Efficient Management Strategy of Malaria Patients in China: A Decision-Tree Modelling Approach

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Research

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Abstract

Background: Early accurate diagnosis and risk assessment for malaria are crucial for improving patients' terminal prognosis, and preventing them from progressing to severe or critical state. This study aims to describe the accuracy of the initial diagnosis of malaria cases with different characteristics, as well as the factors that affect the accuracy in the context of the agenda for a world free of malaria.

Methods: A retrospective study was conducted on 494 patients admitted to hospitals with a diagnosis of malaria from January 2014 through December 2016. Descriptive statistics were calculated and decision tree analysis was performed to predict the probability of patients who may be misdiagnosed.

Results: Of the 494 patients included in this study, the proportions of patients seeking care in county-level, prefecture-level, and provincial-level hospitals were 27.5% (n=136), 26.3% (n=130), and 8.3% (n=41), respectively; the proportions of patients seeking care in clinic, township health center, and Centers for Disease Control and Prevention were 25.9% (n=128), 4.1% (n=20), and 7.9% (n=39), respectively. Nearly 60% of malaria patients were misdiagnosed on their first visit, and 18.8% of patients had complications. The median time from onset to the first visit was 2 days (IQR: 0 - 3 days), and the median time from the first visit to diagnosis was 3 days (IQR: 0 - 4 days). The decision tree classification of malaria patients being misdiagnosed consisted of six categorical variables: healthcare facilities for the initial diagnosis, time interval between onset and initial diagnosis, region, residence type, insurance status, and age.

Conclusion: Insufficient diagnostic capacity of healthcare facilities with lower administrative levels for the first visit was the most important risk factor in misdiagnosing patients. Researchers and clinicians should consider strengthening the primary care facilities, time interval between onset and initial diagnosis, administrated residence, and health insurance status to reduce diagnostic errors.

Background

Malaria is one of the major infectious diseases that continue to present challenges to population health and healthcare systems worldwide, particularly in developing countries [1, 2], where it is a major cause of mortality and morbidity [1, 3]. According to the latest data, an estimated 229 million malaria cases and 409,000 deaths occurred globally in 2019 [3]. China was once a major malaria-endemic country, but the Chinese government made great strides in preventing and controlling malaria [4]. After 70 years of hard work, there has been no report of autochthonous malaria cases for nearly four consecutive years since 2017 [5, 6], meeting the goal of malaria elimination set by the World Health Organization [7, 8].

With the sharp increase in international travel among Chinese people, the risk of imported malaria cases from malaria-endemic areas threatens the maintenance of the malaria elimination goal of China [9]. Among imported malaria cases, falciparum malaria is the most common plasmodium species, which has the potential for fatality [10]. The fatality of malaria in China is rising, with more than four-fifths of deaths associated with serious complications, such as severe brain/liver/kidney lesions, shock, and hemolysis [11, 12].

It is recommended that all malaria cases be treated effectively and affordably within 24 hours of onset [13]. However, not all patients can get a timely and accurate diagnosis. Most cases of “malaria” (i.e., having a fever) are self-diagnosed, and most treatments and deaths occur at home [14]. Early and accurate diagnosis and risk assessment for malaria is crucial for improving patients’ terminal prognosis, and preventing them from progressing to the severe or critical state [15]. In addition, it also helps to reduce the direct or indirect treatment costs for patients and the risk of community transmission [16].

To date, studies identified some factors associated with the misdiagnosis of malaria, including insufficient diagnostic equipment, means of diagnosis, lack of clinical supervision/training for local clinicians, lack of malaria-related knowledge for travelers, plasmodium species, and health system factors [17–24]. Most of these, however, have been carried out in a few malaria-endemic developing countries, or in just one province of China [25]. To our knowledge, studies on misdiagnosis of malaria using samples from multiple provinces and rich clinical medical records in China are limited. This study aims to identify factors associated with the misdiagnosis of malaria and develop a predictive model based on the medical records to guide prevention and reduce misdiagnoses.

Methods

Study design and site

A multi-stage sampling approach was adopted to obtain the study population. In each region of China, two provinces with the highest incidence of malaria were selected, including Zhejiang and Jiangsu in Eastern China, Henan and Anhui in Central China, and Yunnan and Sichuan in Western China [26]. We preliminarily analyzed the number of malaria cases reported by different levels of hospitals based on the data provided by the National Health Committee. We found that most county-level hospitals reported less than 2 cases, and most cases reported in the higher level of hospitals. Then we determined to select two provincial-level hospitals, five prefecture-level hospitals, ten county-level hospitals with relatively large numbers of malaria cases in each province according to the hospitals' list of reported malaria cases during 2014–2016. We collected all patients’ medical records in each selected hospital. According to the sampling design, a total of 1,868 cases from 102 hospitals were selected. Finally, we collected 1,633 cases from 63 hospitals. After screening for completeness of patients’ medical records reported by each hospital, 294 cases from 26 hospitals were finally included in our analysis. Figure 1 shows the geographic distribution of the six selected provinces. Jiangsu and Zhejiang provinces are geographically in proximity to the East China Sea, where the economy is among the best in the country, and have frequent trade exchanges with other countries. Henan and Anhui are China’s inland provinces, bordering each other with flat terrain. High-speed rail and highways passing through these two provinces are connected with most other provinces in the country. Sichuan and Yunnan are mountainous and relatively underdeveloped areas located in Southwestern China. Transport infrastructure and medical facilities are relatively scarce in these two provinces [27].

Data Collection

This is a retrospective study of 494 patients admitted to hospitals with a diagnosis of malaria from January 2014 through December 2016. These patients were confirmed to be positive for *Plasmodium* species by Rapid Diagnostic Tests (RDTs), microscopy, or Polymerase Chain Reaction (PCR). Data were obtained from the patients' medical records using a protocol designed for the study. Demographic, epidemiological, and clinical data were collected from medical records, including age, sex, occupation, education, residence type, health insurance status, detailed course from the onset of symptoms to seeking medical services, treatment details, comorbidities, outcome (cure or death), as well as blood chemicals and microbiology analyses.

Definitions

China has five levels of administrative divisions, namely the provincial, prefectural, county, township, and village levels. There are two main types of health facilities in China [28]. One is a professional public health agency, such as various levels of Centers for Disease Control and Prevention (CDC), which undertakes the detection of some infectious diseases and the prevention of chronic diseases, as well as the distribution of free medications, including antimalarial drugs. The other category is institutions that provide treatment services, including hospitals, township health centers, and village clinics. CDCs and hospitals can be divided into three levels: provincial, prefectural, and county level, aligned with the administrative levels. Township health centers and clinics are generally set up within the jurisdiction of townships and villages. In most cases, medical facilities with higher administrative levels also have higher diagnostic and treatment capabilities.

Statistical Analysis

The descriptive statistics, Chi-square, and t-test analyses were performed with Stata version 15.0 (StataCorp, College Station, TX, USA). Descriptive statistics were used to summarize the sociodemographic characteristics. Statistical significance was defined as a p-value < 0.05. Decision tree analysis using the IBM SPSS Statistics 25.0 (IBM Corp, Armonk, NY, USA)was performed to build an optimum and significant predictive model to predict the probabilities of misdiagnosing patients. The Classification And Regression Trees (CART) techniques were conducted to obtain the best cut-off points in the software [29, 30]. We included initial diagnosis (misdiagnosis/correct diagnosis) as a dependent variable and demographic and clinical characteristics variables (age, gender, marital status, occupation, residence type, region, insurance status, plasmodium species, time interval between onset and initial diagnosis, and healthcare facilities for the initial diagnosis) as independent variables in the model. Parameters of the final CART tree model were set as follows: maximum tree depth was five, with minimum cases in parent node as 10 and in child node as 5.

Ethical approval and consent

The study was approved by the Ethics Committee of the Tongji Medical College of Huazhong University of Science and Technology (IORG0003571). Written permission to access and analyze the research data was granted by the National Health Commission of the People's Republic of China and the administrators of each hospital. Patient information was anonymized and de-identified.

Results

Sociodemographic characteristics

The demographic and clinical characteristics of patients are summarized in Table 1. The median age of the 494 patients was 39 years (range: 11–63 years), and most were male (98.2%). Of these individuals, around 80% were married, 62% lived in rural areas, 35% were employed in agriculture, and 70% had health insurance. The malaria cases were mostly from *Plasmodium falciparum*: 62.4% (n = 308), and cases due to *Plasmodium vivax*, *Plasmodium ovale*, and *Plasmodium malariae* were 19.2% (n = 95), 3.0% (n = 15), and 0.6% (n = 3), respectively.

Table 1
Epidemiological characteristics of individuals with imported malaria

Factors	Number (%)
Gender (n = 494)	
Male	485 (98.2%)
Female	9 (1.8%)
Age (years) (n = 494)	
< 35	205 (41.5%)
≥ 35	289 (58.5%)
Marital Status (n = 494)	
Married	394 (79.8%)
Single/divorce/separated	100 (20.2%)
Occupation (n = 494)	
Agriculture	170 (34.4%)
No-agriculture	324 (65.6%)
Residence (n = 494)	
Rural	304 (62.2%)
Urban	185 (37.8%)
Region (n = 494)	
Eastern	67 (13.6%)
Central	309 (62.6%)
Western	118 (23.9%)
Plasmodium species (n = 494)	
Unclassified	68 (13.8%)
Plasmodium falciparum	308 (62.4%)
Plasmodium ovale	15 (3.0%)
Plasmodium vivax	95 (19.2%)
Plasmodium malariae	3 (0.6%)
Mixed	5 (1.0%)
Rank of healthcare facilities for the initial diagnosis (n = 494)	

Factors	Number (%)
Village clinic	128 (25.9%)
Township health center	20 (4.1%)
County-level CDC	22 (4.5%)
Prefecture-level CDC	15 (3.0%)
Provincial-level CDC	2 (0.4%)
County-level hospital	136 (27.5%)
Prefecture-level hospital	130 (26.3%)
Provincial-level hospital	41 (8.3%)
Initial diagnosis (n = 461)	
Misdiagnosis	265 (57.5%)
Correct diagnosis	196 (42.5%)
Admission pathway (n = 494)	
Emergency	244 (49.4%)
Outpatient	242 (49.0%)
Referral	8 (1.6%)
Symptom (n = 494)	
Fever	491 (99.4%)
Chills	209 (42.3%)
Sweating	191 (38.7%)
Splenomegaly	7 (1.4%)
Anemia	41 (8.3%)
Periodic	123 (24.9%)
Complications developed (n = 494)	
Yes	93 (18.8%)
No	401 (81.2%)
Insurance status (n = 494)	
Insured	346 (70.0%)
Uninsured	148 (30.0%)

Factors	Number (%)
Hospitalization cost (USD) (n = 484)	
36–500	106 (21.8%)
501–1000	136 (28.0%)
1001–2000	161 (33.1%)
2001–34630	83 (17.1%)
Days	Mean, Median, Min, P10, P25, P75, P90, Max
Time interval from fever onset to initial diagnosis	2.0, 1, 0, 0, 3, 5,20
Time interval from initial diagnosis to final diagnosis	3.5, 2, 0, 0, 4, 8, 90
Time interval from fever onset to final diagnosis	5.5, 4, 1, 2, 7, 10, 90

Health seeking behaviour

The proportions of patients seeking care in county-level, prefecture-level, and provincial-level hospital were 27.5% (n = 136), 26.3% (n = 130), and 8.3% (n = 41), respectively; the proportions of patients seeking care in clinic, township health center, and CDC were 25.9% (n = 128), 4.1% (n = 20), and 7.9% (n = 39), respectively. Nearly 60% of malaria patients were misdiagnosed on their first visit, and concerning complications affected 18.8% of the patients. Approximately half of the patients were admitted to the hospital via emergency rooms. Patients with fever, chills, and sweating upon admission were 99.4% (n = 491), 42.3% (n = 209), and 38.7% (n = 191), respectively.

Median time intervals were as follows: from onset to the first medical visit, 2 days (IQR: 0–3 days); from the first medical visit to diagnosis, 3 days (IQR: 0–4 days); and from onset to final diagnosis, 5.5 days (IQR: 2–10 days). Table 2 shows the time interval from symptom onset to initial diagnosis, and from initial diagnosis to final diagnosis of malaria cases in multiple healthcare institutions. The time interval between onset and initial diagnosis in the provincial-level, prefecture-level, and county-level hospitals was 3.3 days, 2.4 days, and 2.2 days, respectively, which was longer than in other health care institutions. The time interval from the initial diagnosis to the final diagnosis in prefecture-level, provincial-level, and county-level CDCs was 0.5 days, 1.0 days, and 1.1 days, respectively, followed by provincial-level hospitals (1.1 days), and prefecture-level hospitals (1.3 days). However, the time interval from the initial diagnosis to the final diagnosis in village clinics, county-level hospitals, and township health centers was much longer than the aforementioned healthcare institutions, which was 5.8 days, 4.8 days, and 4.0 days, respectively.

Table 2
Time interval from symptom onset to initial diagnosis, and from initial diagnosis to final diagnosis of malaria cases in multiple healthcare institutions

Healthcare institutions	Time interval between onset and initial diagnosis Mean (95% CI)	Time interval from initial diagnosis to final diagnosis Mean (95% CI)
Village clinic	1.42 (0.92–1.91)	5.80 (4.42–7.17)
Township health center	1.05 (0.28–1.82)	4.00 (2.43–5.57)
County-level CDC	1.32 (0.59–2.05)	1.09 (0.11–2.07)
Prefecture-level CDC	1.77 (0.85–2.68)	0.47 (0.09–0.84)
Provincial-level CDC	1.25 (-0.22–2.72)	1.00 (-0.96–2.96)
County-level hospital	2.21 (1.78–2.63)	4.83 (3.28–6.38)
Prefecture-level hospital	2.40 (2.00–2.80)	1.29 (0.82–1.77)
Provincial-level hospital	3.32 (2.09–4.55)	1.12 (0.44–1.81)

Factors influencing initial diagnosis and malaria complications

Demographic and epidemiological factors influencing initial diagnosis are shown in Table 3. There was a significant difference in misdiagnosis rate for the initial diagnosis between different regions, plasmodium species, and health care facilities. Among patients from Western China, around 67.5% (n = 79) of patients were not correctly diagnosed, and misdiagnosis rates in Central and Eastern China were 58.8% (n = 163) and 34.3% (n = 23) respectively. Among all *Mixed malaria* cases, 80.0% (n = 4) were not correctly diagnosed at the first medical visit. The misdiagnosis rates of *Mixed*, *Unclassified*, *Plasmodium ovale*, *Plasmodium falciparum*, *Plasmodium vivax*, and *Plasmodium malariae* were 80.0%, 71.7%, 68.5%, 51.4%, 46.7% and 33.3%, respectively. Notably, the misdiagnosis rate was up to 100% at clinics and township health centers, and 68.5% in county-level hospitals during their first medical visit. More generally, the rate of misdiagnosis decreased with the level and quality of health institutions.

Table 3
Influential factors of the malaria cases at initial diagnosis

Influential factors	**Initial diagnosis (% or 95% CI)**		**P-value**
	Misdiagnosis(%)	**Correct diagnosis(%)**	
Gender			
Male	259 (57.3)	193 (42.7)	0.574
Female	6 (66.7)	3 (33.3)	
Age (years)	38.4 (37.2–39.5)	38.3 (37.0–39.6)	0.930
Marital Status			
Married	217 (58.8)	152 (41.2)	0.250
Single/divorce/separated	48 (52.2)	44 (47.8)	
Occupation			
Agriculture	94 (59.1)	65 (40.9)	0.606
No-agriculture	171 (56.6)	131 (43.4)	
Residence			
Rural	161 (57.1)	121 (42.9)	0.841
Unban	101 (58.1)	73 (42.0)	
Region			
Eastern	23 (34.3)	44 (65.7)	0.000
Central	163 (58.8)	114 (41.2)	
Western	79 (67.5)	38 (32.5)	
Insurance status			
Insured	188 (58.0)	136 (42.0)	0.718
Uninsured	77 (56.2)	60 (43.8)	
Plasmodium species			
Unclassified	43 (71.7)	17 (28.3)	0.006
Plasmodium falciparum	147 (51.4)	139 (48.6)	
Plasmodium ovale	63 (68.5)	29 (31.5)	
Plasmodium vivax	7 (46.7)	8 (53.3)	

Influential factors	Initial diagnosis (% or 95% CI)		P-value
	Misdiagnosis(%)	Correct diagnosis(%)	
Plasmodium malariae	1 (33.3)	2 (66.7)	
Mixed	4 (80.0)	1 (20.0)	
Rank of healthcare facilities for the initial diagnosis			
Village clinic	112 (100.0)	0 (0.0)	0.000
Township health center	18 (100.0)	0 (0.0)	
County-level CDC	6 (30.0)	14 (70.0)	
Prefecture-level CDC	6 (40.0)	9 (60.0)	
Provincial-level CDC	1 (50.0)	1 (50.0)	
County-level hospital	87 (68.5)	40 (31.5)	
Prefecture-level hospital	27 (21.3)	100 (78.7)	
Provincial-level hospital	8 (20.0)	32 (80.0)	
Time interval between onset and initial diagnosis	1.6 (1.3–1.9)	2.7 (2.3–3.1)	0.000

No patients infected with *Plasmodium malariae* and *Mixed* species developed complications. Nearly 20% of patients infected with *Plasmodium falciparum* had complications. Except for prefecture-level hospitals, the incidence of complications was relatively low for patients whose first visit was at a higher administrative level of the health care institution. There were 0%, 4.9%, and 8.1% complications in patients initially visiting provincial-level CDCs, provincial-level hospitals, and county-level hospitals, respectively. In contrast, there were 28.1%, 26.9%, and 20.0% complications in patients initially visiting village clinics, prefecture-level hospitals, and township health centers, respectively. The proportion of complications in patients with a correct initial diagnosis was 13.3%, whereas, it was 23.3% in patients with an incorrect initial diagnosis. Furthermore, malaria patients with complications tended to have a significantly longer time interval between onset and initial diagnosis (Table 4).

Table 4
Influential factors for complications developed among the malaria cases

Influential factors	Complications developed (% or 95% CI)		P value
	Yes	No	
Gender			
Male	91 (18.8)	394 (81.2)	0.793
Female	2 (22.2)	7 (77.8)	
Age (years)	38.8 (36.9–40.8)	38.2 (37.3–39.2)	
Marital Status			
Married	71 (18.0)	323 (82.0)	0.363
Single/divorce/separated	22 (22.0)	78 (78.0)	
Occupation			
Agriculture	23 (13.5)	147 (86.5)	0.029
No-agriculture	70 (21.6)	254 (78.4)	
Residence			
Unban	55 (18.1)	249 (81.9)	0.503
Rural	38 (20.5)	147 (79.5)	
Region			
Eastern	9 (13.4)	58 (86.6)	0.000
Central	84 (27.2)	225 (72.8)	
Western	0 (0.0)	118 (100.0)	
Insurance status			
Insured	68 (19.7)	278 (80.4)	0.472
Uninsured	25 (16.9)	123 (83.1)	
Plasmodium species			
Unclassified	24 (35.3)	44 (64.7)	0.000
Plasmodium falciparum	61 (19.8)	247 (80.2)	
Plasmodium ovale	6 (6.3)	89 (93.7)	

Influential factors	**Complications developed (% or 95% CI)**		**P value**
	Yes	**No**	
Plasmodium vivax	2 (13.3)	13 (86.7)	
Plasmodium malariae	0 (0.0)	3 (100.0)	
Mixed	0 (0.0)	5 (100.0)	
Rank of healthcare facilities for the initial diagnosis			
Village clinic	36 (28.1)	92 (71.9)	0.000
Township health center	4 (20.0)	16 (80.0)	
County-level CDC	3 (13.6)	19 (86.4)	
Prefecture-level CDC	2 (13.3)	13 (86.7)	
Provincial-level CDC	0 (0.0)	2 (100.0)	
County-level hospital	11 (8.1)	125 (91.9)	
Prefecture-level hospital	35 (26.9)	95 (73.1)	
Provincial-level hospital	2 (4.9)	39 (95.1)	
Initial diagnosis			
Misdiagnosis	61 (23.0)	204 (77.0)	0.008
Correct diagnosis	26 (13.3)	170 (86.7)	
Time interval between onset and initial diagnosis	1.4 (0.9–2.0)	2.1 (1.8–2.4)	0.030
Time interval between initial diagnosis and final diagnosis	4.2 (3.1–5.4)	3.1 (2.5–3.7)	0.080
Time interval between onset and final diagnosis	5.7 (4.5–6.9)	5.3 (4.7–6.0)	0.631

Decision tree classifier model

Figure 2 shows the decision tree classification of malaria patients being misdiagnosed. This model would be useful to identify the risk factors with the introduction of subgroups with similar risk levels and the risk factors for initial misdiagnosis in the studied patients. The decision tree classification of malaria patients being misdiagnosed consisted of six categorical variables that ranked by their importance: level of healthcare facilities for the initial diagnosis, time interval between onset and initial diagnosis, region, residence type, insurance status, and age. The accuracy of the prediction model was 85.0%.

The decision tree shows that in a subgroup of patients who visited clinics and township health centers for the first time, the probability of a patient being misdiagnosed was 100%. In the subgroup of patients who visited county-level hospitals for the first time, with patients from Eastern China, the probability of being misdiagnosed was 30.8%. In the same situation with patients from Central and Western China, if the time interval between onset and initial diagnosis > 0.5 days, the probability of being misdiagnosed was 68.4%, while if the time interval between onset and initial diagnosis ≤ 0.5 days and age > 41.5 years, there was a 100% probability of being misdiagnosed. In the subgroup of patients who visited healthcare facilities at the county-level and above for the first time, whose time interval between onset and initial diagnosis < 0.25 days, and who lived in the urban areas, 84.6% of individuals was misdiagnosed. In the same situation with the time interval between onset and initial diagnosis > 0.25 days, if the patients seeked care at different levels of CDC, 32.0% of the individuals were misdiagnosed.

Discussion

This study described the accuracy of the initial diagnosis of malaria cases with different characteristics, as well as the factors that affect the accuracy. This study also analyzed the importance of misdiagnosis influencing factors through the CART model. We found that the level of health care facilities for the initial visit was the most important factor affecting whether malaria patients were correctly diagnosed. The proportion of misdiagnosed patients seeking care in township health centers and clinics was 100%. The proportion of misdiagnosed patients seeking care in county-level hospitals dropped to about 70%. Even for patients seeking care at different levels of CDC in China, the rate of misdiagnosis was still very high, which was far from the goal of the National Malaria Elimination Program (NMEP) [31].

In 2010, the Chinese government launched the NMEP (2010–2020) to enable malaria patients to receive timely treatment and reduce delays. Through this action plan, the government provided a large amount of funding to health facilities at all levels to train clinicians to have the ability to perform blood tests for malaria parasites [32]. The studied year was very close to 2020, a year in which the goal was to equip health workers at all levels of facilities with the capacity to diagnose and treat malaria patients. However, according to our investigation, we observe that even though the National Health Commission has developed Rapid Diagnostic Test (RDTs) rolled out to all levels of health institutions, neither public health institutions such as the CDC nor hospitals can accurately diagnose malaria. It is a fact that with the elimination of local malaria, clinicians at all levels of health institutions, especially some health institutions at or below the county level, have not been exposed to malaria cases for a long time, which can easily lead to clinicians inaccurately diagnosing malaria patients with fever as common colds and neglecting to ask about their travel history [33, 34]. Moreover, it was also possible that these institutions may neither have the facilities required for diagnosis nor have physicians qualified to diagnose malaria [35]. In addition, most cases were imported falciparum malaria in the years studied, and the patients were usually in serious condition [36, 37]. Clinicians in health institutions at or below the county level may use their experience to make a preliminary malaria diagnosis. However, accurate diagnosis requires microscope tests and PCR. They would recommend patients to a higher-level hospital or CDC for further diagnosis and treatment.

It is noted that the time interval from the initial diagnosis to final diagnosis for patients seeking care initially in the county-level hospitals, township health centers, and clinics was longer than that of patients seeking care in a higher-level hospital or CDC. If the patient were diagnosed with malaria in time, the clinicians would develop an appropriate treatment plan for the patient, which will significantly reduce the occurrence of complications and prevent the progression of the disease. At the same time, it can also greatly reduce the cost of treatment and the economic burden of patients. The great disparity in the time interval from the initial diagnosis to final diagnosis for patients seeking care between different levels of health facilities should be noted. Patients living near higher-level hospitals usually have access to timely and high-quality medical services compared to patients living in rural areas. In particular, diseases such as malaria are easily misdiagnosed as common colds [38]. If primary health institutions cannot make a correct diagnosis for patients from rural areas, it will greatly increase the probability of their condition getting worse. After achieving the goal of eliminating malaria, it is also necessary to build the sustainable capacity of health workers and facilities at different levels to diagnose malaria, and establish a rapid referral system between primary care institutions and higher-level hospitals which are designated for malaria treatment in each prefecture-level area.

In our study, we also found that misdiagnosis rates between different regions varied greatly. Patients living in Western China were more likely to be misdiagnosed than those living in Eastern and Western China. It reminds us that the disparity of patients seeking care in different regions should be noted. For rural patients living in Western China, due to the inconvenience of transportation, they usually sought care in nearby clinics and township health centers [25]. In the case of insufficient diagnosis and treatment capabilities of local clinicians [21, 39], it was easy to cause patients to be misdiagnosed and delayed. There is a need to allocate more anti-malarial funds to the western region and train qualified doctors to narrow the health disparities between regions.

Limitations of the study

This study has at least three limitations. First, some variables used in the analysis need to be extracted from the medical records. However, a limited number of hospitals surveyed can provide complete medical records. Therefore, patients with incomplete electronic medical records were excluded from this study. Second, some hospitals surveyed refused to provide medical records, so, the actual collected cases are much smaller than the expected cases to be collected. Third, as to whether the patient was correctly diagnosed, some clinicians may not rely on the gold standard RDTs and microscopic examination but rely on personal experience to diagnose that the patient was infected with the plasmodium parasite and then referred the patient to a higher-level institution for further diagnosis. If, as described above, the clinician was unable to make a definite diagnosis, it was also considered a misdiagnosis. The consequence is that misdiagnosis may be overestimated.

Conclusions

Insufficient diagnostic capacity of healthcare facilities with lower administrative levels for the initial visit was found to be the most important risk factor in the Diagnosis of malaria patients. This study suggests that researchers and clinicians should consider comprehensively healthcare facilities for the initial diagnosis, the time interval between onset and initial diagnosis, residence type, and health insurance status to reduce the misdiagnosis rate.

Abbreviations

WHO, World Health Organization; NMEP, National Malaria Elimination Program; Rapid Diagnostic Tests (RDTs); CDCs, Centers for Disease Control and Prevention.

Declarations

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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, DLZ and ZC 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.

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Availability of data and materials

The datasets used in the current study are available from the corresponding author and will also be presented as a supplemental file to 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 to access and analyze the research data was taken from the National Health Commission of People's Republic China and the administrators of each hospital.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

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Figures

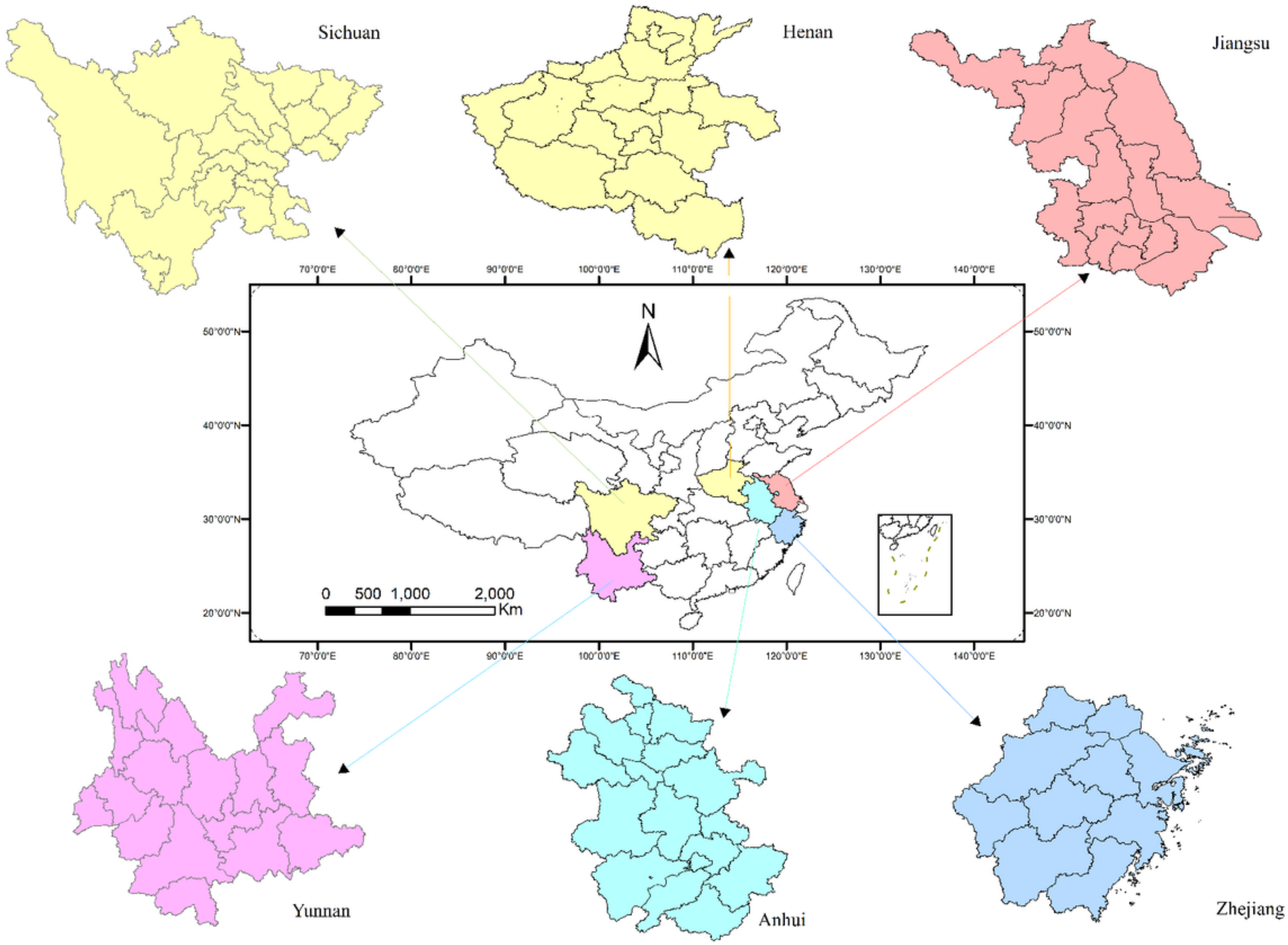

Figure 1

Geographic distribution of the six selected provinces in China

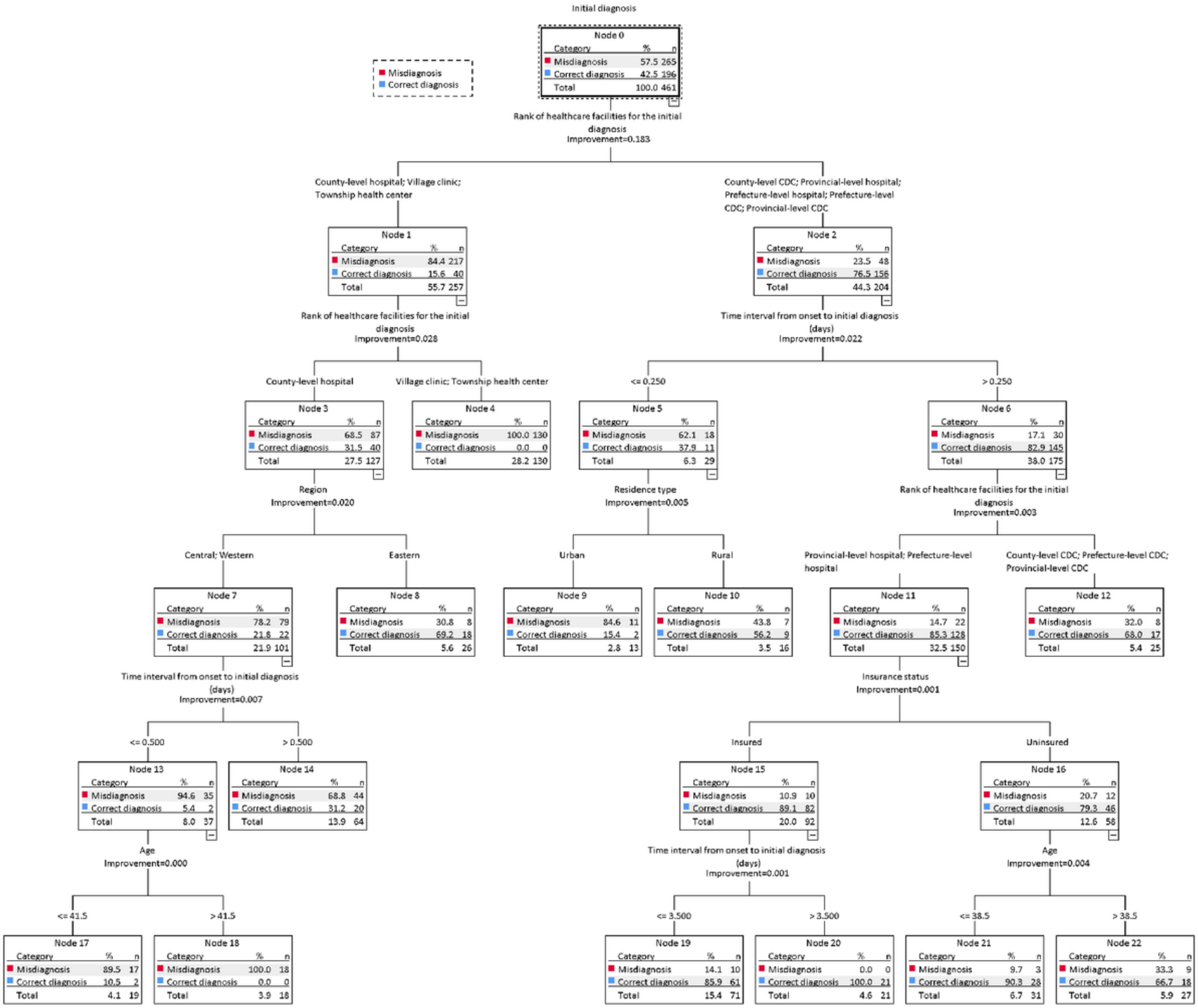

Figure 2

Tree model of initial diagnosis as dependent variable by CART method