Mapping disease has a long history. Disease atlases exist for the rarest of cancers in the developing world, and yet such a basic epidemiological tool does not exist for the single largest cause of mortality in Africa. It is notable that attempts to define the consequences of malaria in Africa can be little more than educated guesses, given the lack of specific details on transmission and population distribution across the continent. It would be convenient if malaria in sub-Saharan Africa could be considered a single problem with a single set of solutions; yet this is clearly not the case. There are enormous variations in Plasmodium falciparum transmission across the continent, from none to the highest ever recorded within close proximity. Recently, interest in the heterogeneity of transmission has been focused by the rekindling of an old debate on the relationships between health impact and level of endemicity. Whatever the outcome of this debate, a detailed knowledge of the distribution of endemicity is going to be essential in targeting resources for the control of malaria. Such information is generally not available in an accessible and standardized format for many countries. This is not only a limitation at the local level; the malaria situation in Africa is not static, and yet tracking the effects of major factors such as chloroquine resistance, urbanization and variations in climate, will be difficult in the absence of a standardized framework for the geography of malaria. In this paper, we provide a background to a new initiative to map malaria risk in Africa.

Epidemiology and Malaria Control

When considering the effects of malaria control under different levels of endemicity, the Conference on malaria in Equatorial Africa held in Kampala in 1950 (Ref. 8) ... '... recommends to governments responsible for the administration of African territories that malaria should be controlled by modern methods as soon as feasible, whatever the original degree of endemicity (our italics) and without awaiting the outcome of further experiments'. This unexceptional statement belies the fact that it was produced against a background of fierce controversy on the relationship between endemicity and the health impact of malaria. It was probably anticipated that the debate would continue, but in fact the next 40 years saw a stagnation of research into the epidemiology of malaria as a disease in favour of approaches that concentrated on the epidemiological basis for eradication, which continued well beyond the point when even the most enthusiastic accepted that this was not an option for Africa. Recently, there has been a resurgency of research into the relationships between transmission intensity and health impact. Several studies have suggested that the basic epidemiology of disease and mortality is determined by transmission intensity. Age, clinical syndromes and rates of disease have been shown to be dependent upon the level of endemicity within a given community. This, in turn, has led to a rekindling of the controversy surrounding the relationships between transmission and disease and, in particular, that mortality due to malaria may actually fall under conditions of high sustained transmission. It is probably no coincidence that, as was the case 40 years ago, this debate continues with the appearance of a tool for malaria control with wide potential application. Forty years ago it was DDT; today it is insecticide treated bednets (ITBN). TDR/WHO are to be applauded for co-ordinating a multisite approach to trials of ITBN efficacy against mortality under different transmission ecologies. Studies have been conducted in settings with estimated annual entomological inoculation rates ranging from between 100 and 1000 in Ghana, between 10 and 60 in Kenya and less than 10 in The Gambia. The trials provided a range of initial protective efficacy estimates against all-cause childhood mortality: 17% in Northern Ghana; 33% on the Kenyan Coast; and 63% in The Gambia. It is too early to know whether these effects will be maintained as the balance between reduced exposure and acquisition of immunity re-adjusts in the newly protected populations. It may be noted in passing that, assuming equal efficacy against malaria-specific events, these results may add some support to the scenario of a reduced contribution of malaria to all-cause childhood mortality as transmission intensity rises.

There is also reason to believe that the success of other malaria-control activities depend upon endemicity. The importance of field testing vaccines under different P. falciparum exposure settings was emphasized during an ECC sponsored meeting on malaria vaccines. By definition, vaccines designed to prime immune responses will be dependent upon both subsequent boosting and previous exposure. Trials of limited and purposively designed 'imperfect' chemoprophylaxis have proved successful in reducing both morbidity and mortality from malaria. The extent of 'imperfect' cover will be dependent upon the frequency of new infections to protected individuals. Furthermore, it has been argued that long half-life antimalarial drugs may provide differential risks and benefits depending upon the seasonality and intensity of transmission. The Amukoye, unpublished).

It is not yet clear how transmission and disease interact, and yet practical recommendations need to be made. During a recent meeting in Brazzaville at the WHO's regional office a statement was prepared recommending the integration of ITBN into malaria control activities across Africa. Forty years on, and policy makers still prefer not to commit themselves as to whether levels of malaria endemicity should influence the choice or expected outcome of a particular malaria-control activity. We believe that it is essential that history not be allowed to repeat itself and a pragmatically driven policy statement lead to complacency over the lack of epidemiological data on which to base control decisions. Whether one believes that the long-term consequences of reducing parasite exposure will result in a sustained reduction, produce no net gains or result in a significant increase in disease, it is difficult to believe that a quantitative approach to the distribution of malaria in humans will not provide a critical component to the rationalization of intervention delivery.
Mapping Malaria Risk in Africa

There have been several attempts to develop malaria maps in East Africa. These were compiled by malariologists working in these countries during the eradication era\(^2\)\(^3\). The maps vary in the extent to which regional categorizations were based upon empirical data, and vary also in the criteria used to define endemicity. For many years, definitions of endemicity, based either on the spleen rate\(^4\) or the parasite rate\(^5\), have been widely used to describe the intensity of malaria transmission in Africa. Nevertheless, the four categories of hypno-, meso-, hyper- and holoendemic stable transmission impose artificial cutoffs from a natural continuum and mask other important features of transmission, such as seasonality or descriptions of topography. Alternative definitions of malaria transmission have been proposed according to "climatic zoning\(^6\)" or "landscape malaria\(^7\)." More recently, Cattani and Teleghemam\(^8\) developed complex 'malaria paradigms' based upon a community's suitability to a variety of control strategies depending upon: species of *Plasmodium*, vectors, level of transmission, population characteristics, social, behavioural and economic characteristics, health infrastructure, use of drugs, influence of development projects and climate/geology. It is hard to find clear evidence of where any classifications of malaria have been used in the effective rationalization of control activities in Africa. Reasons may include the fact that until recently there has been no realistic strategy for disease prevention; a lack of a conceptual framework to explain differences in disease and death from infection rather than models of infection per se; or the definitions have proved oversimplified or overly complex. Currently, control strategies are being promoted for the control of malaria-related mortality through the reduction in transmission intensity through ITBN; evidence is emerging of epidemiological associations between disease and transmission intensity; and now would seem the time to develop new and usable definitions and maps of malaria endemicity across the continent.

The MARA/ARMA Collaboration

The value of maps that allow a continental perspective of malaria endemicity, that are not restricted by international boundaries and that are based upon the integration of many heterogeneous data sets would be extremely valuable. The Mapping Malaria Risk in Africa/Atlas du Risque de la Malarine en Afrique (MARA/ARMA) collaboration is an initiative that has been established to develop such a platform. In brief, the collaboration will undertake to build a spatial information platform using geographic information systems (GIS) to integrate digital and attribute data. Digital data sets will include existing continental data bases such as population, topography, climate and administrative boundaries. The focus of MARA/ARMA will be the construction of a malaria endemicity 'attribute layer' from all available published and unpublished sources. Furthermore, the initiative proposes to develop new definitions of endemicity appropriate for disease control and based upon a variety of malarionetric and climatic parameters (MARA/ARMA Collaboration, unpublished). This spatial information platform will provide health managers, researchers and donors with a basic epidemiological tool to guide future control activities by enabling effective resource allocation and targeting of at-risk groups. The strength of the initiative lies in its collaborative network (see Box 1), the use of GIS as an integration tool\(^8\)\(^9\) and the fact that no such comprehensive compilation of georeferenced malaria data has previously been undertaken.

Acknowledgements

Financial support for the MARA/ARMA collaboration has been provided by IDRC, Canada and The Wellcome Trust, UK. RWS and KM are supported by The Wellcome Trust's Senior Fellowships Programme. The authors are grateful for the encouragement and support for this work by Dr Don de Savigny of IDRC.

References


Parasitology Today, vol. 12, no. 12, 1996
Modelling of Potential Schistosomiasis Vaccination Programmes

M-S. Chan, B.F. Hall and D.A.P. Bundy

Bethesda, USA
July & September 1995

Over the course of two meetings, two months apart, discussion focused on the construction of mathematical models to predict epidemiological impacts of schistosomiasis vaccination programmes in target populations. Initially, we considered structural relations of the model, including characteristics and modes of vaccine action, and then discussed appropriate parameters for these relationships. Subsequently, we used the models to simulate the impacts of different vaccination programmes. The follow-up meeting focused on the discussion of clinical trial designs for potential schistosomiasis vaccines. The discussion and simulations, summarized here, provided insights relevant to the design of both preclinical and clinical schistosomiasis vaccine research, and future population-based immunization programmes.

Model Structure

A consensus existed among the participants (see Box 1) that naturally acquired resistance to infection, vaccine-induced immunity, and immunopathology may all follow different pathways (known as a complementary model) and should be modelled as distinct processes. These three components will be discussed separately.

Naturally acquired resistance to infection. Quantitatively, the most important action of acquired immunity was thought to be protection against further infection by acting against the establishment of adult worms (anti-establishment model). The most immunogenic parts of the life cycle were considered to be the adults and especially the eggs. The target of these responses would be the schistosomulae. Very little is known about either the strength or the duration of immune protection.

There are many additional complexities that may need to be taken into account when modelling the immune response. These arise largely from the fact that this response is really a composite of different immune mechanisms. Naturally acquired resistance may also involve non-immunological responses.

Box 1. Participants at the Meetings

At the workshop:
Man-Suen Chan, Donald Bundy, Mark Woolhouse, Helen Guyatt
(Centre for the Epidemiology of Infectious Disease, Oxford University, UK)
B. Fenton Hall, Stephanie James, Mike Gottlieb, Alan Sher, Allen Cheever, Tom Wynn
(National Institutes of Health, Bethesda, USA)
Mette Strand (Johns Hopkins University, Baltimore, USA)

At the follow-up meeting:
Robert Berquist (Special Programme for Research and Training in Tropical Diseases, World Health Organization, Geneva, Switzerland)
Nabil Galal (Schistosomiasis Research Project, Cairo, Egypt)
Maged Al-Sherbiny (Egyptian Reference Diagnostic Center, Cairo, Egypt)
Edgar Carvalho (Hospital Universitario Prof. E. Santos, Salvador, Brazil)
Carter Digs (US Agency for International Development, Washington DC, USA)
Dan Colley (Division of Parasitic Diseases, Centers for Disease Control, Atlanta, GA, USA)
Taha El-Khoby (Schistosomiasis Research Project, Ministry of Health, Cairo, Egypt)
Edward Pierce (Cornell University, Ithaca, NY, USA)
Dragana Jankovic (National Institutes of Health, Bethesda, USA)
Don Harn (Harvard University, USA)
Barend Mons (European Commission, Brussels, Belgium)