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Needs and Challenges in Modelling Malaria for Emergency Contexts

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Abstract

While modelling is an essential component in understanding malaria epidemiology and design of better control measures, it rarely considers the particular contexts encountered in emergency settings. By linking these situations with the transmission parameters our aim is to correct this bias and call for a better collaboration between relief actors.
In 2018, approximately 70 million people were considered to be forcibly displaced, whether internally displaced, returnees or people living in humanitarian emergencies [1]. A quarter of these were located in sub-Saharan Africa. At the same time, 90% of worldwide malaria-associated deaths currently occur in sub-Saharan Africa, about a third of which take place within complex humanitarian emergency settings [1, 2, 3].

Different from normative contexts where malaria control is routine and even elimination strategies are being implemented, in unstable conditions malaria incidence is poorly understood and subject to composite short-term changes. Controlling malaria in such settings requires tools with particular target profiles, amongst which rapid deployment, adaptability, practicality and ease of implementation are paramount. While modelling is often considered essential in determining if and how a strategy or a combination of strategies can impact the malaria burden [4,5], the case of emergency settings is rarely considered. Our aim is here to highlight, through defining an emergency setting, how modelling approaches could help designing more efficient and effective malaria control programmes while fostering collaboration between the actors involved in humanitarian aid.

What defines an emergency situation?

According to the World Health Organization, complex emergencies are situations of disrupted livelihoods and threats to life produced by warfare, civil disturbance and large-scale movements of people, in which any emergency response has to be conducted in a difficult political and security environment. Complex emergencies combine internal conflict with large-scale displacements of people, mass famine or food shortage, and
Adapting malaria modelling to emergency settings: What can be done?

It is unlikely that a ‘one size fits all’ modelling approach will work in emergency settings, and a variety of scenarios would need to be considered. Even more than in less complex contexts, the adaptation to heterogeneous and unstable situations and the ability to provide long-term sustainable solutions are major aspects to conduct an efficient programme aiming at decreasing malaria mortality and morbidity.

Proposed models would require a number of parameters ranging from relevant epidemiological and medical population information, and consider the type and quality of tools and their potential combinations. Some examples of this include population composition and movement, human ecology, pre-existing local activities of malaria control, diagnosis and access to healthcare. This should ultimately allow a determination on which specific tools would be more adapted to the situation (e.g. Insecticide-Treated Cover and Blankets, repellents, IRS campaigns). The approaches should also acknowledge that there might be some context-specific challenges in emergency settings to use some of these approaches, whether classical or innovative.

Translation into parameters

In the definition of an emergency setting, a number of aspects can be translated into parameters to feed epidemiological models of malaria (Figure 1). The most straightforward manner is to consider the classical basic reproductive number, $R_0$, describing the number of secondary cases of malaria arising from a single case in an
otherwise uninfected population [7] and it’s more recent neoclassical assumptions taking into account a variety of parameters affecting malaria transmission [8,9].

The impact of large-scale displacement of people

One of the major aspects associated with emergency settings is large-scale population displacement, which in terms of malaria epidemiology can affect transmission in a variety of ways. Such changes may not only be in absolute numbers but in other major determinants of malaria epidemiology [9], such as age distribution, with often more children, young adults and women of childbearing age; the migration [10] and the malaria immune status [11], affecting the spread of the disease. As a corollary using spatially-explicit models can be particularly useful in scenarios where heterogeneity is important in the environment (e.g. disturbed landscapes), interactions in the human populations (e.g. differences in immunity in long-term nearby residents vs newly displaced people) as well as the vector or the parasites ones (e.g. vectorial capacity varying over short distances and potentially different parasite species).

Mass famine or food shortage

When herd immunity can be impaired due to an influx of malaria-susceptible populations arriving from an area with no or little malaria transmission, the compounding effect of mass famine and food shortage leading to acute or chronic malnutrition may have an important impact on disease incidence and evolution [12, 13]. This will typically lead to a diminished immunity (affecting then the recovery rate, the factor r in $R_0$) and an increased malaria-related mortality.

Fragile or failing economic, political, and social institutions
Often emergency setting are closely linked with a fragile social and socio-economical system as well as inadequate infrastructures with limited access to rapid diagnosis and where the risk of misdiagnosis is high [14]. This can then lead to a number of aspects that could be considered in models whose aim is to include the access to treatment and infrastructures, the quality of medical care as well as to the presence or absence of vector control activities that will influence several mosquito-related parameters \((m, a\) and \(\mu)\).

Natural disasters

Natural disasters typically exacerbate and amplify pre-existing challenges encountered in complex humanitarian settings. This can imply changes in ecological conditions (e.g. flooding) and may result in the initial destruction of breeding sites but also in the creation of new ones that can result in an ‘off-season’ malaria peak. In addition, natural disasters are likely to deepen logistic constraints affecting the delivery of control tools.

Data collection

One of the major challenges in emergency humanitarian contexts, particularly in the acute phase, is the difficulty to get accurate data, which would be important in the calibration of models [15]. Typically, most emergency assessments are ‘quick and dirty’, and as such the number, type and characteristics of data parameters and points to be collected need to be carefully considered and prioritised, including that of the resident/host populations.

Implementation
Time-efficiency of implementation is also an essential aspect of tackling malaria in an emergency setting. The speed and the quality of the tool and the subsequent control strategy deployment are critical to prevent avoidable malaria-associated deaths. Choosing between a less effective strategy that can be quickly implemented, and more efficacious options that require more time to develop, resulting in significant implementation delay, is where such a tool will have the greatest value. Models could be a real asset to guide such decisions, particularly if operationalizable through easily accessed and user-friendly interfaces with minimum prior training.

**Conclusion**

Overall there is a need for modelling approaches that would not only consider the biological and epidemiological parameters for malaria control in emergency settings but also the various factors, often difficult to estimate, that are unique to such situations. Such models should build upon existing tools and available solutions (low-hanging fruits) to analyse and suggest improved designs that consider the whole range of tools available for malaria control (*e.g.* case management, drugs, vector control). This could also lead to improved planning, budgeting and collaboration between the actors providing emergency relief and assistance. The use of models and a better collaboration and service delivery between the various actors involved in relief in emergency settings should develop beyond malaria in multiple other conditions in a more holistic and multisectorial manner.

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Resources

i https://malariaatlas.org/

ii https://www.severemalaria.org/

iii http://popstats.unhcr.org/en/overview

References


Figure 1. Parameters related to the definition of emergency settings and their potential impact on the transmission of malaria. $R_0$, basic reproductive ratio; $m$, number of mosquitoes per human host; $a$, biting rate of the mosquitoes on their human host; $b$, infectivity of mosquitoes to humans; $c$, infectivity of humans to mosquitoes; $\mu$, mortality of adult mosquitoes; $T$, incubation period of parasites within the mosquito vector; $r$, rate of recovery of infected humans.
**Mass famine or food shortage**

**Immunity functions**
- General immunity
- Transmission-blocking immunity that may affect infectivity of humans to mosquitoes \([c]\)
- Pre-erythrocytic immunity that may affect infection of mosquitoes to humans \([b]\)

**Large-scale displacement of people**

**Demographic effects**
- Size of human population (noting \(R_0\) considers an infinite population in its classical form)
- Human population density
- Age distribution

**Essential tool characteristics for malaria in emergency settings**
- Speed of deployment
- Adaptability
- Practicality
- Ease of implementation

**Fragile or failing economic, political and social institutions**

**Socio-economic factors**
- Access to treatment and infrastructures
- Quality of medical care
- Vector control programme
- Dysfunctional normative social institutions
- Disrupted social welfare mechanisms

\[
R_0 = \frac{mbca^2e}{r} T
\]

**Environmental factors**
- Seasonality & rainfall
- Temperature
- Humidity
- Increased pools of stagnant water

**Natural disasters**

**Immunity functions**
- General immunity
- Transmission-blocking immunity that may affect infectivity of humans to mosquitoes \([c]\)
- Pre-erythrocytic immunity that may affect infection of mosquitoes to humans \([b]\)