Visceral Leishmaniasis
Epidemiology

Sudan

Risk mapping of visceral leishmaniasis in Sudan

Sudan
Gedaref State, Eastern Sudan

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Abstract

Visceral leishmaniasis (VL) is highly influenced by environmental factors. A study was carried out in 2001-2002 to map the distribution and risk of kala-azar in Sudan and investigate the history of infection by *Leishmania donovani* in Gedaref State, Eastern Sudan. Geographical Information Systems (GIS) were used to extract and map regression results for environmental variables of 190 villages in Gedaref State. VL incidence in each village was calculated from hospital records. Using logistic and linear multivariate regression analyses, models were developed to determine which environmental factors explain variability in VL presence and incidence. Average rainfall and altitude were proved to be the best predictors of VL incidence. The resulting models were mapped using GIS software predicting both VL presence/absence and incidence at any locality in Gedaref State. The results of the models were confirmed by leishmanin skin testing carried out on 4850 people living in 11 villages located in 3 different kala-azar endemic areas in Gedaref State (Atbara, Rahad and Gedaref areas). Force of infection of *L. donovani*, varied greatly, both in time and space, indicating that between 1990 and 2000 in the Rahad area, the incidence of *L. donovani* infection increased by 4.5-fold, as compared to 1980-1990. In contrast, the 1990-2000 incidence of infection of *L. donovani* in the Atbara and Gedaref areas, dropped by 3.5- and 2.3-fold, respectively, from that observed for 1980-1990. Leishmanian skin test results also indicated a significant variation in the exposure of different tribes, sexes and age groups. Results of an entomological survey showed that the only vector in the region is *Phlebotomus orientalis* and the village habitats are the main sites where people contract the infection.

Publications

Elnaiem DA, et al. Risk mapping of visceral leishmaniasis: The role of local variation of rainfall and altitude on presence and incidence of kala azar in eastern Sudan. *Am. J. Trop. Med. Hyg*., 2002, 66:6.

Background

The present work describes an attempt to develop a detailed eco-epidemiology model for mapping the distribution and incidence of VL at the village level in Gedaref State in relation to different environmental factors. In addition to providing the first detailed map describing the occurrence and incidence of the disease in this important VL focus, the study also investigates how local variations in environmental factors affect the disease burden in different endemic villages.

Materials and methods

Study area Gedaref State is bordered in the east by Ethiopia, in the south and west by the River Rahad, and in the north-east by the Atbara River. The region is a flat plain with almost no relief, and the principal soil type is vertisols. The climate is tropical continental, with an estimated annual rainfall of 400-1400 mm. The year is sharply divided between the rainy season, June-October, and the dry season, November-May. The mean minimum temperature is 21.0 °C in the rainy season and 18.3 °C in the dry

Conclusions and implications of the study

- The models developed in this study provide detailed mapping of classified incidence of VL in Gedaref State. The fact that the models were derived from environmental variables resulted in the production of risk maps that could predict disease burden in areas not covered by the initial data.
- The risk maps produced from this study should be of great value for planning locations of treatment centres, for finding appropriate places for human settlement, and for deciding where to extend the control programmes.
- The produced models could be used to predict VL presence and incidence in others areas of Sudan where the disease is transmitted by the same vector.
- The novel approach of this study can be used for other parts of the world to predict and map VL transmitted by different vectors. Such studies would provide a global understanding of the VL problem and help prioritize control programmes.

season; corresponding maxima are 37.3 °C and 40.6 °C. The natural vegetation is dry savanna woodland. The main indigenous trees are *Balanitis aegyptica, Acacia senegal, A. mellifera, Combretum spp., Calotropis procera*, as well as some riverine vegetation. Along the river banks some fruit orchards are found. Dura, sesame, dockhon, and groundnuts are grown as cash crops over extensive areas. The human population of Gedaref State belongs to many ethnic groups, most of whom have a recent history of settlement in the region.

Visceral leishmaniasis cases, human population and village location data The case data analysed in this study were obtained from detailed records of 2 treatment centres established and operated by MSF-Holland in Umkra'a, situated close to the River Rahad, and in Kassab village, situated close to Gedaref town. Although a few patients were also diagnosed in Gedaref and Hawata hospitals and in other rural dispensaries, most patients have been referred to the 2 MSF VL treatment centres as a result of the high cost of treatment (estimated at US$ 170 per patient).

Data on cases and human populations were initially handled within Excel and SPSS software to calculate the numbers of cases of VL reported to the treatment centres during 1996-1999. Data were then entered in a new file containing the names of villages, their coordinates, councils, and the human population, and analysed to determine annual incidence (per 1000 people) in different villages. Coordinates of village locations were obtained from readings of a Magellan global positioning system and from maps produced by the South Kassala Agricultural Project.

Environmental data Environmental data corresponding to the coordinates of each of the study villages were extracted from a number of satellite sources and digital databases by Arcview GIS software with Spatial Analyst, and the public domain software WINDISP 3. The U.S. Geological Survey (USGS) hydrologic data set was used to obtain a detailed description of the topography of the area. Information on vegetation status was obtained from data archives of the vegetation sensor on board the French satellite system, SPOT. Ten daily images of 10 daily rainfall estimates for the years 1996-1998 were obtained from the Africa Data Dissemination Service and analyzed by Windisp 3 GIS software to obtain the average annual rainfall for each village. Soil types of different villages were read from a map produced by the South Kassala Agricultural Project and classified into 9 classes. Through the use of Arcview GIS software, the distance of each village from each of the 2 treatment centres and the two seasonal rivers was calculated.

Statistical and GIS analysis of environmental and VL incidence data Correlation analysis was performed to determine the relationship between the incidence of the disease and different environmental variables. Stepwise multivariate analysis was then carried out by binary logistic and linear regressions to determine predictor variables affecting the presence and incidence of VL, respectively. The produced models were then entered into the map calculator module of Spatial Analyst and used to create maps of probability of disease presence and incidence.

Main study findings

The mean incidence of VL per 1000 people was 6.91, with marked variation between different villages, ranging from 0 to 53.21. Clear clustering of high incidence villages and areas of low altitude and high rainfall zones was noticeable on the maps.

The results showed that distance from the river, the topography, rainfall, and the minimum Normalized Difference Vegetation Index (NDVI) are the main environmental variables independently associated with the distribution and incidence of VL in Gedaref State. These variables influence the populations of the vector and reservoir hosts of *L. donovani* by affecting other microclimatic factors in the area. *Phlebotomus orientalis* is known to thrive in habitats characterized by the presence of *B. aegyptica* trees, *A.senegal* trees, and vertisols. The vector was also found to inhabit a "climate space" of rainfall of 400-1200 mm and of annual mean maximum daily temperatures of 34-38 °C. Because most of the region is covered by vertisol, it is not surprising that this factor did not seem to affect the distribution of disease within the region.

In all the analysis carried out in this study, annual rainfall appeared to be the most important predictive variable affecting both the probability of presence and incidence of the disease. Rainfall may affect the vector and reservoir hosts by affecting the vegetation, the temperature, and the relative humidity.

Conclusions and recommendations

The models developed in this study provide detailed mapping of classified incidence of VL in Gedaref State. The fact that the 2 models were derived from environmental variables resulted in the production of risk maps that could predict disease burden in areas not covered by the intial data. It is suggested that the novel approach of this study can be used for other parts of the world to predict and map VL.