Epidemiology of malaria in the municipality of Cruzeiro do Sul, State of Acre, Brazil, in 2010: uses of a control chart at the local level

ABSTRACT

Introduction: This study describes the uses of a control chart in the malaria surveillance at the local level, signaling whether there is a need to intensify or adapt control measures. Methods: The districts of Cruzeiro do Sul (n=14), State of Acre, Brazil, were classified into three groups: I) those with an incidence lower than expected; II) those with an incidence within the expected range; and III) those with an epidemic. Results: Thirteen of the fourteen districts had outbreaks of malaria at some point in 2010, and six districts showed persistent malaria epidemic throughout the year. Conclusions: The control chart may help the malaria control at the local level.

Keywords: Malaria. Control chart. Brazilian Amazon.
and January of 2007 - were then excluded. The same procedure was adopted for the months of February to December. The time series were defined using the five remaining monthly values, thus, enabling calculation of the lower control limit (LCL) and upper control limit (UCL) monthly. The districts were classified into three groups: I) those who had disease incidence below the expected threshold; II) those who reported cases of the disease within the expected range; and III) those who registered as malaria epidemics.

The data were obtained from the Epidemiological Surveillance Information System for Malaria (SIVEP-Malaria), the State Secretariat for Health of Acre, and the Municipal Secretariat for Health of Cruzeiro do Sul. The Epi-info statistical software was used for data analysis. The methodology of this study was approved by the Ethics Committee of the School of Medicine of the University of Brasilia. The use of malaria notification data was authorized by the Health Surveillance Secretariat of the Ministry of Health.

Table 1 shows the autochthonous malaria cases notified by month and year of occurrence in the period of 2003 to 2010. Analysis of the control chart based on time series of the total number of malaria cases (all species) showed that, in the municipality of Cruzeiro do Sul, all the months of 2010 were epidemic for this disease (Figure 1A). This result allowed us to infer that, at least since January 2010, the incidence of malaria showed a less-than-expected response in relation to the control measures. The incidence of *P. falciparum* behaved differently (Figure 1B). Epidemic months for *P. falciparum* occurred from January to September 2010. It should be observed that there was a sharp increase in notifications in May; however, there was a decrease in the subsequent months. However, since October, registered cases remained below the upper control limit, establishing the end of the *P. falciparum* epidemic. Nonetheless, with the persistent incidence of cases within the upper and lower control ranges, the researchers can infer that the response of *P. falciparum* malaria to control measures met what was expected for 2010.

An analysis of the control chart and variation of the total incidence of malaria cases in 2010, based on 14 districts (Figure 2), indicated that there was a reduction in numbers below the lower limit - although for a few months only and at the end of the year - in three districts

**Table 1 - Autochthonous cases of malaria and *Plasmodium falciparum* malaria reported, according to the year and month, in Cruzeiro do Sul, State of Acre, Brazil, from 2003 to 2010.**

<table>
<thead>
<tr>
<th>Year</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td>posit</td>
<td><em>Pf</em></td>
<td>posit</td>
<td><em>Pf</em></td>
<td>posit</td>
<td><em>Pf</em></td>
<td>posit</td>
<td><em>Pf</em></td>
</tr>
<tr>
<td>Jan</td>
<td>140</td>
<td>13</td>
<td>1,150</td>
<td>238</td>
<td>960</td>
<td>180</td>
<td>6,071</td>
<td>1,914</td>
</tr>
<tr>
<td>Feb</td>
<td>94</td>
<td>26</td>
<td>1,012</td>
<td>223</td>
<td>793</td>
<td>160</td>
<td>3,841</td>
<td>1,365</td>
</tr>
<tr>
<td>Mar</td>
<td>146</td>
<td>30</td>
<td>2,024</td>
<td>502</td>
<td>755</td>
<td>131</td>
<td>4,380</td>
<td>1,642</td>
</tr>
<tr>
<td>Apr</td>
<td>172</td>
<td>51</td>
<td>1,599</td>
<td>356</td>
<td>941</td>
<td>149</td>
<td>4,879</td>
<td>1,487</td>
</tr>
<tr>
<td>May</td>
<td>138</td>
<td>23</td>
<td>1,172</td>
<td>300</td>
<td>1,104</td>
<td>211</td>
<td>4,412</td>
<td>1,705</td>
</tr>
<tr>
<td>Jun</td>
<td>138</td>
<td>24</td>
<td>923</td>
<td>248</td>
<td>1,789</td>
<td>294</td>
<td>3,972</td>
<td>1,559</td>
</tr>
<tr>
<td>Jul</td>
<td>140</td>
<td>31</td>
<td>740</td>
<td>157</td>
<td>2,194</td>
<td>388</td>
<td>3,852</td>
<td>1,700</td>
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<tr>
<td>Aug</td>
<td>149</td>
<td>34</td>
<td>696</td>
<td>105</td>
<td>1,719</td>
<td>359</td>
<td>3,239</td>
<td>1,323</td>
</tr>
<tr>
<td>Sep</td>
<td>249</td>
<td>59</td>
<td>955</td>
<td>144</td>
<td>1,509</td>
<td>438</td>
<td>2,602</td>
<td>931</td>
</tr>
<tr>
<td>Oct</td>
<td>400</td>
<td>74</td>
<td>1,326</td>
<td>245</td>
<td>2,416</td>
<td>668</td>
<td>3,113</td>
<td>771</td>
</tr>
<tr>
<td>Nov</td>
<td>796</td>
<td>189</td>
<td>1,695</td>
<td>335</td>
<td>5,142</td>
<td>1,525</td>
<td>3,482</td>
<td>873</td>
</tr>
<tr>
<td>Dec</td>
<td>1,328</td>
<td>401</td>
<td>1,380</td>
<td>269</td>
<td>5,722</td>
<td>1,787</td>
<td>2,604</td>
<td>578</td>
</tr>
<tr>
<td>Total</td>
<td>3,890</td>
<td>955</td>
<td>14,672</td>
<td>3,122</td>
<td>25,044</td>
<td>6,290</td>
<td>45,447</td>
<td>15,848</td>
</tr>
</tbody>
</table>

Source: Ministry of Health – Epidemiological Surveillance Information System for Malaria (SIVEP-Malaria).

**posi**: Autochthonous cases of malaria (all species); **Pf**: *Plasmodium falciparum* malaria cases.
(Districts 2, 3, 4, 6, 7, and 11), basically, all of the 12 months of 2010 were epidemic (except for District 3, where 11 months were epidemic). Moreover, all of the 14 districts of Cruzeiro do Sul registered at least one epidemic month in 2010, except for District 8, where the incidence of the disease remained within expected values (or occasionally below them) throughout the year.

As mentioned earlier, District 13 has a single locality, where there were no notifications of the disease in 2010, except for the months of January, May, and November. In this district, the lower limits of the control chart were also equal to zero, which do not allow us to observe a reduction below the expected limits and complicate the analysis of these data (Figure 2).

When analyzing only the last two months of the year (November and December of 2010), the researchers noted that the epidemic persisted in seven districts (Districts 2, 3, 4, 5, 6, 7, and 11), indicating that the response with regards to incidence of the disease was less than expected in terms of the control measures adopted (Figure 2). In other 6 districts (Districts 1, 8, 9, 10, 12, and 14), the incidence of the disease during these two months was within or below the expected ranges, indicating control of the epidemic.

An analysis of the time distribution of incident cases of malaria in contrast to expected values based on a historical series not only allowed us to discuss how useful this methodology is but also helped to describe the seasonality of the event and to raise hypotheses about the effectiveness of the control measures adopted. An analysis of the notifications in Cruzeiro do Sul described that 13 of the 14 districts had an epidemic at some point during the year 2010, and 6 districts showed persistence of the epidemic throughout the year.

Prevention is a key element in disease control. Even when recommended actions are being taken, the researchers must anticipate the problem to prevent damage by reducing the incidence of the disease and its consequences for the population9. Other ways, such as soil conditions, vegetation, temperature, high humidity, and abundant rainfall are highly conducive to malaria transmission10, and all of these conditions are present throughout the territory of Cruzeiro do Sul, like most other municipalities of the Brazilian Amazon. In addition, other factors associated with humans and biological issues related to Plasmodium, and the vector may contribute to worsen the situation11. It should be noted that the density of the malaria vector is high in the municipality, which is probably related to the increased number of fish farming tanks. The main economic activities, whose characteristics are primarily rural, possibly favor migration of the population between the rural and urban areas, making this population with low or no acquired immunity12 susceptible to the disease and leading to high levels of malaria transmission in the municipality.

In this study, in addition to detecting malaria epidemics, the control chart was applied to other uses as well. For instance, it was used for assessing the results of the control measures, according to the behavior shown in the chart in terms of monthly incidence of the disease in the year of monitoring. This function allowed authorities to collect evidence, even if preliminary, at the district or municipal level, in a simple and quick manner about the possible impact of the interventions being adopted, thus, allowing for necessary adjustments in a timely manner or further studies in specific locations that are not responding. The use of a control chart entirely devoted to early detection of epidemics may shift the focus from the need of effectively reducing the incidence of malaria - as long as it remains within the expected limit, which restricts its contribution to the population facing the social and economic damage brought about by this disease. The functions of the control chart demonstrated in this study will bring a challenge for authorities who, besides seeking reduction in the absolute number of cases compared with previous years, will be able to consider statistical parameters to define targets for the reduction of the disease - guided by historical series, which will point to effective control when the incidence of the disease remains below the lower limits of the control chart.

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**FIGURE 2** – Control chart of malaria cases, according to different health districts in the municipality of Cruzeiro do Sul, State of Acre, Brazil, from 2003 to 2010. LCL: lower control limit; UCL: upper control limit.
Finally, for the control chart to be better applied by local teams, as in the districts of Cruzeiro do Sul and other municipalities, it is important that the process of chart generation be automated. The main objective of automation is to ensure that the result is obtained several times in the same time range and with the same quality in a valid and reproducible way.

To improve the epidemiological surveillance of malaria, it is recommended that the use of the control chart be included in the routine services undertaken in the municipalities of the Brazilian Amazon. Control charts can serve as an additional tool to help detect outbreaks and epidemics timely and, also, to monitor the results of actions aimed at controlling the disease at the local level. There must be prompt update of notifications, allowing for analysis for proper interventions. The automation of the tool will ensure the validity and reproducibility of the results, which will serve to support disease surveillance. It is necessary that professionals have a better understanding of the epidemiological data of an area, seeking other forms of control at the local level besides those usually developed to effectively reduce the disease. It is also important that they carry out specific studies to better understand the context of areas not responsive to the control measures adopted.

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**REFERENCES**


**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest.