Using retrospective epidemiological data to determine malaria epidemic prone areas and development of an epidemic early warning system in Mpwapwa District, Central Tanzania

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Abstract: This study was carried out in order to determine the occurrence of malaria epidemics and epidemic prone areas and to develop an early warning system in Mpwapwa district of central Tanzania. Retrospective epidemiological and meteorological data covering a period of 5 years (1998-2002) were collected. Data from health facilities indicated that the district experienced marked malaria epidemics in 1999 and 2001. A positive relationship was observed between monthly malaria cases and maximum temperature. Similarly, a remarkably high number of severely affected and admitted malaria patients were recorded in 1999 and 2001. There was a marked increase in the number of severe cases of malaria during May-June 1999 and March 2001 coinciding with periods of malaria epidemics in the district. A 4-fold increase in cases of severe malaria was observed in May 1999 as compared with the same period in 1998. From 2000 to 2001 the cases of severe malaria increased by 8-folds during the same period of the year. There was a sharp increase in the number of blood transfusion during the malaria epidemic of March 2001. During this period of epidemic, there was an increase in malaria case fatality rate in both age groups and a 50% increase of cases of severe and complicated malaria. In the two identified epidemic years (1999 and 2001) the total number of patients aged ≥5 years admitted to the district hospital due to malaria doubled compared with those of the respective previous years. The marked malaria epidemic was associated with higher ambient temperature, a previous long period of drought and, long periods of rainfall during the year. It is concluded that an effective district malaria early warning system should be developed to provide a prompt and adequate action towards reduction of morbidity and mortality rates, and to reduce the number of new cases and the spread of the disease to other areas.

Key words: malaria, epidemics, surveillance, early warning system, Tanzania

Introduction

Malaria is the commonest communicable disease in Tanzania, being the primary cause of morbidity and mortality in the country. However, malaria endemicity in the country is not homogenous. In the warm humid coastal and low-lying areas transmission occurs throughout the year. In other areas malaria transmission occurs during part of the year and in a few areas it occurs as epidemics and only in some years (Mboera & Kitua, 2001).

Malaria epidemic may be defined as a sharp increase in the incidence of a disease among a population in which it was unknown. Conversely, it may refer to a seasonal or other increase of clinical malaria in an area with moderately endemic malaria (Gilles, 1993), or the occurrence of a number of new cases of malaria clearly exceeding the number expected at a particular time and place.

Frequent malaria epidemics have been reported in some districts of Tanzania. These include the semi-arid areas of Dodoma and mountainous areas of Muheza, Lushoto, Babati, Hanang, Mbulu, Muleba, Sumbawanga and Loliondo Districts (Mboera & Kitua, 2001; Mboera, 2004). Many of the observed malaria epidemics in the country were associated with an increase in immigrants into and from malarious areas, antimalarial drug resistance and ecological changes (Mboera, 2004).

Most malaria epidemics in Tanzania occur unnoticed, and if noticed, the response is often too late to save lives of severely affected individuals. This situation could be prevented where there is a mechanism in place to predict the occurrence of such outbreaks for better epidemic preparedness. Epidemics should therefore, be detected early enough in their evolution to prevent or at least to mitigate their effects, as far as possible, their impact on mortality and severe morbidity. It is therefore necessary to establish a monitoring system capable of detecting the earliest indicators that trigger the chain of determinant events.

Morbidity monitoring has been the classic method of epidemiological surveillance, in which one of the standard methods of detecting deviations from

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normality has been the plotting of endemoepidemic indices (Najera *et al.,* 1998). The first step to establish a malaria epidemic monitoring system requires the collection of retrospective monthly data of at least 5 years (Najera *et al.*, 1998). This will helps to establish "normal malaria trend" from which deviations from the normal can be plotted. Health facility-based epidemiological data may be used to monitor the trend of morbidity and mortality due to malaria. In general, an epidemic of malaria may be identified in a situation when the numbers of malaria cases are in excess of the normal number at a specific period of time and place. Therefore the""normal" numbers have to be known by taking epidemiological data of several years into consideration.

The objective of this study was to collect retrospective epidemiological and meteorological data that could be used to determine epidemic prone areas and develop a malaria epidemic early warning system in Mpwapwa district of central Tanzania.

Materials and Methods

Study area

This study was carried out in Mpwapwa District (6°45'S, 36°20'E) of central Tanzania. The area receives an average precipitation of about 700 mm per year with a unimodal type of distribution of which about 90% falls between December and April, and there is usually a dry spell in February. Average monthly temperatures ranges from a minimum of 15.8°C in August to a maximum of 27.7°C in November (Mboera *et al.,* 2001).

Retrospective epidemiological and meteorological data

Data on malaria cases and deaths were collected from all health facilities in the district using Health Management Information System (HMIS) Book 2/27(A-B). From each health facility, data collected included: (i) number of clinically diagnosed malaria cases; (ii) number of microscopically diagnosed malaria cases; (iii) number of blood transfusion carried out in the facilities; (iv) numbers of admission and number of malaria in-patients; (v) number of malaria specific deaths among in-patients; and (vi) number of patients diagnosed with anaemia.

Monthly data on temperature, rainfall and relative humidity were obtained from the Livestock Production Research Institute, Mpwapwa. Epidemiological and meteorological data covering a period from 1991-2001 were collected.

Data analysis

Data were collected and entered in a Microsoft Excel matrix that was prepared for the purpose. For each health facility, the monthly malaria cases for each year from 1997 to 2001 were analysed. Among the data for the five years, the largest and the 2nd largest number of cases for each month were determined. A line graph was plotted for the 2nd largest number of cases. This line graph served as a reference "normal malaria trend" comparing data for subsequent years. The line represented the upper normal limit of number of cases seen at the health facility. During the subsequent years, monthly malaria cases were plotted on the reference line graph. When the monthly number of cases exceeded a point on the original reference line graph or the upper normal limit, it indicated the beginning of an epidemic.

This procedure was followed for each of the five years selected. The reference line-graph plotted for "the 2nd largest number" known as the third quartile for the data incorporating 5 observations was also plotted. Yearly variations below or equal to the third quartile were assumed to be normal variations. Any number greater than the 2nd largest number was therefore, assumed to be abnormally high.

Results

On average over 80,694 malaria cases were reported annually in the district. Of these 39.4% were in the <5 years children and 60.6% in individuals ≥5 years. Among the outpatients, malaria accounted for 37-47% of all diagnoses at health facilities in the district.

Table 1: Outpatient malaria and anaemia cases between 1997 and 2001 in Mpwapwa District

Year	1997	1998	1999	2000	2001
Total population	222,817	228,296	233,910	239,662	245,414
Total ≥ 5 yr	176,026	180,354	184,789	189,333	193,877
Total < 5 yr	46,792	47,942	49,121	50,329	100,413
Malaria in ≥5	22,304	29,598	39,970	35,253	20,554
Malaria In > 5	36,966	47,430	58,918	52,336	29,526
Total malaria cases	59,270	77,028	98,888	87,589	50,080
Total diagnosis in < 5	53,020	70,967	90,960	88,214	43,565
Total diagnosis in ≥ 5	90,314	117,851	157,350	149,712	63,898
Total diagnosis	143,334	188,818	248,310	237,926	107,463
Malaria/Total diagnoses (%)	41	41	40	37	47
Anaemia cases in < 5	1,690	2,497	2,455	2,083	1,310
%<5 anaemia + malaria	8	8	6	6	6
Total blood smear	11,190	11,283	15,314	12,699	4,254
% blood smear positive	19	63	51	55	43

The annual malaria incidence in the district was 204-423/1000 in all age groups. The respective malaria incidence in the < 5years and ≥5 years ranged between 399 and 814/1000, respectively.

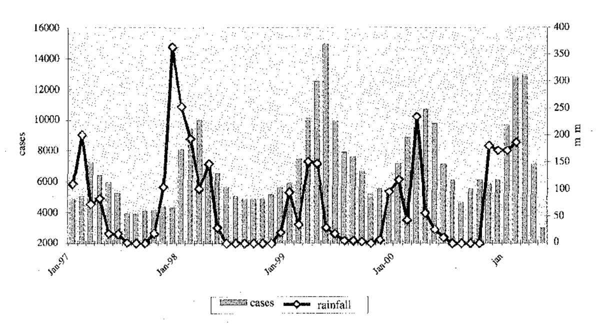

Figure 1: Malaria cases in relation to rainfall in Mpwapwa District, 1997-2001

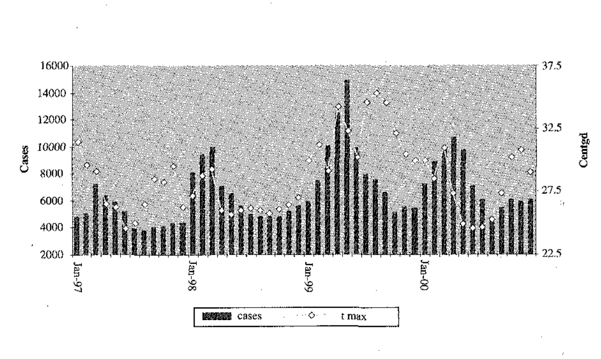

Figure 2: Malaria cases in relation to maximum temperature 1997-2000

A positive relationship was observed between monthly malaria cases and maximum temperature (Figure 2). Relatively high ambient temperatures and large number of malaria cases were reported in 1999 than in any of the previous 10 years (data not shown). Similarly, a remarkably high number of severely affected and admitted malaria patients were recorded in 1999 and 2001, with most cases of admission due to malaria and/or anaemia being observed during March of each year.

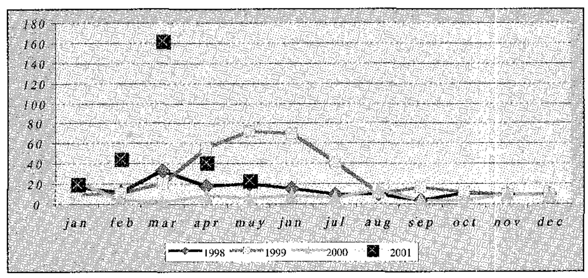

Figure 3: Severe malaria among inpatients in Mpwapwa District Hospital

An analysis of the incidence of severe malaria at Mpwapwa District Hospital was also made. There was a marked increase in the number of cases of severe malaria during May-June 1999 and March 2001 (Figure 3), coinciding with periods of malaria epidemics in the district. A 4-fold increase in cases of severe malaria was observed in May 1999 as compared with the same period in 1998. From 2000 to 2001 cases of severe malaria increased by 8-folds during the same period of the year.

Most of the anaemia cases occurred during the rainy season between January and June. There was a positive relationship between malaria cases and anaemia in children < 5 years of age. The pattern of anaemia corresponded to the pattern of malaria in this age group.

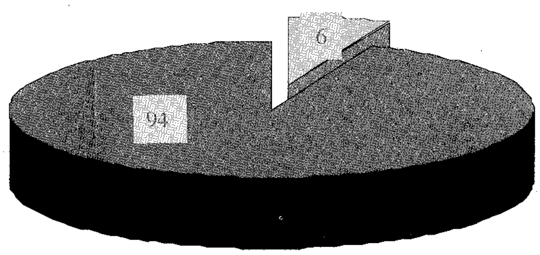

Figure 4: Parasitological versus clinical malaria diagnoses in Mpwapwa district

Most of the malaria cases reported in the district were based on clinical diagnoses. Laboratory diagnostic services were only available at the district hospital and 2 of the 3 health centres. Laboratory confirmation of the cases accounted for only 6% of all reported cases (Figure 4). About 47% of the blood smears examined in the laboratories were positive for malaria parasites.

The highest blood transfusion rate at Mpwapwa District Hospital was observed in January-March, a period when most cases of malaria and anaemia were experienced in the district. There was a sharp increase in the number of blood transfusion during the malaria epidemic of March 2001. Analysis of the in-patient data showed that malaria and anaemia contributed to 70-94% of all deaths at health facilities in the district. A seasonal pattern of death due to malaria was also observed from data collected at the district hospital. A larger number of deaths due to malaria were observed during the malaria outbreak of 1999. Between May and July 1999, a total of 30 deaths due to malaria were recorded compared with 7 and 5 during the same period in 1998 and 2000, respectively.

Of the 3 Divisions of Mpwapwa district, Kibakwe was markedly affected by the 1999 and 2001 malaria epidemics. Kibakwe Division lies at over 1000 m above sea level and comprises the highlands of Mwanawotta and Wangi, which lie at over 1700 m. Other areas affected by the two malaria epidemics included Berege, Lumuma and Mima. Kibakwe, Lumuma, Berege, Mwanawota and Mima were the most affected Wards in the district (Table 2). Closer observations of the collected information showed that higher malaria incidences were also recorded during the *El Nino* rains of 1998 even in areas where malaria was considered to be relatively stable.

Table 2: Marked malaria epidemics by Wards in Mpwapwa District

Ward	Year	Month with a peak malaria incidence
Berege	2001	January
Kibakwe	1999	May
	2001	March
Lumuma	1999	May
	1999	February
Mima	1999	May
Mwanawota	1999	May/June

Discussion

Previous studies in Mpwapwa district (Mboera *et al.*, 2001) have shown a variation in parasite rates in different villages within the same district. The parasite rates observed in the district were higher at lower altitudes than at higher altitudes. Malaria parasitaemia, though at a lower rate, were detected even in individuals living in Mwanawota and Wangi, at over 1700 m above sea level.

Data from health facilities indicate that the district experienced marked malaria epidemics in 1999 and 2001. These outbreaks were however, not detected promptly by either the district authorities or the respective health facilities. Detailed analyses have shown clearly that serious epidemics occurred in Kibakwe Division. Kibakwe Division lying at altitudes between 1000-1900m (Mboera *et al.*, 2001) has experienced several seasonal upsurges of malaria cases for many years (data not shown). These and other findings indicate that malaria transmission in this part of the district is highly unstable hence the area is prone to frequent epidemics. Recent studies have already shown that malaria prevalence among schoolchildren in the area ranged from 1.5 to 8.5 in the highlands and 26.5-51.9% in the lowlands (Mboera *et al.*, 2001).

The malaria epidemics in Mpwapwa district were experienced in areas of low malaria endemicity where local conditions allow for the importation of the disease. Kibakwe Division includes areas of lowlands and highlands and the likelihood of malaria epidemics due to low immunity among the population cannot be ignored (Mboera *et al.*, 2001). The malaria epidemic of 1999 was directly associated with climatic factors, particularly rainfall and temperature. Highest ambient temperatures and prolonged period of rainfall were recorded in the district during the year. In addition, a prolonged period of drought preceded the malaria outbreak. Unlike the 1999 epidemic, the malaria epidemic of 2001 was associated with heavy but brief rainfalls. Various studies have shown that malaria epidemics may be linked to environmental changes and increased mean rainfall and ambient temperatures (Brown *et al.*, 1998; Garay, 1998; Lindblade *et al.*, 1999; Kilian *et al.*, 1999). Environmental changes that result from global and local processes are likely to have some effects on vectors of malaria.

Malaria epidemics have been reported in Mvumi in a nearby district of Dodoma in 1987 and 1994 (Wakibara *et al.*, 1997). Mvumi lies in the semi-arid area of the central plateau of Tanzania. Although the 1987 malaria epidemic in Mvumi was associated with the change in mosquito-host preference (Mboera & Kitua, 2001), the two (Mpwapwa and Dodoma) districts are characterised by low to moderate rainfall with high inter-annual variability which are likely to precipitate unreliable crop harvest, famine and hence a decrease in body immunity which predispose the population to severe attacks of malaria (Mboera, 2004a).

In many parts of Africa, a period of drought is a common characteristic prior to malaria epidemics (WHO, 2001). This phenomenon was observed in the Mpwapwa District malaria epidemic of 1999. From informal group discussions with communities in the district, there was famine during the second half of 1998 that was experienced before the rains of 1999. The area experienced a long drought period than in any other period during the preceding 5 years. Epidemic following drought periods appear to catch health services unawares and the result is often high case fatality rates. Droughts are associated with food shortage, absence (low) of malaria transmission and waning of immunity among the population. Such links between droughts, food shortages and epidemic have been reported during the devastating malaria epidemic recorded in Mbulu District in 1942 (Clyde, 1967) and Muleba District in 1998 (Garay, 1998).

The two malaria epidemics in Mpwapwa district were not detected on time. This was most probably due to lack of a functional surveillance system that could have helped the district to monitor epidemics. This is a common problem in most of the districts in Tanzania (Mboera, 2004a). Although epidemiological data are available in most of the health facilities, this information is not utilised for surveillance purposes as observed in this study. Districts compile data from health facilities, but the data are not analysed and made available for disease monitoring and response by the respective facilities. A well-designed and efficiently implemented surveillance programme is envisaged to provide a means for detecting epidemics earlier, documenting their geographical and demographic spread and estimating the magnitude of the outbreak in order to initiate timely action.

As already described above, setting epidemic thresholds is more commonly achieved by comparing the normal mean/median cases of previous years (at least the previous five years) with the current case numbers over a set time (e.g. week or month). Initially this may be from suspected malaria cases only but subsequent confirmation using a thick blood film will confirm or deny the suspected change in malaria case numbers. In some cases, mean±2SD method is used to determine thresholds for malaria epidemics. This involves the calculation of the long-term mean of monthly malaria cases (derived from a minimum 5-year data set from which abnormal years have been excluded) and an epidemic threshold set at two times the standard deviation of the mean. Experience from other parts of Africa, where this threshold method has been tested, indicates that it has high sensitivity, but low specificity and predictive value. The use of malaria weekly monitoring chart may therefore, be used to provide both alert and action lines. These kinds of charts have been tested and introduced in all health facilities in Mpwapwa district since 2003.

In conclusion, an urgent need to explore the basic malaria epidemic predictive factors and establish a sustainable surveillance system should be emphasised for effective provision of health services. Health data collection, analysis, reporting and utilisation in disease surveillance should therefore, be strengthened in each district. An effective district malaria control programme should provide a prompt and adequate action towards reduction of morbidity and mortality rates, and prevent the occurring of new cases and the spread of the disease to other areas. To achieve this, models of malaria transmission should be established and used to predict malaria epidemics in each area of the district. This is because an early warning system may be used as an important strategy in malaria surveillance. The detection and interpretation of changes in the pattern of the constructed time series is central to the timely prediction of an epidemic.

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