Communication/Comunicação

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

Epidemiologia da malária no município de Cruzeiro do Sul, Estado do Acre, Brasil, no ano de 2010: demonstração dos usos do diagrama de controle em nível local

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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.

RESUMO

Introdução: Este estudo descreve os usos do diagrama de controle na vigilância da malária, em nível local, alertando sobre a necessidade de intensificar ou adequar ações de controle. **Métodos:** Os distritos de Cruzeiro do Sul (n=14), Estado do Acre, Brasil, foram classificados em 3 grupos: I) com incidência abaixo dos valores esperados; II) com incidência dentro dos valores esperados; III) com epidemia. **Resultados:** Treze dos quatorze distritos apresentaram epidemias em algum momento no ano e seis apresentaram persistência da condição epidêmica ao longo de todo o ano de 2010. **Conclusões:** O diagrama de controle poderá subsidiar o controle da malária em nível local.

Palavras-chaves: Malária. Diagrama de controle. Amazônia Brasileira.

Despite advances in the surveillance and control of malaria by various interventions over the years, some issues have not yet been resolved, and the incidence of the disease remains high in some municipalities of the Brazilian Amazon. In 2009, more than 60 municipalities were classified as high-risk for malaria transmission. This high parasite index indicated the need for improved surveillance of the disease to support control measures and prevent an epidemic situation, with more cases reported than expected. It is also necessary to routinely evaluate whether these actions are contributing to reduce the incidence of the disease.

Important studies have been conducted to monitor the incidence of the disease and support control measures. These included the early warning system for malaria control in northern Thailand[1], the systems for the early detection of malaria epidemics in Africa[2], the malaria early warning in Kenya[3,4], and alert threshold algorithms and malaria epidemic detection in Ethiopia[5]. In Brazil, a study, conducted with national data, concluded that the control chart based on the median and third quartile was the most suitable for early detection of malaria epidemics in the Brazilian Amazon[6]. In addition, one of World Health Organization's (WHO) strategies for disease control is to strengthen the local capacity to enable and promote regular assessment of malaria, aiming at appropriate and timely interventions. In this sense, this study presents a proposal for use of the control chart to perform an epidemiological evalution of the disease in municipal micro-areas, modeled after analysis of the incidence of malaria in the municipality of Cruzeiro do Sul in 2010.

The municipality of Cruzeiro do Sul, located in the state of Acre, in the Brazilian Amazon, recorded 21,397 autochthonous cases of malaria in 2010, accounting alone for 58.5% of all notifications in the state. It was the 4th in the number of cases of the disease in Brazil, accounting for 5.2% of the total cases in the country. It is the second most populous City of Acre, with 78,444 inhabitants[7], which represents 10.7% of the total state population. To facilitate the control of malaria, the municipality was geographically divided into 14 districts and 168 localities.

To develop a control chart, the researchers considered the total number of positive cases (all species: *Plasmodium falciparum* + *Plasmodium vivax*) and the total number of positive cases of *P. falciparum* malaria, as it causes a more severe disease in infected patients. The researchers considered only cases to whom the reported place of infection was Cruzeiro do Sul, according to the information system. The analysis was conducted on the overall incidence of malaria in the municipality and also on the incidence of malaria stratified by the 14 districts. The year of monitoring was 2010.

To define the limits of the control chart, the researchers considered the quartiles of distribution of malaria cases based on the time series of monthly incidences from 2003 to 2009. The lower control limit of incidence (first quartile) and the upper control limit (third quartile) were calculated using the following criteria: first, the monthly incidences of the seven years preceding the year of monitoring were identified; next, the researchers excluded the two highest incidences of each month. For instance, in Cruzeiro do Sul, the following monthly incidences were recorded in January from 2003 to 2009: in 2003 (140 cases), 2004 (1,150), 2005 (960), 2006 (6,071), 2007 (2,348), 2008 (1,988), and 2009 (1,411 cases). Data with the highest number of notifications - January of 2006

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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[8]. 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 and only at the end of the year - in three districts
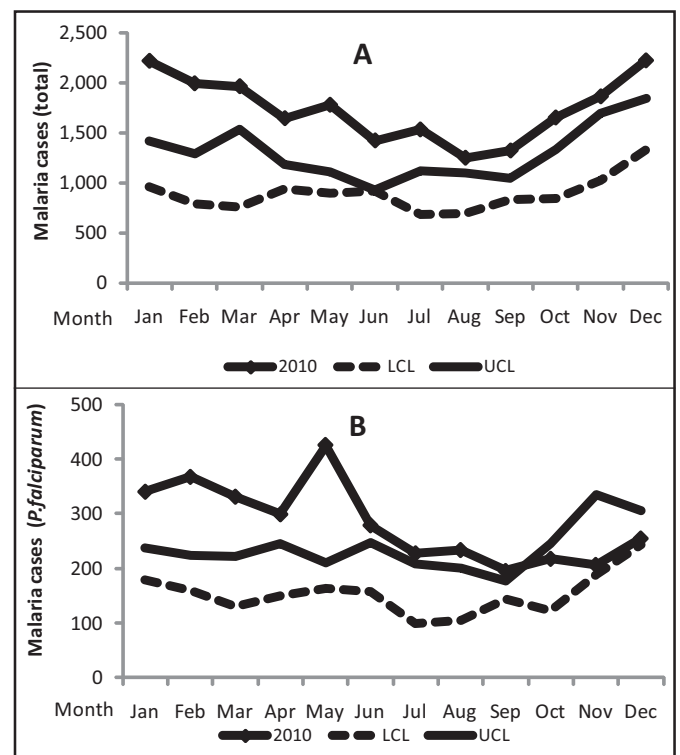
FIGURE 1 - Control chart of malaria cases in the municipality of Cruzeiro do Sul, State of Acre, Brazil, from 2003 to 2010.

LCL: lower control limit; **UCL:** upper control limit.

(Districts 8, 9, and 14), suggesting transient effectiveness of the control measures in these areas.

It was also noted that the incidence of malaria remained within or below the expected ranges in six districts (Districts 1, 8, 9, 10, 12, and 14) at the end of the second half of 2010 (**Figure 2**). District 5, despite the fact that the incidence of malaria remained within expected ranges most of the time, showed a significant increase of incidence starting in October of 2010, which characterized an epidemic at that time and place. In the remaining 6 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.

Month	Year															
	2003		2004		2005		2006		2007		2008		2009		2010	
	posit	Pf	posit	Pf	posit	Pf	posit	Pf	posit	Pf	posit	Pf	posit	Pf	posit	Pf
Jan	140	13	1,150	238	960	180	6,071	1,914	2,348	454	1,988	292	1,411	215	2,218	340
Feb	94	26	1,012	223	793	160	3,841	1,365	1,958	375	1,463	234	1,284	183	1,992	367
Mar	146	30	2,024	502	755	131	4,380	1,642	2,130	439	1,529	222	1,266	217	1,963	331
Apr	172	51	1,599	356	941	149	3,879	1,487	2,200	428	1,184	193	1,004	245	1,642	299
May	138	23	1,172	300	1,104	211	4,412	1,705	2,041	386	993	164	891	182	1,777	425
Jun	138	24	923	248	1,789	294	3,972	1,559	2,326	483	922	158	915	189	1,419	279
Jul	140	31	740	157	2,194	388	3,852	1,700	2,296	524	685	100	1,117	209	1,529	228
Aug	149	34	696	105	1,719	359	3,239	1,323	2,121	365	764	139	1,093	201	1,245	234
Sep	249	59	955	144	1,509	438	2,602	931	1,651	291	833	172	1,045	178	1,318	196
Oct	400	74	1,326	245	2,416	668	3,113	771	2,744	526	841	178	1,129	123	1,658	218
Nov	796	189	1,695	335	5,142	1,525	3,482	873	2,623	434	1,017	176	1,698	263	2,413	289
Dec	1,328	401	1,380	269	5,722	1,787	2,604	578	1,927	305	1,246	230	1,837	244	2,223	255
Total	**3,890**	**955**	**14,672**	**3,122**	**25,044**	**6,290**	**45,447**	**15,848**	**26,365**	**5,010**	**13,465**	**2,258**	**14,690**	**2,449**	**21,397**	**3.461**

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

posit: Autochthonous cases of malaria (all species); **Pf:** *Plasmodium falciparum* malaria cases.
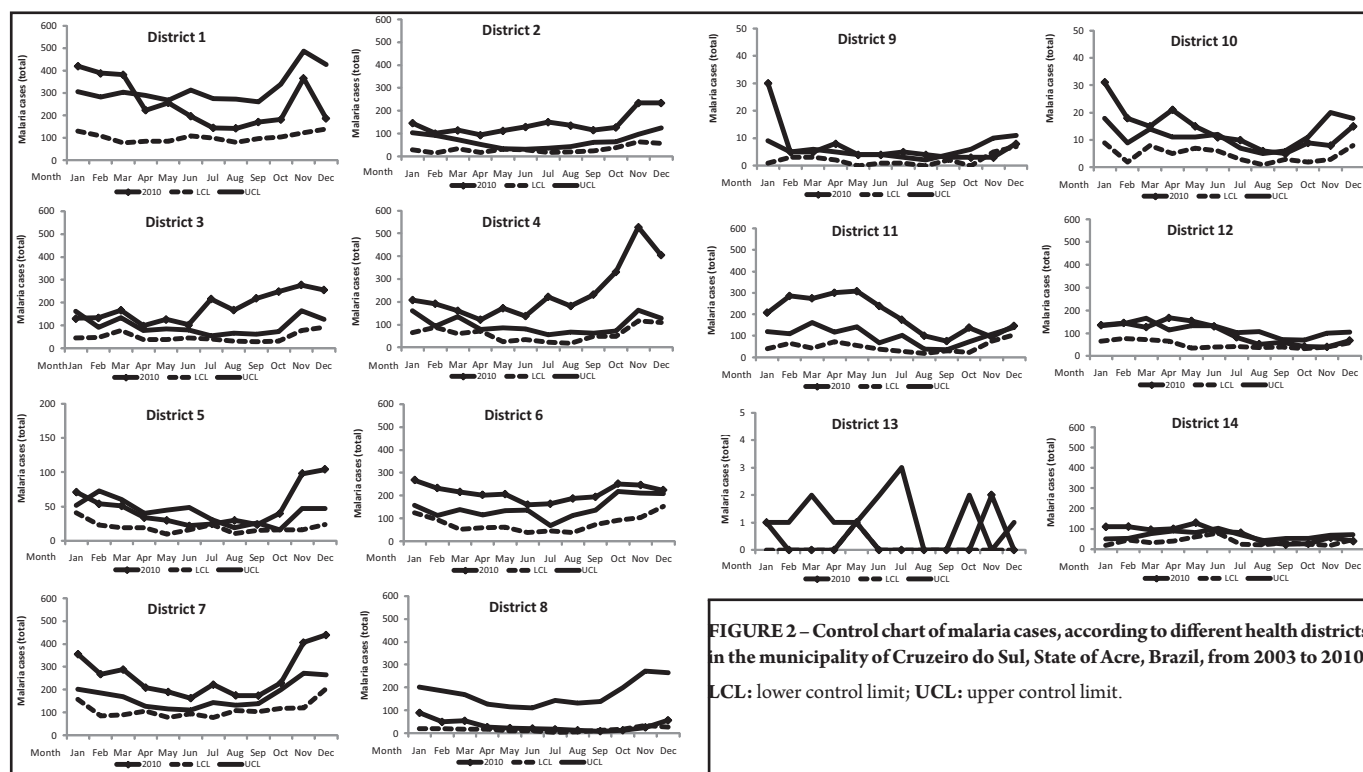
FIGURE 2 – Control chart of malaria cases, according to different health districts in the municipality of Cruzeiro do Sul, State of Acre, Brazil, from 2003 to 2010.
LCL: lower control limit; **UCL:** upper control limit.

(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 population[9]. Other ways, such as soil conditions, vegetation, temperature, high humidity, and abundant rainfall are highly conducive to malaria

transmission[10], 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 situation[11]. 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 immunity[12] 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.

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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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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