Chapter

Use of Spatial Epidemiology in Neglected Tropical Diseases Control, Elimination and Eradication

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Abstract

The burden of disease due to neglected tropical diseases in tropical and sub-tropical regions of the world still remains enormous. The diseases are prevalent in poor and marginalized communities where water and sanitation are a challenge and these communities are still grappling with other challenges like unemployment and other diseases. Africa shares the greatest burden of these diseases with women and children being the worst hit. In an effort to reduce the impact that these diseases have had on humans, global commitments and targets have been set to collectively deal with these diseases. Crucial to these global calls is epidemiological data showing exactly where these diseases occur so that the limited resources for control which is common in these poorer communities are targeted to areas where they will achieve maximum impact. Spatial epidemiology tools such as geographic information systems and remote sensing are therefore needed.

Keywords: neglected tropical diseases, control, spatial epidemiology, geographic information systems, remote sensing

1. Introduction

Neglected tropical diseases (NTDs) also known as diseases of poverty refer to a diverse group of diseases that cause serious morbidity and lead to mortality in the long term, especially in the poorest tropical and sub-tropical regions of the world [1]. These diseases are most prevalent in areas that are referred to as neglected because they do not receive much funding and attention compared to other diseases such as HIV, Malaria, Tuberculosis and now COVID-19 among others and the mechanisms under which they cause disease are not fully understood but are currently being studied just like most of the communicable diseases [1–3]. The epidemiology and transmission dynamic of these diseases are now being understood and this information is crucial for control, elimination and eradication [4]. NTDs include Buruli ulcer, Chagas diseases, Dengue and Chikungunya, Dracunculiasis (Guinea worm), Echinococcosis, food-borne trematodes, Human African Trypanosomiasis (sleeping sickness), leishmaniasis, Leprosy (Hansen's disease), Lymphatic filariasis, Mycetoma, Onchocerciasis (river blindness), Rabies, Scabies, Schistosomiasis, Snakebite envenoming, Soil-transmitted helminthiases, Taeniasis/cysticercosis, Trachoma and Yaws (endemic treponematoses) diseases [2, 5].

NTDs affect approximately 1 billion of the total global population especially in low- and middle-income countries with Africa especially Sub-Saharan Africa accounting for approximately 40 to 51% of the total NTD burden [2, 6, 7]. They are not only responsible for health effects but also result in serious personal, social and economic impacts on populations [1] due to physical disabilities, disfigurement and blindness which lead to stigma, discrimination and loss of social status in adults and malnutrition, retarded growth and compromised cognitive development and school absenteeism in children [1, 7]. The mortality associated with NTDs is usually low compared to other infectious diseases and was estimated to be 242,000 in 2000 [8, 9].

2. Epidemiology of NTDs

The epidemiology of NTDs globally is determined by many factors, poverty and socioeconomic status being a major factor [10, 11] as it imparts on people's access to clean water and sanitation [12], quality education and its impact of behavioral factors key to NTD control [13] as well as general living conditions [14]. Other factors affecting the epidemiology and transmission dynamics of NTDs include war and conflicts [15] and weather and climate change which support the survival and distribution of the vectors for most of NTDs and restrict the distribution of most of the NTDs to the tropical and sub-tropical regions of the world [16]. Disturbance to the natural ecosystems due to rapid urbanization [10], globalization and international travel [17] and the mushrooming of cities with poor planning for sanitation [18] are other factors perpetuating the spread of NTDs.

The distribution of NTDs is prominent in the tropical and sub-tropical regions of Africa, Asia, Oceania, the Middle East and America [7, 19, 20]. In Africa, common NTDs include trachoma, ascariasis, hookworm, trichuriasis, lymphatic Filariasis, schistosomiasis including female genital schistosomiasis (FGS) [21], onchocerciasis, human African trypanosomiasis (HAT), loasis, leprosy and guinea worm [22–24]. They are predominantly found in West Africa; Nigeria, Chad, Niger, Mali and most of the Sahel region; Central Africa, Democratic Republic of Congo, Central African Republic, Sudan, Uganda and Angola and in Southern and Eastern African countries such as Zambia, Zimbabwe, Malawi, Mozambique and Tanzania [7, 20].

In Asia and Oceania, the NTDs are mostly found in India, Indonesia and China. This region has the highest burden of leprosy, lymphatic filariasis, soil-transmitted Helminthes, dengue and other arboviruses, yaws, scabies, trachoma, Japanese encephalitis and leishmaniasis [20, 25, 26] mostly in Indonesia and Papua New Guinea as well as India and South Asia. Although there is great success toward the elimination of schistosomiasis in China, which can also be true for soil-transmitted Helminthes since the treatment and control dynamics are the same, [27], China is known for food-borne trematodes such as clonorchiasis and paragonimiasis and other NTDs including trachoma and leprosy [26].

In the Middle East, the common NTDs are trachoma, leprosy, schistosomiasis, onchocerciasis, trichuriasis, rift valley fever, fascioliasis, soil-transmitted Helminthes and leishmaniasis [28]. These are found in parts of North Africa and the Sahel region (Morocco, Algeria, Libya and Egypt), Yemen, Oman, Saudi Arabia, Jordan, Syria and Iraq [20, 29].

The distribution of NTDs in the Americas is centered in the regions of Brazil and the Amazon region, Gran Chaco area and the Mesoamerica and Texas regions [20]. In parts of Brazil and the Amazon region, common NTDs include Chagas' disease, leishmaniasis, schistosomiasis, dengue fever, leprosy, onchocerciasis and lymphatic filariasis [30]. Lymphatic filariasis, Schistosomiasis, Onchocerciasis, Trachoma and Soil-transmitted helminthiases are common NTDs in the Gran Chaco region of the Americas comprising of Bolivia, Paraguay, northern Argentina and parts of Brazil. The Mesoamerica and Texas regions of the America are common for intestinal helminth infections, cysticercosis, cutaneous leishmaniasis, dengue and Chagas disease [31].

3. Control, elimination and eradication of NTDs

The interventions toward NTDs are enshrined in the local, regional and global commitments using holistic strategies aimed at preventing and reducing transmission, reducing morbidity and mortality and ultimately eliminating and eradicating these diseases as public health problems [32]. The specific strategies employed can vary depending on the type and prevalence of NTDs in a particular region [33]. Tailored approaches are often necessary to address the unique challenges presented by each disease in a given geographic area [34]. The interventions toward of NTDs are now shifting from traditional approach, where it was only a responsibility of health departments in different countries, to a multi-sectoral approach. The current approach is anchored on collaboration involving governments, non-governmental organizations, pharmaceutical companies and international organizations which is critical for resource mobilization, technical expertise and coordination of efforts. Within counties, NTD interventions often require collaboration among health ministries, education, water and sanitation departments and other sectors. A multi-sectoral approach is essential to address the root causes of NTDs, such as poverty and inadequate access to clean water and sanitation [35].

Previously, the major strategies in the interventions toward NTDs were centered around preventive chemotherapy treatment (PCT) through mass drug administrations (MDA) as well as individual case finding and management, which is also known as innovative and intensified disease management (IDM) for NTDs [36]. There is now a paradigm shift because the proposed NTD interventions strategies now have vector control and social science approaches [7, 37, 38].

The NTDs intervention through PCT involves large-scale administration of drugs to the identified population at risk without any need for diagnosis to confirm infection status [39]. The drugs are administered to the populations at risk and regular interval for a specified period time. It is highly recommended that MDAs are conducted in an integrated manner to maximize on the cost of conducting the programs and also increase the impact of the drugs used and improve health outcomes since NTD epidemiology in most settings shows an overlap and because some drugs used in MDAs on a particular NTD may also be effective against other NTDs [40–42]. The NTDs targeted under this strategy include lymphatic filariasis, onchocerciasis, trachoma, schistosomiasis and soil-transmitted helminthiasis [36]. For trachoma treatment, two antibiotics, 1% tetracycline eye ointment and azithromycin are recommended. The SAFE strategy (Surgery, Antibiotics, Facial cleanliness and Environmental improvement) is also applied in trachoma management [43].

Strategy	Commitment(s)
The London Declaration on NTDs (2012).	• Stakeholders agree to control, eradicate or eliminate 10 NTDs by 2020.
The Regional Strategy on Neglected Tropical Diseases in the WHO African Region (document afr/rc63/10); AFR/RC63/R6, Sept. 2013.	• Country ownership and leadership of NTDs. • Broad-based national and international coordination and collaboration on NTDs. • Empowerment of people and communities in NTD control. • Evidence-based approach generated through scientific evidence mapping, monitoring, evaluation and research. • Strengthening health systems for NTDs. • Equity and gender-based interventions for NTDs [47].
The 66.12th World Health Assembly Resolution: WHA66., 2013.	• Prioritize prevention, control, elimination and eradication of NTDs in national health agendas. • Sustain the development and updating of evidence-based strategies for prevention, control and elimination of NTDs. • Collect additional information on the costing of interventions and of the socioeconomic impact NTDs. • Collaborate with partners in key areas to implement interventions to prevent and control NTDs. • Ensure predictable, long-term financing for sustained interventions against NTDs. • Build national capacity to implement preventive chemotherapy interventions. • Review programmatic progress in the preparation of strategic and operational plans for NTDs. • Intensify national control activities, harmonize strategies and control methods, for NTDs. • Improve coordination with related sectors on NTD.
The Addis Ababa NTD Commitment (2014)	• Work to increase domestic contribution to the implementation of NTD programs. • Promote a multi-sectoral approach in the implementation of NTD program goals. • Ensure the adoption of both long-range strategic and annual implementation plans for NTDs. • Report and use program data in a timely fashion. • Ensure that the implementation of NTD programs contributes to the strengthening the overall health system.
The 70th World Health Assembly (WHA) held in Geneva, Switzerland in May 2017.	Global Vector Control Response (2017–2030) adopted aimed at • Preventing, detecting, reporting and responding to outbreaks of vector-borne diseases; • Using an integrated approach when preventing, detecting, reporting and responding to outbreaks of vector-borne diseases.

Strategy	Commitment(s)
The 73rd World Health Assembly, WHA73; 13 November 2020.	• Member States to implement the new road map for neglected tropical diseases 2021–2030, "Ending the neglect to attain the Sustainable Development Goals: a road map for neglected tropical diseases 2021–2030". • Advocating for and providing technical assistance and guidance to Member States and partners in the implementation of the new road map for neglected tropical diseases 2021–2030 toward reaching Sustainable Development Goal target 3.3.
The 2021–2030 NTD Road Map (2020).	Facilitation of accelerated progress toward control, elimination, interruption of transmission, and eradication of NTDs through three strategic pillars of: • Accelerating programmatic action with a focus on impact rather than progress measures; • Intensifying cross-cutting approaches; • Changing operating models and culture to facilitate country ownership for NTD control.

Table 1.
Commitments toward NTDs prevention, control, elimination and eradication.

Single-dose albendazole (400 mg) or mebendazole (500 mg) are used during MDAs for the treatment of predominantly schoolgoing children against ascariasis and hookworms infections and in areas where trichuriasis may be present in addition to ascariasis and hookworm infections, ivermectin (IVM) is added to the combination of the drugs [44, 45]. IVM is also used in MDAs for onchocerciasis using a standard dose of 150–200 μg/kg, and in areas where onchocerciasis and LF are co-endemic, a combination of IVM and albendazole is used. For LF endemic areas, diethylcarbamazine (DEC) has been used in MDAs while for schistosomiasis, praziquantel (PZQ) is the drug of choice [44, 46].

The diseases considered under IDM control of NTDs include human African trypanosomiasis, leishmaniasis, Chagas diseases and Buruli ulcer [36]. Unlike PCT-based NTDs, where diagnosis is not a priority before treatment, IDM of NTDs is based on diagnosis and detection of disease to prompt treatment. These diseases demand a well-established health system with technical capacity at all levels to identify and diagnose these diseases [43].

Table 1 below shows some of the strategies for the control of NTDs with focus on the African region.

4. Use of spatial epidemiology in the control, elimination and eradication of NTDS

So far, interventions toward NTDs have, to a large extent, been centered on MDAs and IDM though other opportunities are emerging that can help regions affected by these diseases reach elimination and where possible eradication status [6, 7, 12, 20, 36, 39]. The success of these intervention programs depends on the availability of up-to-date and reliable information on the geographical distribution of the diseases. Recently, the development and application of tools such as geographic information systems (GIS), remote sensing (RS) and spatial statistics have enhanced the understanding on the geographical distribution and mapping of NTDs [48–53]. The various ways through which GIS and RS technologies have been applied in NTDs interventions are discussed herein.

4.1 Disease distribution and hotspot identification

The distribution and hotspot identification of NTDs is essential in the determination of interventions and the maps that are developed using GIS and RS technologies depend on the nature of the NTD and the level of the intervention, whether it is control, elimination or eradication [54, 55]. Risk mapping is therefore a first stage in NTD interventions [56]. GIS and RS tools have been used in NTD control programs to map and show areas with the highest prevalence so that the resources for interventions which are usually scarce can be targeted at areas with the highest prevalence. Spatial statistics in a GIS system can also be used to estimate the numbers of the population at risk needing the intervention, information which is key to NTDs program managers [57, 58]. These strategies have been used for those NTDs that have been targeted for control using MDAs. NTDs that fall under IDM are targeted for elimination and therefore locations showing where actual transmission is taking place in GIS systems are required for application of the interventions and also for monitoring and evaluation purposes [55].

4.2 Mapping NTDs vector distribution

Vector-borne diseases account for a large proportion of all NTDs [37] and all vector-borne diseases combined account for about 17% of all communicable diseases. The distribution of vectors can be mapped using GIS so that areas that need control like the use of indoor residual spraying (IRS) and the distribution of mosquito nets can be prioritized in areas where there are more mosquitoes [59].

4.3 Predictive modeling of NTDs

Predictive modeling of NTDs using GIS and RS technologies has been used in cases where some data are available about the prevalence of the disease or vectors and such data are used to predict in other areas where the disease or vectors are likely to occur [51]. One approach is where RS data on environmental and climate factors affecting the distribution and survival of the vectors are used in a GIS system to generate hotspots for the distribution of NTDs [23, 24, 60]. In these studies, on NTDs, RS data such as temperature, precipitation, vegetation index alongside vector abundance and disease prevalence data have been used [61]. Using these approaches, spatial epidemiology can therefore be applied in developing early warning systems for NTD.

4.4 Climate change and disease modeling

There is evidence that climate change may affect the distribution of vector-borne diseases including NTDs [16, 62–65]. Remote sensing data can be used to study the effects of climate change on NTD transmission. Predictive models can help estimate future disease risks based on changing environmental conditions. GIS and RS technologies have been applied in predicting how climate change may impact on the geographical distribution of *Schistosoma japonicum, S. mansoni* and *S. haematobium* using snail data. The developed model predicted that between 2021–2050 and 2071–2100, there could be an increase in the transmission of schistosomiasis [66] in some areas while other areas may also shrink in transmission.

4.5 Disease surveillance, monitoring and evaluation

As NTD interventions move into elimination and eradication stages, the use of spatial epidemiology will be a major advantage [6]. Through GIS, program managers can monitor whether the applied interventions over a specified period and depending on a particular NTD have been effective or not. This can be achieved by creating outputs in a GIS system showing changes in disease prevalence and transmission patterns over time. This will help evaluate whether the interventions have achieved the desired impact or not [67].

5. Conclusion

As control, elimination and eradication are prioritized in line with the WHO 2021–2030 roadmap for NTDs, risk maps before and after MDA and surveillance are needed. The use of GIS and RS technologies has potential to provide a clear understanding of the epidemiology and transmission dynamics of NTDs. This will lead to the production of maps highlighting the hotspots where interventions are needed. The potential use of GIS and RS in the modeling, mapping and control of NTDs in areas where these diseases are prevalent must therefore be emphasized. Critical to this is the building of capacity in spatial epidemiology especially in African settings where the capacities are still limited. There are still challenges with quality and up-to-date data on most NTDs in several settings and this may affect the quality of spatial outputs. With evidence that climate change may affect the distribution of NTDs transmitted by vectors, in situ studies on climate change are therefore proposed. More research is necessary to develop new tools, diagnostics and treatments for NTDs. The current spatial epidemiology tools must be evaluated and refined so that they can be applied in effective NTD control, elimination and eradication strategies. The possibility of using an integrated application of spatial epidemiology like in the case of malaria and lymphatic filariasis must be explored since the two diseases are transmitted by mosquito vectors. Comparative studies are also needed to compare the sensitivity and specificity of spatial epidemiology modelsdeveloped from using prevalence data against those developed using vector data only. Spatial models are also needed to show how the impact of using all the interventions for NTDs will perform in line with WHO 2021–2030 roadmap for NTDs.

Conflict of interest

The authors declare no conflict of interest.

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