020. The citation frequency of high-cited articles varied greatly in each stage, and the theme represented by articles also varied greatly. In the 1980s, the most cited articles mainly focused on *Anopheles*; in the 1990s, the themes increased, but the antimalarial drugs and vectors were the main ones; in 2000s and 2010s, there were more citation to the epidemic analysis; but in the past ten years, retrospective and summary research articles received more attention.

### Keyword frequency analysis

The word clouds of different stages (Fig. 3) reveal the following features: 1) *falciparum malaria*, *vivax malaria* were the main types of malaria in China; 2) *Anopheles sinensis* was main malaria vector; 3)

imported cases, surveillance and elimination had come at the forefront of concerns in the fourth stage.

For the analysis of single keyword, the keyword '*Plasmodium falciparum*', it maintained the fourth rank in the first three stages, but its' K/A ratio had been in a state of decline, 17.05% in 1980s, 13.04% in 1990s, 9.86% in 2000s. The keyword 'falciparum malaria', it's frequency rank rose from seventh in 1980s to fourth in 2010s, but its' K/A ratio declined from 12.97% in 1980s to 7.82% in 2010s. These results suggested that there were some common patterns in the change of K/A ratio.

The heat map (Fig. 4a) showed two obvious change pattern of K/A ratio from an overall perspective. It clearly showed that the K/A ratio of some keywords continuously decreased, and some continuously increased (Fig. 4b and Fig. 4c). Keywords in continuous decrease of K/A ratio were 'internal medicine', '*Plasmodium falciparum*', 'vivax malaria', 'falciparum malaria', '*Anopheles sinensis*', 'antimalaria drugs', etc. Keywords in continuous increase included 'imported case', 'surveillance', 'artemisinin', 'floating population', 'epidemiological characteristic', 'elimination', etc. In essence, these two patterns were the manifestation of the research theme change.

### **Keywords co-occurrence network**

Figures 5, 6, 7, and 8 were the maps of keyword co-occurrence network in four stages.

According to the strength of the co-occurrence relationship, the keywords in the four stages were respectively divided into 5 clusters in 1980s (Fig. 5), 6 clusters in 1990s (Fig. 6), 5 clusters in 2000s (Fig. 7), and 7 clusters in 2010s (Fig. 8). These clusters were considered as research themes, and each theme could be divided into sub-themes according to the subjects that were represented by specific keywords in the cluster.

From the perspective of whole network maps of four stages, in 1980s (Fig. 5), the blue cluster was centered on 'Anopheles' and included keyword '*Anopheles sinensis*', '*Anopheles anthropophagus*' and '*Anopheles minimus*'. And the same situation occurred in 1990s (Fig. 6, green cluster). This two clusters had obvious boundaries with other clusters in their own networks. This result indicated that researches on Anopheles had high independence. But in 2000s, this kind of independence became weak. And in 2010s (Fig. 8), this kind of independence was disappeared. The boundaries of clusters were difficult to identify. For the analysis of the network structure among the clusters, the boundaries between two clusters in one stage became more and more blurred, especially in 2010s (Fig. 8). Figure 8 also showed that many main nodes in one clusters are also intermediaries with other clusters. This result suggested that the relationship between research themes is no longer the weak connection due to sub-themes' co-occurrence in the past, but a strong connection that emerged from the deep integration of the subjects and research methods.

From the perspective of the cluster in different network maps, in the blue cluster in 1980s (Fig. 5), the peripheral keywords, which were around the central keyword '*Anopheles sinensis*', included 'retention spray', 'ecological habit', 'life history', etc. However, in the blue clusters in 2010s (Fig. 8), peripheral

keywords around the central keyword '*Anopheles sinensis*', included 'surveillance', 'drug resistance', etc. It was found that the keywords that represented the research object, such as 'falciparum malaria', '*Plasmodium falciparum*', '*Anopheles sinensis*', were always the central keywords in different stages. But peripheral keywords, which represented the research fields, around central keywords changed. For '*Anopheles sinensis*', in 1980s, the research direction was entomology. In 2010s, the research direction was insect vector control. So this result indicated that the research direction around the central keywords was changing with the process of malaria elimination.

For the analysis at node level, in all four keyword co-occurrence network maps, some nodes in one cluster only had co-occurrence with the nodes inside this cluster, and other nodes had co-occurrence with multiple nodes outside this cluster. Under this common feature, there were differences in details, such as the link density between nodes. In Fig. 7, we clearly observed that the network of green clusters looks more complex than the red clusters on the premise that the number of nodes is not much different between the red clusters and the green clusters. This result indicated that the co-occurrence between the nodes in the green cluster was more divergent, while the co-occurrence relationship between the nodes in the red cluster was more directional. This meant that the sub-themes represented by the nodes in the red cluster have a high degree of independence.

## Discussion

This research indicates three trends that Chinese article publication presented from a long-term perspective: a) research are continuously implemented from control to elimination; b) multidisciplinary participation becomes a trend especially after local transmission is blocked; c) drug resistance has long been identified as a concern. These trends, showed by this bibliometric analysis, are consistent with the actual historical process of malaria control and elimination in China.

### Continuous epidemiological investigations and surveillance

The highly cited articles and Top 25 keywords among four stages indicate that whether in the control or elimination phase, epidemiological investigations and surveillance have always been given considerable attention in China. Epidemiological Investigation and surveillance help epidemiologists obtain basic information about malaria cases or plasmodium, such as the breeding ground of the vector, the source of imported cases, and the possibility of re-transmission [4]. This information helps to develop targeted interventions. In the 1980s, the main subjects of the investigations were vectors and transmission patterns [26–28]. In 2001, nationwide epidemiological investigation reports of malaria case began to be published [29]. In the 2010s, epidemiological investigations of imported cases were implemented in many provinces and border regions [30–33]. Although the subjects of the investigation have changed, the emphasis on the investigation has never weakened. In essence, this reflects that the development, adjustment, and termination of China's anti-malarial strategies always base on local epidemic and other evidences.

### The need for multidisciplinary participation

The diversification of keyword co-occurrence networks indicates the general improvement of multidisciplinary participation which is needed to optimize large-scale social mobilization. Malaria elimination is a long-term project that requires continuous input, even when the epidemic trend has been reduced from sporadic to no local transmission. Actually, large-scale social mobilization is the most valuable and sustainable input.

In China, social mobilization involves not only joint prevention and control between different regions [34, 35], but also cooperation between different administrative departments, such as the Ministry of Health, Ministry of Commerce, and Inspection and Quarantine Bureau. But the closer to the realization of elimination, the more precise case tracking and patient management are needed. The greater the need for preventive measures for a wider range of healthy people is, the higher the cost is. For such a large-scale social mobilization, how to make it efficient and precise is a problem. To solve this problem, multidisciplinary participation is inevitable, including Social Management, Education, Journalism and Communication, Evaluation of Healthcare Program, International Relations, etc. Multidisciplinary participation would help to design more efficient, low-cost and targeted interventions from multiple nodes in the transmission path. Therefore, large-scale social mobilization and multidisciplinary participation should be encouraged as much as possible in other regions for the development of malaria strategy.

## Limitation

This study has two limitations. First, the Chinese journal databases do not allow users to download the reference information. So we did not make a co-citation analysis. Second, this study focuses on the comparison of different stages. The details in a single stage are not fully displayed. And there are many sub-topic analysis that can be implemented. Therefore, we would like to share the original data (the bibliographic information of 16,290 articles) analyzed in this study with other researchers to jointly dig these data and explore the potential value.

## Conclusion

This study reveals the trends in the research themes and hotspots in malaria field in past 40 years. The reveal of these trends could help researchers in other malaria epidemic areas to fully understand the research process of malaria elimination strategy and technology. And the results also provided domestic experts with qualitative evidence for the summary of China's experience on malaria control and elimination. More important than these results are that this research would let researchers and policy makers aware of the importance of the investigation, surveillance, and multidisciplinary participation.

## Abbreviations

BICOMB

Bibliographic Items Co-occurrence Matrix Builder

CNKI

China National Knowledge Infrastructure

K/A ratio

Keyword/Articles ratio

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets during the current study available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' contributions

YD, GZ, JC, and JH conceived and designed the study. YD was responsible for the bibliometric analysis and the first draft of the manuscript while JH, and JC critically revised the manuscript. All authors read and approved the final manuscript.

### Acknowledgements

Not applicable.

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## Figures

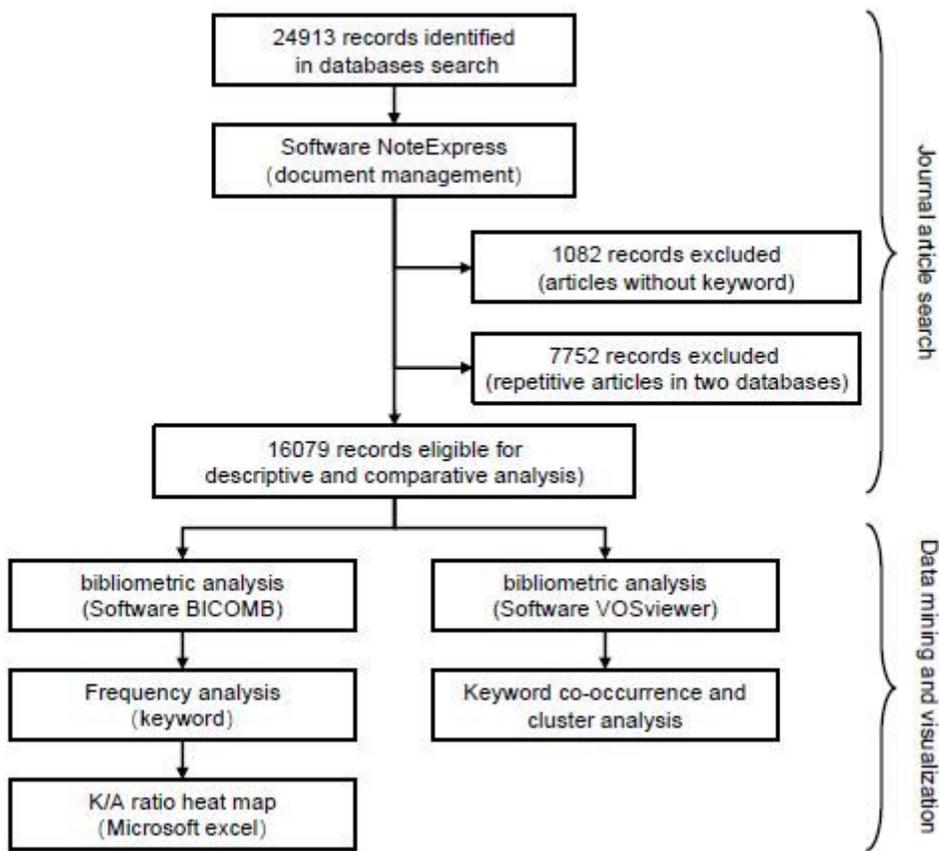


Figure 1

The framework of this research

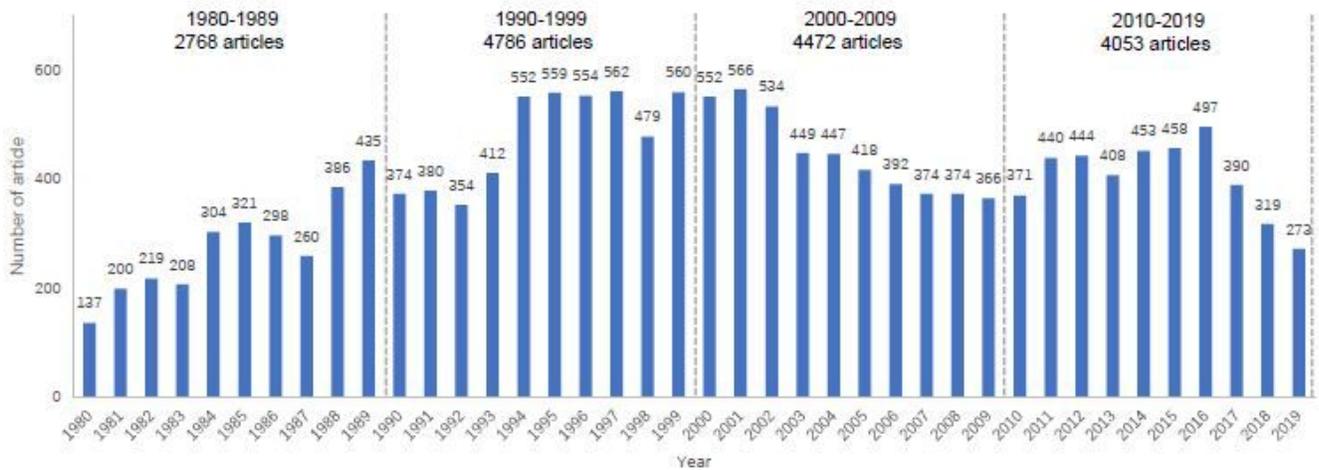


Figure 2

Publication trend from 1980 to 2019



**Figure 3**

Word Clouds of top 100 keywords in four stages

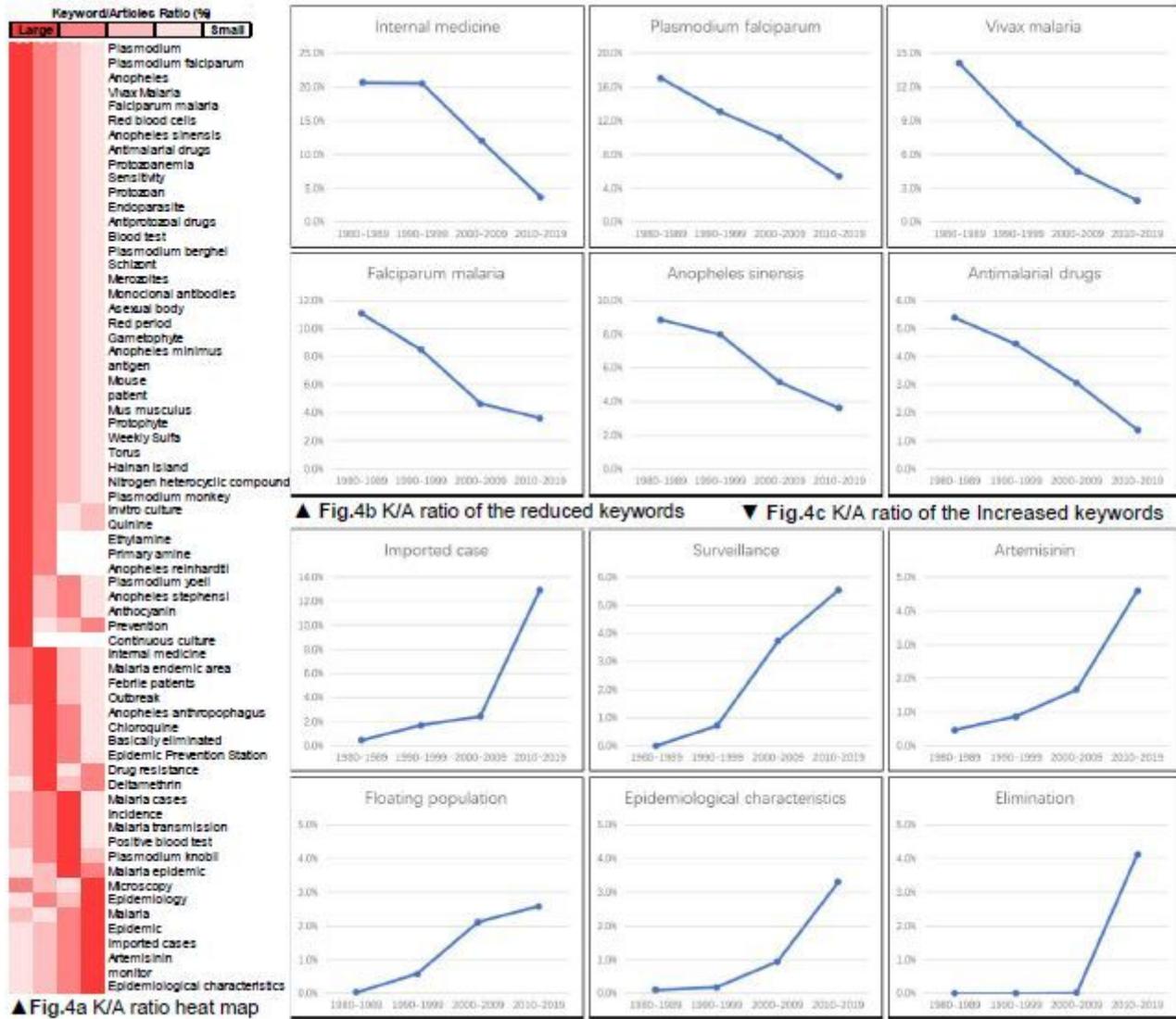


Figure 4

a K/A ratio heat map



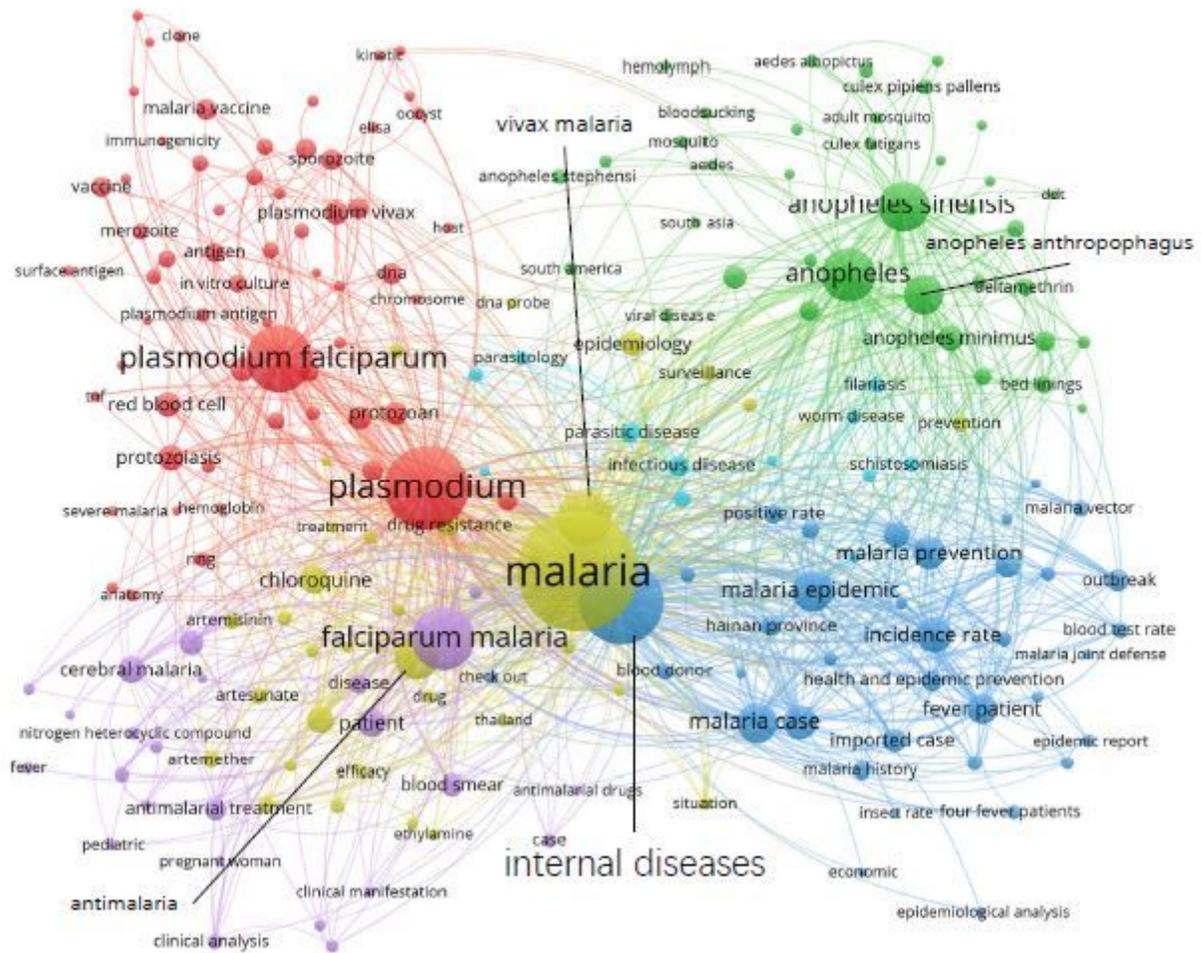
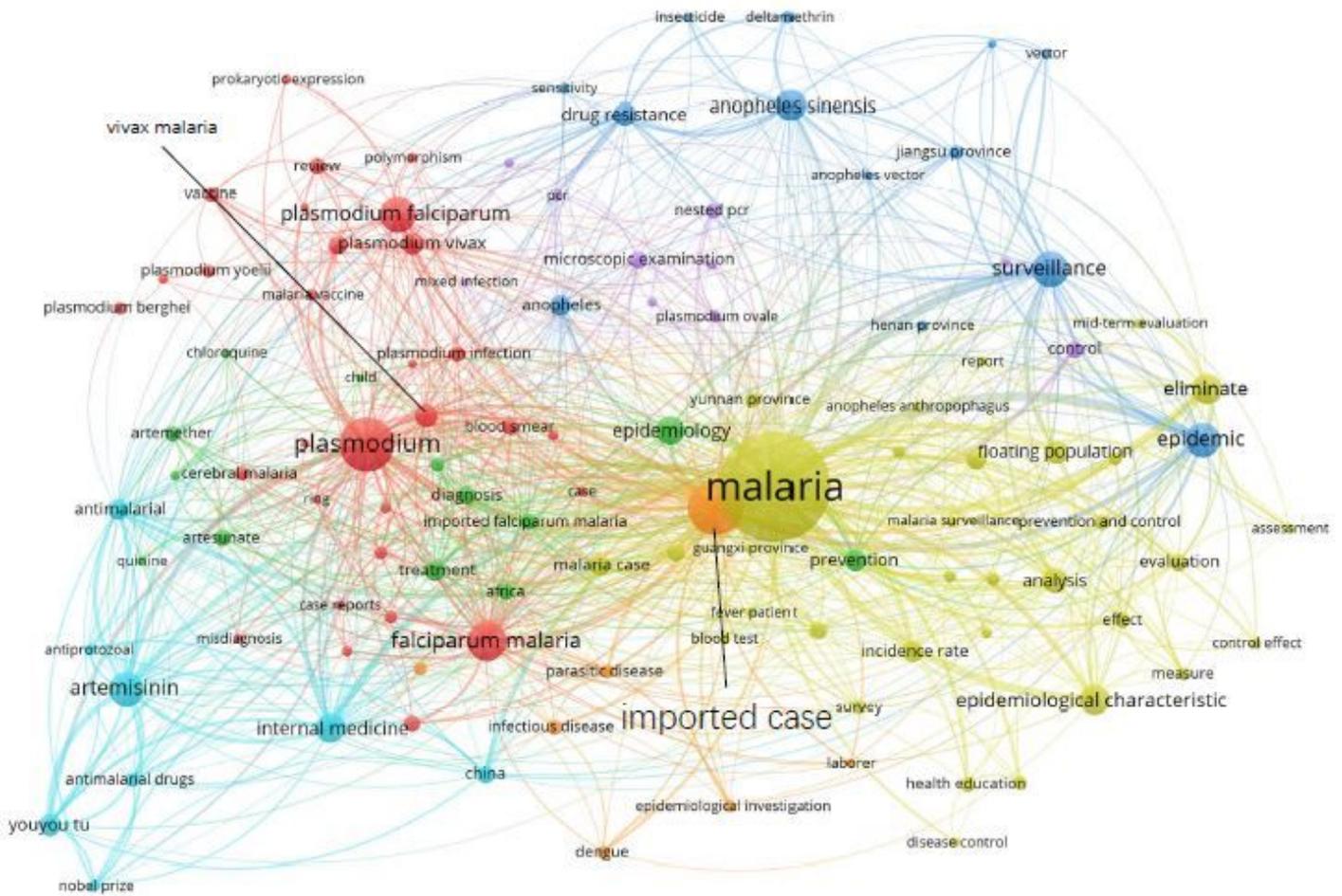


Figure 6

Keyword co-occurrence network map (1990-1999)





**Figure 8**

Keyword co-occurrence network map (2010-2019)

## Supplementary Files

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- [Additionalfile10907.xlsx](#)