Barriers to the Elimination of Lymphatic Filariasis in Sub-Saharan Africa

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This paper examines barriers to the elimination of Lymphatic Filariasis (LF) in Sub-Saharan Africa. Caused predominantly by the filarial worm Wuchereria bancrofti, LF infects 120 million people worldwide, with about 40 million people showing symptoms like hydrocele, lymphedema, or elephantiasis. In 2000, the World Health Organization established the Global Program to Eliminate Lymphatic Filariasis (GPELF) with the ultimate goal of eliminating LF by 2020. However, many obstacles persist throughout Sub-Saharan Africa that will make this goal difficult to achieve. This paper relies on a range of research studies to present a comprehensive picture of the current barriers to LF elimination in Sub-Saharan Africa. Species-specific barriers include heterogeneity in the vector distribution, varying ability to pick up and transmit LF and different feeding and resting behaviors. In addition, variations in habitat and weather, urban transmission, and the impact of human behavior are general barriers that contribute to ongoing transmission.

Introduction

Lymphatic Filariasis (LF) is a neglected tropical disease that persists in developing countries and impoverished communities throughout Sub-Saharan Africa, Asia, South and Central America. An estimated 1.3 billion people are at risk for contracting LF, with 120 million people currently infected.[1] LF is a parasitic disease that occurs when infective larvae are transmitted to a human host when a mosquito feeds on a human.[1] Three types of filarial worms cause LF: Wuchereria bancrofti, Brugia malayi, and Brugia timori. Of these, W. bancrofti is the biggest source of infection, responsible for about 90% of LF cases.[2]

Forty million people infected with LF are disfigured or incapacitated with symptoms like lymphedema (tissue swelling), elephantiasis (skin/tissue thickening), and hydrocele (fluid accumulation in the scrotum).[1] The remaining two-thirds of infected individuals show no visible symptoms of LF, but may experience immunosuppression or renal dysfunction[3]. While LF does not typically cause mortality, the disfiguring symptoms caused by this infection can have significant implications with respect to accomplishing routine tasks and daily social interaction. Those with chronic and disfiguring conditions can alleviate discomfort and prevent secondary infection through rigorous hygiene practices such as washing the affected body parts with soap and water.

The World Health Organization has identified LF as a candidate for elimination due to advances in diagnosis and treatment as well as a greater understanding of its epidemiology.[1] These advances paved the way for a global elimination strategy, and in 1993 LF was identified as one of only six eradicable diseases. The World Health Organization includes LF among the top 17 neglected tropical diseases (NTDs): "a diverse group of diseases with distinct characteristics that thrive mainly among the poorest populations."[4] The Global Program to Eliminate Lymphatic Filariasis (GPELF), established by WHO in 2000, views elimination of this disease as a tangible way to improve health outcomes in the developing world.[5] The ultimate goal of GPELF is to eliminate LF by the year 2020.

Treatment for LF involves the administration of albendazole and either ivermectin or diethylcarbamazine and these drugs kill the microfilariae in the blood of an infected individual.[5] The treatment regimen for LF is capable of preventing future infections and stopping the progression of disease in those who are already infected. The current strategy for eliminating LF in Africa is a five-year, uninterrupted mass drug administration (MDA) program delivered to 80% of the population.[6] During MDA, entire populations are treated regardless of the presence of symptoms. Between 2000 and 2012 approximately 4.4 billion treatments were delivered to 984 million people in 56 countries.[1] Prevention of LF also involves mosquito control through insecticide treated nets, indoor residual spraying, or removal of mosquito breeding sites. In addition to MDA, management of morbidity and the prevention of disability among affected individuals are important aspects of LF control.[5]

The topic of LF is important to public health due to the disability it causes in endemic areas. Disfiguration caused by LF has economic repercussions because it debilitates healthy citizens who would otherwise contribute to economic growth.[3, 7-9] In addition, the condition can be highly stigmatizing for individuals with chronic disabling symptoms that restrict social interactions.[10-13] Visible manifestations of LF, including lymphedema of the limbs, breasts and genitalia, have profound social consequences.[12-13] The status of LF as a neglected disease means that health education to the populations in danger regarding symptomology, prevention and transmission does not receive the same attention as more prominently-known diseases like HIV/AIDS and tuberculosis.

This lack of education leads to misconceptions and further stigmatizes affected individuals. Increased knowledge of LF will inform healthcare policy, leading to a more effective elimination strategy. The majority of research on LF has focused on individual barriers to elimination. This paper attempts to collate relevant research articles on a variety of barriers in order to provide a comprehensive overview of the most important barriers to elimination of LF.

Background:

Important Terms

Threshold Biting Rate (TBR): the vector biting rate below which infection cannot be sustained in the population.

Worm breakpoint: the parasite prevalence below which local extinction occurs.

Microfilariae (microfilariae): an early stage in the parasite life cycle that circulates in the bloodstream of the host.

Monthly Biting Rate (MBR): the estimated number of mosquitoes that will bite an individual in a community in a month's time.

Monthly Transmission Potential (MTP): the number of infective larvae to which a person is exposed each month.

Annual Biting Rate (ABR): the average number of vectors that take a blood meal per human host per year.

Annual Transmission Potential (ATP): the estimated number of infective larvae that would have been transmitted to a subject at a particular site per year.

Anopheles gambiae Complex: a group of at least seven species of mosquitoes that are anatomically similar but exhibit different behaviors. Includes the An. gambiae senso stricto (s.s.) mosquito.

Exophilic: a preference of mosquitoes to rest outdoors after taking a blood meal.

Endophilic: a preference of mosquitoes to rest indoors after taking a blood meal.

Anthropophilic: a preference of mosquitoes to feed on humans.

Zoophilic: a preference of mosquitoes to feed on animals.

Exophagic: a preference of mosquitoes to feed outdoors.

Endophagic: a preference of mosquitoes to feed indoors.

Mosquito Species

Several mosquito species are capable vectors of LF and contribute to ongoing transmission. Within the Anopheles genus, LF vectors include An. arabiensis, An. gambiae, An. merus, An melas, and An. funestus (See table below). An. gambiae s.s. is found throughout Sub-Saharan Africa and considered one of the most efficient vectors due to its long lifespan, short larval development period, and other behavioral traits.[14] An. arabiensis is also significant due to its wide geographic distribution and behavioral plasticity.[15]

In addition, Culex quinquefasciatus is an important vector throughout Sub-Saharan Africa (see map 1). This vector has a worldwide distribution and predominates in urban areas around human dwellings.[16] Cx. quinquefasciatus thrives in pit latrines, cess pits, and other areas with decomposing organic matter.[16-18] Although researchers have established the behavioral tendencies of mosquitoes through entomological studies, most of these species have exhibited variability in feeding and resting as well as an ability to adapt to changing environments.

Further Analysis of Various Mosquito Species and their Relation to LF

Changes In the An. gambiae Complex

The composition of the vector population in a given area will significantly impact the transmission of LF due to the feeding and resting behaviors described above. A recent study by Derua and colleagues (2012) in Tanzania revealed a change in the relative abundance of mosquito species in the An. gambiae complex. An. gambiae s.s. was previously the most abundant vector but researchers observed a shift in mosquito composition whereby An. Arabiensis was the predominant vector in the complex.[19] This finding could impact the vector control programs in this region and alter intervention strategies for reducing the mosquito population because An. arabiensis mosquitoes exhibit different feeding and resting behaviors than An. gambiae s.s. Derua's study compared current measures of the Anopheles mosquito population with data from the 1980's.[19] In the earlier survey period An. gambiae s.s. and An. arabiensis were almost equally distributed at 39.2% and 41.9% respectively; data from 2012 revealed a significant shift in composition whereby 76.8% of the sampled vector population was from the An. arabiensis species while An. gambiae had decreased significantly.[19] These findings are similar to another study in Moshi Tanzania that showed that An. arabiensis mosquitoes accounted for 79.5% of the total mosquito population and 99.3% of the Anopheles species.[20]

The make-up of the vector population can impact vector control and overall transmission of W. bancrofti. Due to the exophagic and exophilic tendencies of An. arabiensis, there is a decreased probability that these vectors will come into contact with insecticide treated material like bed nets or walls.[14,19,20,] In addition, those mosquitoes that do rest indoors after feeding (i.e. endophilic behavior) have a tendency to avoid surfaces that have been sprayed with insecticide.[21] As a result, control programs that have been predicated on indoor residual spraying and distribution of insecticide treated nets will be less effective.[18] This study also detected an increase in the population of the An. merus vector species, posing further problems for control programs.[19] This mosquito is difficult to control with insecticide treated materials and larvicides due to its feeding and resting behavior.[8]

The increased prevalence of both the An. merus and An. arabiensis vectors has implications for vector control programs and for LF elimination programs at large. In order to effectively control the population of these vectors, their ecology and behaviors must be understood and this information should be applied to the development of control techniques. For example, in areas where endophilic and endophagic mosquitoes predominate, long lasting insecticide treated nets and indoor residual spraying should be implemented. In contrast, in areas where mosquitoes are exophilic and exophagic, vector control programs

Species	Target	Feeding	Resting	Location
An. arabiensis	Zoophilic	Exophagic	Exophilic	Dry savannah environments across Sub-Saharan Africa
An. gambiae s.s.	Anthropophilic	Endophagic	Endophilic	Humid forested areas across Sub-Saharan Africa
An. merus	Both	Exophagic	Exophilic	Coastal East and Southern Africa
An. funestus	Anthropophilic	Endophagic	Endophilic	Various environments throughout Sub-Saharan Africa
An. melas	Both	Exophagic	Endophagic	Coastal West Africa
Cx. quinquefasciatus	Both	Both	Both	Various environments throughout Sub-Saharan Africa

Note: these characterizations only describe tendencies, and most of these species exhibit a variety of behaviors

Map 1: The global distribution of Cx. quinquefasciatus (Source: University of Florida entomology).

should focus on reducing potential mosquito breeding sites.[18]

Infectivity Among Mansonia Species

Past research on the vectors of W. bancrofti in Africa have highlighted the importance of the Anopheles species in the dynamics of transmission.[22] Although Mansonia species are known carriers of W. bancrofti in Asia, they had not been considered as vectors in Africa.[23] However, researchers Ughasi and colleagues (2012) have released the first report since 1958 highlighting the potential for Mansonia species to be vectors of LF in West Africa.[23] In the study, 825 mosquitoes were collected in Ghana, 239 (29%) of which belonged to the Mansonia species. All of these 239 Mansonia spp mosquitoes were identified as M. Africana, five of which were found to be infective with W. bancrofti. In addition, 388 stored Mansonia spp mosquitoes from a previous collection were examined, with a distribution of 144 M. Africana and 244 M. uniformis. Eleven (7.6%) M. africana and 7 (2.9%) M. uniformis mosquitoes were found to be infected with the W. bancrofti parasite.

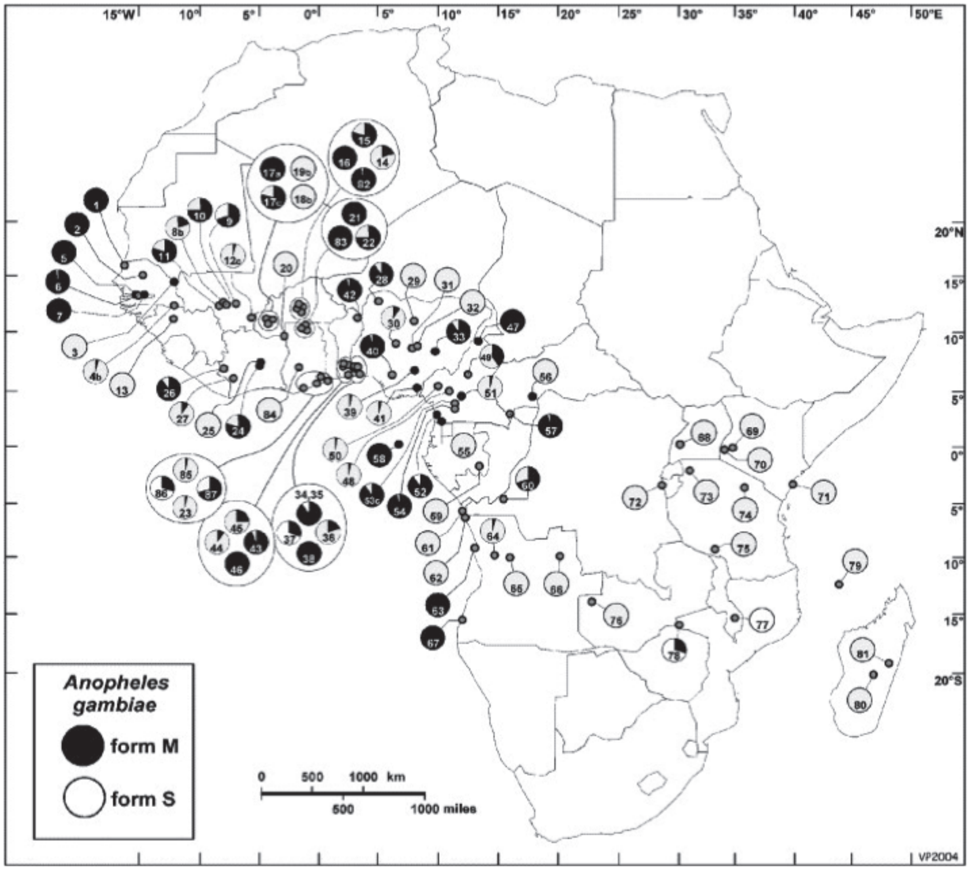
The observation that Mansonia mosquitoes are LF vectors in West Africa has significant implications for elimination efforts, demonstrating that the transmission system in this region could be more complex than expected. Mansonia spp are important vectors, but they have not been factored into the elimination strategy. Because Anopheles mosquitoes exhibit facilitation (discussed below), elimination is feasible through MDA alone in areas where they are vectors.[23] The LF elimination campaign in West Africa is based on the assumption that Anopheles are the only vectors of W. bancrofti in this area.[24] However, the observation that Mansonia mosquitoes are LF vectors could present a significant challenge to the GPELF in eliminating LF with MDA alone in this sub-region, necessitating increased vector control efforts.[24,25]

Impact of An. gambiae M Molecular Form on Transmission

Furthermore, past research has demonstrated varying transmission efficiencies among different molecular forms of An. Gambiae s.s. mosquitoes, termed the M and S molecular forms.[24] Researchers have identified two 'molecular forms' of the An. gambiae mosquito, defined according to single nucleotide differences in the ribosomal DNA region.[26] There is significant variation in the distribution of the M and S forms across Sub-Saharan Africa. The M/S distributions are geographically defined and influenced by environmental factors and habitat characteristics. For example, in Ghana, the An. gambiae S form is clustered in the 'middle belt' while the An. gambiae M form is clustered along the coast and in the Northern Savannah.[25] The M and S forms are associated with factors like elevation, rainfall, and temperature according to an analysis of geographic and climatic conditions. In Ghana, the M form predominates in coastal savanna areas due to the presence of permanent breeding conditions provided by irrigation facilities as well as ponds of water resulting from river run-off.[25] In contrast, the abundance of the S form in the middle of the country can be attributed to the fact that this region is mountainous and forested with lower mean temperatures and the highest recorded rainfall in the country.[25] Although the studies above focus on Ghana, the M and S molecular forms of An. gambiae have been identified across Sub-Saharan Africa (see map 3).[26]

Due to the impact of important variables like temperature and precipitation, the An. gambiae M form has demonstrated a more latitudinal range in West Africa than the S form and is especially dominant in the hot and arid areas around the Sahel.[27] This research reveals that variations in the landscape impact the distribution of W. bancrofti vectors, and transmission dynamics can change drastically between the regions of one country. Mapping the abundance of various mosquitoes and determining their relationship to the W. bancrofti transmission is an essential in determining the necessary number of rounds of MDA.

The M form has been identified as the more efficient vector of LF. In areas where the M form is the predominant vector, longer MDA treatment periods may be required to end transmission. For example, de Souza and colleagues (2012) hypothesized that LF transmission in S form-dominant areas may be interrupted after three to five rounds of



Map 2: The 24 countries where M and S molecular forms were identified.45

Map 2: Approximate distribution of An. gambiae ss in Africa. (Source: University of Florida entomology).

MDA. In contrast, areas with high proportions of the M form or the vector require more than five rounds of MDA, supplemented with vector control.[24] A similar research study by de Souza and colleagues (2010) was aimed at determining the spatial distribution of the An. gambiae molecular forms in Ghana, and their relationship with disease prevalence.[25] The data demonstrated that An. gambiae M was significantly positively associated with LF while An. gambiae S was significantly negatively associated with LF.[25] As a result, locations with high An. gambiae M distribution were observed to have significantly higher LF prevalence than areas where the An. gambiae S form was significantly high.[25] Due to the varying efficiencies of M and S form mosquitoes as vectors, researchers must characterize the mosquito population to determine where the M form predominates. This entomological research will inform MDA and allow health authorities to tailor treatment programs according to local vector conditions.

Diversity among LF vectors and implications for global elimination

Important threshold levels

The threshold biting rate (TBR) and the worm breakpoint are two threshold levels that have important implications for LF elimination.[28] Mathematical models can be used to determine the appropriate TBR and worm breakpoint necessary to end transmission in a certain population.[29] However, the variation of threshold levels between communities means that findings from one area may not be generalizable to another area. Therefore, it is necessary to fit mathematical models to site-specific infection data in order to determine accurate threshold levels.[28]

One study demonstrated that ignoring local transmission dynamics will likely lead to the failure of a WHO recommended MDA strategy.[30] Using a model, researchers were able to simulate the impact of the diethylcarbamazine /albendazole drug administration among 80% of the population, in three endemic communities. The simulations of disease transmission demonstrated a wide variation between the communities due to varying transmission dynamics. The probability of LF elimination declines markedly with increased community annual biting rate (ABR).[30] In addition, TBRs varied widely between communities, with high significance levels. Consideration of the TBR, ABR, worm breakpoint is important in determining if current treatment strategies are sufficient. These findings suggest that the WHO-recommended global strategy to eliminate LF ignores variation in local transmission dynamics among communities.[28,30] The authors assert that the simulations "demonstrate the likely failure of a fixed global strategy."[30] Determining an endpoint (the point at which transmission has reached a low enough level that it cannot continue, even in the absence of drug administration[31]) for an MDA control program should be contingent on site-specific infection data related to these threshold levels. For example, it may be necessary for a community to implement additional rounds of MDA and also to implement more comprehensive vector control due to local data on TBR and worm breakpoints. In order to gain a comprehensive understanding of variation in threshold levels researchers should use predictive models to generate estimates.[30]

Facilitation and Limitation Processes

In the past researchers have tried to establish the microfilariae levels at which vectors are incapable of picking up and transmitting infection by studying the density-dependent processes of limitation and facilitation. These processes are tied to the threshold levels discussed above that guide transmission dynamics in communities. Both of these processes are related to the relationship between the microfilariae intake and output of stage three infective larvae (L_3).[18,32] In mosquitoes that exhibit limitation or facilitation, the number of infective larvae that develop in the mosquito is not proportional to the number of microfilariae ingested by the mosquito. Limitation is a process in which the output of infective larvae decreases as the number of ingested microfilariae increases. As a result, the output of infective larvae per vector decreases at high microfilariae densities.[18, 32] Vectors that exhibit limitation are highly efficient at sustaining transmission even at low microfilariae densities. Therefore, limitation processes counteract elimination efforts by shifting transmission thresholds toward lower values, necessitating more intensive control efforts.[18, 32] This process has been observed among Culex mosquito populations.[17]

In contrast, vectors that exhibit facilitation possess a cibarial armature that lacerates ingested microfilariae.[32] These vectors are efficient mainly at high microfilariae levels. At low microfilariae densities the cibarial armature substantially reduces the proportion of surviving microfilariae. However, at high microfilariae densities the armature becomes inefficient as it is masked by several lacerated microfilariae, allowing the survival of others.[18,32] As a result of this process, transmission of LF is inefficient and transmission thresholds are shifted towards higher values.[18] Therefore, the measures required to interrupt transmission are less intensive and easier to achieve. The process of facilitation often occurs among Anopheles species mosquitoes.

Health authorities should design LF control strategies with a comprehensive understanding of the vector transmission potential in various areas, specifically the processes of limitation or facilitation that these vectors exhibit. Differences in vector capabilities may explain why some MDA campaigns are not successful in breaking the cycle of transmission. An understanding of vectorial capacity at the local level is very important during the implementation of an MDA campaign to determine the characteristics of mosquitoes and inform decisions regarding the number of treatments required to break transmission. MDA campaigns should be tailored according to these findings to ensure that community members receive a sufficient number of treatments.

The failure to eliminate LF in Ghana demonstrates the importance of limitation and facilitation. The assumption that Anopheles mosquitoes are the only vectors of LF in Ghana and that they exhibit facilitation has informed the LF elimination campaign and influenced current treatment protocols.[24] Where Anopheles mosquitoes exhibit facilitation, elimination may be feasible through MDA alone (i.e. vector control is not necessary).[23,33] It is assumed that low level parasitemia resulting from MDA in Anopheles transmission areas will lead to interruption of transmission.[22,33] Despite this, 5-8 rounds of MDA treatment have failed to eliminate LF in some communities in Ghana due to the diversity of vector species.[24] This may be because some species of Anopheles (specifically An. Melas) exhibit limitation and are thus more efficient vectors.[33] Also significant is the finding that limitation and facilitation processes can both occur within a very small geographic range.[33] These findings reinforce the importance of entomological studies to assess what vector species are contributing to LF transmission. In areas where limitation occurs, vector control is very important to interrupting transmission.

General Barriers to Elimination:

Insecticide Resistance

In addition to the barriers described above, there are some general barriers that contribute to ongoing transmission of LF in Sub-Saharan Africa. Vector control is an important supplement to MDA in areas of endemic LF transmission.[34] However, the development of insecticide resistance among various vectors of LF will threaten control efforts if vector control activities do not effectively reduce mosquito populations. On the East African coast, the mosquito species Culex quinquefasciatus is the most important vector of W. bancrofti.[17] This mosquito has proven to be an efficient vector of W. bancrofti, capable of stable transmission even at very low levels of microfilariae in the blood. Results from a study in Zanzibar demonstrated that Culex mosquitoes were resistant to all insecticides tested on the island of Pemba, the second largest island of the Zanzibar Archipelago.[17] The median lethal time, or LT_{50} (time taken to kill approximately 50% of mosquitoes) for mosquitoes from the islands of Pemba and Unguja, when exposed to the pyrethroid lambda-cyhalothrin, demonstrated a significant resistance to this insecticide.[17] In addition, resistance to the insecticides dichlorodiphenyltrichloroethane (DDT) and pyrethroid has been widely observed among An. gambiae and An. Arabiensis in a number of countries across Sub-Saharan Africa.[17, 24, 36] In countries that have achieved potential elimination of LF, insecticide resistance will be problematic if LF were to reemerge due to migration or human movement. If mosquitoes are not susceptible to previously effective insecticides, it will be necessary to revise vector control strategies through the development and use of new insecticides.

Seasonal Variations

Fluctuation of climatic conditions also impacts LF transmission dynamics as seasonal variations in temperature, rainfall, and humidity have a direct impact on LF transmission. In some areas, significant variation in W. bancrofti transmission may occur within a relatively small geographic area due to differences in environmental conditions like temperature and rainfall that impact vector breeding habitats.[37] Mosquito densities and the proliferation of various mosquito species may be directly linked with seasonal patterns, and this can impact transmission dynamics of LF.

In the Rwegoshora study, the monthly transmission potential (MTP) in the two communities varied seasonally, and fluctuated according to weather conditions.[37] At one study site, a high level of transmission was observed in July-September (shortly after the rainy season).[37] Here, the MTP was 13.5 times higher in May than in November, suggesting strong seasonal fluctuations in transmission. The other study site experienced a similar rise in transmission during and shortly after the rainy season. Conversely, this site experienced virtually no transmission during the dry season. These results demonstrate that transmission does not occur uniformly throughout the year, but fluctuates drastically according to seasonal changes. This seasonal variation must be accounted for when developing a program for elimination of LF by strengthening vector control activities during periods of high transmission. An important aspect of vector control is universal bed net coverage with either insecticide treated nets (ITNs) or long lasting insecticidal nets (LLIN). One study in Uganda demonstrated that LLINs paired with MDA resulted in a sharp decrease in transmission potential[38] and two in Kenya found that ITNs offered effective personal protection against W. bancrofti transmission.[39,40] Research supports the effectiveness of ITNs in reducing transmission of LF.

Variations In Vector Breeding Habitat

Transmission intensity may be significantly heterogeneous within a relatively small geographic area due to differences in the habitats available for vector breeding.[37, 41] Therefore, mosquito breeding behavior should not be considered uniform, even within a single community. Household location relative to pit latrines and other mosquito breeding sites can impact the transmission potential for the members of the household.

The diversity of transmission dynamics within a single community was observed in one study conducted by Rwegoshora and colleagues (2007) in rural Tanzania.[41] Although the distance between the first and last village house was only 3.4 km, the data revealed significant variations between homes in regards to ABR and annual transmission potential (ATP). The household ABR for all vector species combined ranged from 920 to 23,353 within the community.[41] Even homes located close to each other showed a significant disparity in ABR and two homes located only 4.6 m apart had an ABR of 7385 and 17,688 respectively, due in part to the presence of a pit latrine on the latter property. Thereofer, significant variations in W. bancrofti transmission within a relatively small geographic area can be primarily attributed to differences in the habitats available for vector breeding.[37]

Rwegoshora's study has important implications for vector control strategies in LF-endemic areas because exposure to LF is not always homogenous in a community. Mosquito density, transmission potential and the clinical manifestations of LF may vary significantly between households. The abundance of the Cx. quinquefasciatus vector species can be attributed to the presence of pit latrines, and the study demonstrated highly variable vector densities based on a home's proximity to a highly productive pit latrine.[41] Therefore, vector control authorities should target pit latrines in vector control strategies where Cx. Quinquefasciatus is present. For example, treating pit latrines with floating layers of polystyrene beads has been shown to effectively reduce the population of Cx, quinquefasciatus mosquitoes.[42,43] Treating pit latrines and other mosquito breeding sites is one aspect of vector control that should be employed.

Transmission in the Urban Setting

Due to its strong association with substandard living conditions, urban LF is strongly concentrated in areas of low socioeconomic status. This is particularly problematic due to population growth occurring in low-income developing countries: in Sub-Saharan Africa the urban population is estimated to exceed 50% by 2030.[44] Thus, the transmission dynamics of LF in urban areas must be thoroughly understood and considered when designing elimination programs. The dynamic between rural and urban elimination strategies should be studied to inform existing elimination campaigns.

Unfortunately, studies of urban transmission of LF in Sub-Saharan Africa are rare. Two studies in the three major urban areas of Ghana (Bawku, Bolgatanga, and Secondi/Takoradi) demonstrated elephantiasis of the leg and the presence of filarial antigen in several individuals.[45] and other small studies occurred in Jos, Nigeria,[46] Dar es Salaam,.[47,48] These surveys are not sufficient to inform policy decisions regarding the implementation of LF elimination measures in urban centers of Sub-Saharan Africa because they are not representative of all urban areas in Africa. Although LF is widespread in rural areas, urban transmission is an important issue especially in small and medium sized cities, which have the largest potential for population growth.[44] Future research should take into account behavioral differences in rural and urban environments, the socio-economic context of urban LF and epidemiological determinants which impact transmission.

In urban environments Culex quinquefasciatus are important vectors of LF. W. bancrofti has demonstrated a significant potential for urban transmission, primarily because the Cx. quinquefasciatus vector thrives in crowded cities with poor sanitation and sewerage facilities.[44] In the past, research and control activities related to LF elimination campaigns have focused on rural areas while urban areas have been neglected.[44] However, urban populations in Sub-Saharan Africa also face a significant burden of LF, due in part to Cx. quinquefasciatus mosquitoes.[44-46] Due to the rapid growth of cities, LF elimination campaigns should incorporate strategies for the control of LF in urban areas. More research is needed in this area to determine the most effective way to combat LF in the context of an urban environment.

Social Barriers to the Uptake of Treatment

In addition to the mosquito behaviors described above, human behavior and its impact on transmission dynamics is also an important consideration. Noncompliance with drug regimens can be a significant problem in the implementation of a successful elimination campaign. In order for elimination to occur, it has been suggested that approximately 65-80% of the population must be treated over four to six years.[49] In the interest of global elimination, it is necessary to reduce patient noncompliance and to identify those who are reluctant to take their medication. Researchers have identified fear of treatment as a major cause of noncompliance.[49,50] The medications ivermectin and albendazole may result in unpleasant side effects including nausea, headache, dizziness, fever, malaise, vomiting, decreased appetite and exacerbation of existing symptoms.[49,50] The consequent fear of side effects has been cited as a major barrier to the uptake of treatment. In addition, problems related to the size, number and taste of the tablets were associated with noncompliance and some participants felt that the tablets were too large for children to swallow, and also that the bitter taste and smell elicited nausea.[50] Other problems related to drug uptake include skepticism of the government and international organizations, a concern that the drugs cause infertility, and doubts about drug efficacy.[49] Limited or ineffective health communication in the form of radio spots, posters, or television programs can fuel misconceptions among both patients and health workers alike, contributing to a misunderstanding of MDA and a mistrust of the effectiveness of treatment.[49] Patient noncompliance can be reduced by improving the quality of health messages before and during MDA and also by reducing misconceptions through targeted advertisements and other sensitization activities. Health workers must include effective and culturally sensitive health messaging as a component of LF elimination.

Discussion

LF persists in most countries throughout Sub-Saharan Africa despite health campaigns aimed at eliminating the disease. In many areas where mass drug administration has been implemented, LF continues to thrive due to the reasons described in this paper. The GPELF has established 2020 as the international endpoint for LF elimination, but the issues impeding elimination efforts in Africa will prove to be a major obstacle in the coming years. In order to achieve elimination by 2020, health authorities must reassess their elimination strategies, taking into account the heterogeneity associated with LF disease ecology.

In all areas of Africa, capacity building, needs assessments and educational campaigns are vital next steps on the path to elimination. Capacity building includes identifying and training more drug distributors to participate in MDA campaigns as well as engaging local community members to participate in a comprehensive and sustainable vector control program. It also includes fostering collaboration between various government personnel and non-governmental organizations to facilitate the effective implementation of elimination strategies. Needs assessments and monitoring activities can inform these efforts by identifying resource limitations and emphasizing issues that need to be addressed. Finally, educational campaigns are necessary to ensure patient compliance with drug regimens.

In countries where MDA has not interrupted transmission (i.e. Ghana and Burkina Faso) or where MDA has yet to begin (i.e. Liberia), an integrated vector control program should be implemented and sustained. Vector control should target pit latrines, cess pools, and other sources of human waste in areas where Cx. quinquefasciatus mosquitoes contribute to LF transmission. Researchers must analyze the species composition and diversity to determine the best strategy given available resources. A successful LF elimination campaign should be founded on a comprehensive knowledge base regarding local vector composition and transmission dynamics.

Lymphatic Filariasis has been identified as a candidate for elimination in many sub-Saharan African countries but there are many barriers to the successful elimination of this disease. The vector composition in a given area and the variety of feeding and resting behaviors associated with each species can complicate elimination efforts. The abundance of certain highly competent vectors that exhibit limitation processes can result in continued transmission despite MDA. Other variations related to season and habitat impact add to the heterogeneity of transmission and risk of LF within communities. This paper provides a summary of the various obstacles to elimination. Further research can only add to our growing understanding of LF epidemiology and vector characteristics across Africa, allowing us to develop targeted and context-specific interventions.

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