OUTBREAK OF VIVAX MALARIA IN AREAS ADJACENT TO THE DEMILITARIZED ZONE, SOUTH KOREA, 1998

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Abstract. Malaria had been eradicated in the Republic of Korea (South Korea) by the late 1970s. In 1993, a soldier was infected with Plasmodium vivax in the Demilitarized Zone (DMZ; the border area between North and South Korea), and since then, the number of cases has been steadily increasing year after year. In 1998, 3,932 vivax malaria cases were microscopically confirmed, affecting 2,784 (70.8%) soldiers (including discharged soldiers) and 1,148 (29.2%) civilians. These cases occurred throughout the year, peaking in July (30.1%) and August (30.5%). Most of the patients were infected in areas in or near the DMZ. Taking into consideration entomologic, socioeconomic, and epidemiologic factors, it is postulated that there has been an epidemic of malaria in North Korea since 1993, with the number of cases increasing yearly; the continuous infiltration across the DMZ from North Korea of infected female mosquitoes of the vector species Anopheles sinensis resulted in an outbreak of vivax malaria in the DMZ of South Korea.

INTRODUCTION

In Korea, Plasmodium vivax malaria was prevalent throughout the country during the Korean War (1950–1953). In the summer of 1951, 3,169 cases among United States soldiers were reported, and there were 8,855 and 5,741 cases among Korean soldiers in 1953 and 1954, respectively. The incidence of malaria had progressively declined after the Korean War, particularly in the southwest plains. The government of the Republic of Korea, with the assistance of the World Health Organization (WHO), established the National Malaria Eradication Service in 1959. In the period 1961–1965, passive case detection activities, including drug administration, were implemented all over the country. A total of patients with 45,395 fever were examined for malaria parasites, and 13,929 patients were positive for Plasmodium vivax (30.7% of slide-positive rate). Mass blood surveys throughout the country in 1961–1965 showed that the number of malaria cases per 100,000 population was 0.54 in flat areas, 10.9 in hilly areas, and 34.6 in mountainous areas, in spite of a much higher density of vector mosquitoes in the flat areas.

Active case detection works were also applied in 3 main foci areas in 1963–1966 as a tool of malaria control, and these lasted until 1969 in some areas. In the 1960s, it was confirmed that in most flat areas, a state of anophelism with the number of cases increasing yearly; the continuous infiltration across the DMZ from North Korea of infected female mosquitoes of the vector species Anopheles sinensis resulted in an outbreak of vivax malaria in the DMZ of South Korea.

epidemiological, ecological, and social conditions in South Korea were almost identical to those in Japan.

Since one case of indigenous malaria was found at Paju-gun, Kyonggi-do in 1993, the number of cases has steadily increased year after year, totaling 25 cases in 1994, 107 in 1995, 356 in 1996, and 1,724 in 1997. In addition, a total of 40 cases were reported among members of the U.S. Army stationed in the western Demilitarized Zone (DMZ, the border area between North and South Korea) during 1994–1997. In 1998, vivax malaria in South Korea increased to 3,932 microscopically confirmed cases. Here, we report the 1998 malaria cases along with an epidemiological analysis.

MATERIALS AND METHODS

Because malaria is one of the second-class communicable diseases to be reported, physicians at hospitals and clinics all over Korea must report malaria cases to the Ministry of Health and Welfare through the National Institute of Health. Malaria cases among army soldiers are also reported by military hospitals to the Ministry of Health and Welfare. All the patients reported during January 1 to December 31, 1998, were collected and analyzed for epidemiological information.

The localities of malaria cases were divided into 2 areas: malarial and nonmalarial. The malarial areas where many cases were reported in 1993–1998 include Paju-si, Yonchon-gun, Kimpo-si, Koyang-si, Tongdunchon-si, Pochon-gun, and Yangju-gun in Kyonggi-do; Kangwha-gun in Inchon special city; and Cholwon-gun, Yanggu-gun, and Hwachon-gun in Kangwon-do, all of which are located within 10–20 km from the western flat and hilly areas of the DMZ. All other areas were treated as nonmalarial areas, where only a small number of cases were sporadically reported. A questionnaire was sent to civilian patients who were reported in nonmalarial area to determine where they had been infected.

The occurrence of cases in military personnel was analyzed weekly and compared with the seasonal prevalence of the population of the vector species, Anopheles sinensis, collected weekly by light traps at 4 locations near the DMZ (Paju-si, Hwachon-gun, Yanggu-gun, and Inje-gun) in 1998.
Meteorological data were collected from the monthly climatologic record of 2 meteorological stations (Seoul and Inchon), which are the nearest stations to the malarial area. Mean air temperature and total precipitation in the main mosquito season (June–August) were collected and compared with the averages from 1951–1980 at the same stations.

RESULTS

From January 1 to December 31, 1998, a total of 3,932 cases were officially reported in South Korea as laboratory-confirmed *Plasmodium vivax* malaria. Of these, 1,148 cases (29.2%) occurred in civilians and 2,784 cases (70.8%) occurred in soldiers, including discharged soldiers who were infected during army duty but in whom malarial paroxysms appeared after discharge from army service.

Malaria cases were reported throughout the year, totaling 6 cases (0.2%) in January, 8 (0.2%) in February, 9 (0.2%) in March, 40 (1.0%) in April, 164 (4.2%) in May, 509 (12.9%) in June, 1,182 (30.1%) in July, 1,199 (30.5%) in August, 553 (14.1%) in September, 219 (5.6%) in October, 34 (0.9%) in November, and 9 (0.2%) in December, a pattern of which was almost identical to the seasonal case occurrence in the 1960s (Figure 1). Weekly occurrence of 1,469 malaria cases in soldiers and the population density of the vector species (*Anopheles sinensis*) are compared in Figure 2. The number of *An. sinensis* rose steeply from the second week of June, reached a peak during the fourth week of June, and then continuously decreased until the fourth week of July. On the other hand, the malaria cases kept increasing from the first week of May, reaching a peak in the fourth week of July, maintaining a high occurrence until the second week of August, then sharply decreasing.

The age and sex of the civilian patients with malaria are given in Table 1. Among 2,784 cases occurring in soldiers, 1,379 were reported in Kyonggi-do, 119 in Inchon special city, 464 in Kangwon-do, 293 in Seoul special city, 30 in Chungchongbuk-do, 61 in Chungchongnam-do, 22 in Taegon special city, 40 in Kyongsangbuk, 51 in Taegu special city, 96 Kyongsangnam-do, 11 in Ulsan special city, 96 in Kyongsangnam-do, 106 in Pusan special city, 22 in Chollabuk-do, 56 in Chollanam-do, 28 in Kwangju special city, and 6 in Cheju-do. All these soldiers were stationed and served in or near the DMZ during their terms of service. The location of the cases occurring in civilians is given in Table 2. Among 1,148 cases of the civilians, 809 (70.5%) resided in malarial areas and 339 (29.5% of the civilians, or 8.6% of the total) resided in other areas. Among 339 patients in nonmalarial areas, 157 answered the questionnaire, and all of them had visited the malarial areas in the malaria-transmission season. Many of them (44.6%) had visited family members caught in a flood disaster in early August; 19.1% traveled for various business activities (official, commercial, and others) and 36.3% for recreational purposes. All of them stayed in the area for > 2 days (4.6 days on average). One hundred eighty-two civilians (4.6% of the total people with malaria) did not answer the questionnaire. All others (95.4%) were infected in the malarial areas (in or near the DMZ). Even though it was unclear where the 182 civilians were infected, it is postulated that they were not secondary cases because most of them resided in large urban areas (special cities) where malaria transmission does not occur, whereas the others who lived in rural areas were sporadically reported at different locations.

![Figure 1](image1.png)  
**Figure 1.** Monthly occurrence of *Plasmodium vivax* malaria cases in South Korea in the 1960s and in 1998.

![Figure 2](image2.png)  
**Figure 2.** Weekly occurrence of malaria cases and the population density of *Anopheles sinensis* at 4 locations in north Kyonggi-do in 1998. Cases of the shaded area would be infected in 1997.

### Table 1

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Male sex</th>
<th>Female sex</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–10</td>
<td>24</td>
<td>20</td>
<td>44</td>
<td>3.8</td>
</tr>
<tr>
<td>11–20</td>
<td>72</td>
<td>35</td>
<td>107</td>
<td>9.3</td>
</tr>
<tr>
<td>21–30</td>
<td>95</td>
<td>46</td>
<td>141</td>
<td>12.3</td>
</tr>
<tr>
<td>31–40</td>
<td>196</td>
<td>83</td>
<td>279</td>
<td>24.3</td>
</tr>
<tr>
<td>41–50</td>
<td>151</td>
<td>69</td>
<td>220</td>
<td>19.2</td>
</tr>
<tr>
<td>51–60</td>
<td>93</td>
<td>68</td>
<td>161</td>
<td>14.1</td>
</tr>
<tr>
<td>61–70</td>
<td>75</td>
<td>56</td>
<td>131</td>
<td>11.4</td>
</tr>
<tr>
<td>≥71</td>
<td>31</td>
<td>32</td>
<td>63</td>
<td>5.5</td>
</tr>
<tr>
<td>Total</td>
<td>737</td>
<td>409</td>
<td>1,146</td>
<td>100</td>
</tr>
<tr>
<td>%</td>
<td>64.3</td>
<td>35.7</td>
<td>100</td>
<td>–</td>
</tr>
</tbody>
</table>
DISCUSSION

The true number of malaria cases in previous years (1993–1997) in South Korea is confusing because different authors report the cases from different sources: 1) 650 civilians\(^1\); 2) 1,642 total (27 from the U.S. Army, 1,154 from the Republic of Korea army, and 461 civilians),\(^10\) and 3) 1,545 Republic of Korea army members\(^12\) and 2,219 total patients.\(^13\) The official data from the National Institute of Health\(^6\)–\(^9\) were 1 case in 1993, 20 cases in 1994, 107 cases in 1995, 356 cases in 1996, and 1,724 cases in 1997, as shown in Table 3. The total cases for 1998 increased 2.3-fold compared with 1997, for a 2.0-fold increase in soldiers and a 3.2-fold increase in civilians. From an epidemiological aspect, an increasing rate of cases of malaria in soldiers should have been higher than that of civilians because soldiers on sentry duty were extensively exposed to mosquito bites throughout the night in the DMZ; cows and pigs for zoophilic mosquito feeding were not available. The fact that most soldiers serving in or near the DMZ had been given antimalarial prophylaxis with chloroquine throughout the whole mosquito season and primaquine at end of the season resulted in a much lower increase in the number of affected soldiers compared with civilians.

Regarding the short-term incubation period of vivax malaria, affected patients usually appeared about a month after occurrence of vector mosquitoes, the result of the sporogonic period of 12 days and the incubation period of 13 days.\(^14\),\(^15\) However, Figures 1 and 2 show that vivax malaria in Korea occurred throughout the year, sharply increasing in May (before the numbers of vector mosquitoes started increasing), with the peak during the fourth week of July. All cases in January–May, and some cases in June–July, are estimated to be cases from a protracted incubation period; we believe the patients had been infected the previous summer. Tiburskaja and others\(^16\) reported that North Korean vivax malaria had both a 17–22-day short incubation period and a 274–386-day long incubation period. Garnham and others\(^17\) observed that exoerythrocytic stages of the North Korean strain could still be found in the liver 255 days after the second inocu-
lation of sporozoites. Tiburskaja and Vrublevskaja\(^1\) reported that among 77 artificially infected cases of the North Korean vivax strain, only 24.7% showed a short-term incubation period; all the others (75.3%) were prolonged incubation, showing 1.3, 14.3, 13.2, 18.2, 18.2, 16.9, 3.9, and 2.6% after 5, 8, 9, 10, 11, 12, and 13 months, respectively. The fact that the seasonal occurrence of the vivax malaria cases of 1998 showed 1.3, 14.3, 18.2, 18.2, 16.9, 3.9, and 2.6% after 5, 8, 9, 10, 11, 12, and 13 months, respectively. The fact that the seasonal occurrence of the vivax malaria cases of 1998 was the same as those in the 1960s (Figure 1) indirectly indicates that the present strain is identical to the previous one.

We have typical unstable vivax malaria in Korea. The vector species, An. sinensis, is highly zoophilic,\(^19\) has low to moderate longevity,\(^20\) and shows high population density.\(^20\) Climatic conditions are favorable for a short period of transmission (June–September), and immunity of the population is very low or nonexistent. Because South Korea eradicated malaria in the late 1970s, questions remain: what was the source of reinfection, and why have malaria cases been continuously increasing year after year since 1993, in spite of active control and prevention measures, such as case detection with treatment, frequent applications of pesticide by fogging, and personal protection against mosquito bites?

As previously mentioned,\(^21\) it has been speculated that the source of infection is the sporozoite-infected vector mosquitoes dispersed from North Korea across the DMZ. Recently, meteorological factors have been favorable to the vector population on the Korean peninsula (North and South Korea). There were floods after heavy rainfalls in July 1993, August 1995, June 1996, and August 1998, and higher temperature were recorded in 1994–1998 (Table 4).

As a consequence, the population density of vector mosquitoes increased considerably. There were few data available to compare the population density of An. sinensis between the earlier years and for 1993–1998. The number of An. sinensis per person per hour during a whole night of human biting collections was 34.8 at Okku, Chollabuk-do in 1964,\(^20\) 7.9 at Yangpyong, Kyonggi-do in 1965,\(^1\) and 2.1 at Sinchang, Chungchonnam-do in 1967,\(^22\) whereas they were 81.1 at Paju, Kyonggi-do in 1995.\(^23\) The number of An. sinensis per light trap per night through May–October averaged 172 at 18 locations in Chollabuk-do in 1985–1990,\(^24\) whereas they averaged 1,337 at 4 locations in north Kyonggi-do in 1995.\(^21\)

In South Korea, other vector or socioecological factors were unfavorable to malaria transmission. We have a well-organized passive case detection network for rapid case detection and treatment, so the source of infection can be eliminated without delay. Human-vector contact is very low because 1) An. sinensis is highly zoophilic, and many cows and pigs are available for mosquito feeding; 2) \(~80\%\) of the female mosquitoes appear after 11 PM, when most people are asleep inside mosquito-proof houses; 3) low to moderate longevity has resulted from agricultural pesticide applications and vector control measures, mainly by fogging; and 4) personal protection against mosquito bites is widely applied.\(^21\) It is difficult to produce a secondary case from a primary patient, because a vector mosquito has to bite a patient (primary case), and then bite a human (secondary case) again after the 12 days of the sporogonic period. Because the human blood index of An. sinensis was 0.007 at a malarious area in 1999,\(^25\) the probability of 2 human bites by one mosquito is 0.000049. Because the proportion of daily survival of An. sinensis was 0.871 at malarious areas in 1999,\(^25\) the proportion of survival for 12 days is 0.0191. Therefore, the probability of a mosquito biting 2 humans at a 12-day interval would be 0.0000094. On the other hand, when it is postulated that malaria cases are trans-

### Table 3

Number of vivax malaria cases in South Korea in 1993–1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Active duty</th>
<th>Discharged*</th>
<th>Total</th>
<th>Civilians</th>
<th>Total no. of cases</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>1994</td>
<td>18</td>
<td>0</td>
<td>18 (90%)</td>
<td>2 (10%)</td>
<td>2</td>
<td>20×</td>
</tr>
<tr>
<td>1995</td>
<td>88</td>
<td>11</td>
<td>99 (92.5%)</td>
<td>8 (7.5%)</td>
<td>107</td>
<td>5.4×</td>
</tr>
<tr>
<td>1996</td>
<td>285</td>
<td>24</td>
<td>309 (86.8%)</td>
<td>47 (13.2%)</td>
<td>356</td>
<td>3.3×</td>
</tr>
<tr>
<td>1997</td>
<td>1,156</td>
<td>207</td>
<td>1,363 (79.1%)</td>
<td>361 (20.9%)</td>
<td>1,724</td>
<td>4.8×</td>
</tr>
<tr>
<td>1998</td>
<td>1,657</td>
<td>1,127</td>
<td>2,784 (70.8%)</td>
<td>1,148 (29.2%)</td>
<td>3,932</td>
<td>2.3×</td>
</tr>
<tr>
<td>Total</td>
<td>3,205</td>
<td>1,369</td>
<td>4,574 (74.5%)</td>
<td>1,566 (25.5%)</td>
<td>6,140</td>
<td>–</td>
</tr>
</tbody>
</table>

* These soldiers with malaria were infected while on service in or near the Demilitarized Zone, and paroxysm occurred at home after discharge.

### Table 4

Precipitation and average temperature of north Kyonggi-do (average of Inchon and Seoul) during the mosquito seasons of 1993–1996

<table>
<thead>
<tr>
<th>Year</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Total</th>
<th>Fold</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Average</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>167</td>
<td>438†</td>
<td>169</td>
<td>774</td>
<td>1.1×</td>
<td>20.6</td>
<td>23.9</td>
<td>23.1</td>
<td>22.5</td>
<td>−0.7</td>
</tr>
<tr>
<td>1994</td>
<td>74</td>
<td>117</td>
<td>253</td>
<td>444</td>
<td>−1.6×</td>
<td>21.9</td>
<td>27.9</td>
<td>27.4</td>
<td>25.7</td>
<td>+2.5</td>
</tr>
<tr>
<td>1995</td>
<td>77</td>
<td>402†</td>
<td>101</td>
<td>741</td>
<td>1.6×</td>
<td>21.0</td>
<td>24.1</td>
<td>25.9</td>
<td>23.7</td>
<td>+0.5</td>
</tr>
<tr>
<td>1996</td>
<td>245</td>
<td>395</td>
<td>24</td>
<td>1,183</td>
<td>1.0×</td>
<td>21.5</td>
<td>24.0</td>
<td>25.7</td>
<td>23.7</td>
<td>+0.4</td>
</tr>
<tr>
<td>1997</td>
<td>93</td>
<td>265</td>
<td>230</td>
<td>588</td>
<td>−1.2×</td>
<td>22.6</td>
<td>25.5</td>
<td>26.5</td>
<td>24.9</td>
<td>+1.7</td>
</tr>
<tr>
<td>1998</td>
<td>211</td>
<td>319</td>
<td>903†</td>
<td>1,432</td>
<td>2.0×</td>
<td>21.3</td>
<td>24.5</td>
<td>25.0</td>
<td>23.6</td>
<td>+0.4</td>
</tr>
</tbody>
</table>

* Average of Inchon and Seoul.
† Flood with a local downpour.
mitted by sporozoite-infected mosquitoes dispersed from North Korea, just one random bite produces a case. The chance should be high enough to produce many cases, compared with 2 bites with a 12-day interval.

In North Korea, entomologic, socioeconomic, and human behavioral factors may be favorable to malaria transmission. Such factors, among others, include poor medical facilities; no antimalarial drugs; malnutrition; very few cows and pigs, compelling mosquitoes to attack the human population; poor housing; no personal protection against mosquito bites; and the long mosquito life span, resulting from the lack of vector control activities and agricultural pesticide application. These postulates on the situation of North Korea are all based on newspaper reports, unofficial information, and other sources because official information from North Korea is not available. However, the government of North Korea did officially admit for the first time in 1998 that there was malaria in 3 provinces (Kangwon, South Hwanghae, and Kaesong) along the DMZ and in 4 neighboring provinces (North Hwanghae, South Pyongan, North Pyongan, and Nampo), and requested the WHO Regional Office for Southeast Asia to provide 100 kg of chloroquine-phosphate powder.

We postulate that there has been an epidemic of malaria in North Korea since 1993, with the number of cases increasing year after year, and the continuous infiltration of infected females of *An. sinensis* across the DMZ from North Korea has resulted in an outbreak of vivax malaria at the border area of South Korea, which is located at the peripheral edge of an epidemic area of North Korea.

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