

Report 18: The potential public health impact of COVID-19 on malaria in Africa.

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Summary

The COVID-19 pandemic is likely to severely interrupt health systems in Sub-Saharan Africa (SSA) over the coming weeks and months. Approximately 90% of malaria deaths occur in this region of the world, with an estimated 380,000 deaths from malaria in 2018. Much of the gain made in malaria control over the last decade has been due to the distribution of long-lasting insecticide treated nets (LLINs). Many SSA countries planned to distribute these in 2020. We used COVID-19 and malaria transmission models to understand the likely impact that disruption to these distributions, alongside other core health services, could have on the malaria burden. Results indicate that if all malaria-control activities are highly disrupted then the malaria burden in 2020 could more than double that in the previous year, resulting in large malaria epidemics across the region. These will depend on the course of the COVID-19 epidemic and how it interrupts local health system. Our results also demonstrate that it is essential to prioritise the LLIN distributions either before or as soon as possible into local COVID-19 epidemics to mitigate this risk. Additional planning to ensure other malaria prevention activities are continued where possible, alongside planning to ensure basic access to antimalarial treatment, will further minimise the risk of substantial additional malaria mortality.

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1. Introduction

The COVID-19 pandemic is likely to have wide-reaching implications for malaria and its control. The burden of malaria is heavily concentrated in Sub-Saharan Africa (SSA) where cases and deaths associated with COVID-19 are beginning to rise. As a result, many countries in SSA are implementing societal measures which aim to lower contact between people and hence reduce transmission, with partial or full lockdowns currently reported as being in place in 37 countries [1]. Even under reasonably optimistic scenarios regarding mitigation of COVID-19, the epidemic could result in millions of deaths as hospitals and local health centres quickly become overwhelmed [2].

As witnessed in China, Europe and North America to date, COVID-19 is likely to over-burden most health systems meaning this pandemic will likely have a profound impact on diseases such as malaria. In response to restrictions placed on movement, it is likely that malaria prevention activities will be scaled back. The most effective strategy for reducing malaria is the mass distribution of long-lasting insecticide treated nets (LLINs). These LLINs are typically distributed centrally within a community and these gatherings may be cancelled or poorly attended as COVID-19 spreads. Similarly, other important anti-malarial interventions such as seasonal malaria chemoprevention (SMC) and the indoor residual spraying of insecticide (IRS) are conducted house-to-house and could also be scaled back substantially or require different delivery mechanisms. The World Health Organization has stressed that all routine prevention and case management should be continued to the extent possible [3]. However National Malaria Control Programmes (NMCPs) will come under intense pressure to reduce activities in the face of any widespread increase in COVID-19 attributable deaths and COVID-19 disease induced absenteeism.

Here we attempt to quantify the direct impact that the spread of COVID-19 will have on *Plasmodium falciparum* malaria morbidity and mortality in SSA using mathematical models of COVID-19 and malaria. It is assumed that one disease does not directly influence the transmission or severity of the other, but that COVID-19 impacts malaria via its repercussions on the health system and the distribution channels for malaria prevention. Predictions of the timing of the COVID-19 epidemic in different African countries are highly uncertain so illustrative examples are used to show how different COVID-19 mitigation and suppression strategies will influence malaria transmission. We only consider impact over a 12-month period. The pervasive and potentially huge indirect effects resulting from the COVID-19 epidemic, such as increased poverty, malnutrition and social instability, which themselves may influence malaria burden are also not considered here.

2. Results

Four scenarios for the COVID-19 epidemic are considered. The first – an entirely unmitigated COVID-19 epidemic – is a counterfactual against which the impact of mitigation and suppression of the disease can be judged. Whilst it is unlikely to occur in practice, this scenario is included as it illustrates that a rapid spread that would be highly disruptive to malaria services but for a limited period of time (red lines, Figure 1). The second scenario – termed mitigation – is one in which social contact is reduced but where the effective reproduction number R_t remains above 1 and hence a single-peaked epidemic occurs. This scenario has a significantly lower peak – and hence lower demand on the health system – than the unmitigated scenario but is predicted to be spread out and cause a longer period of disruption to other malaria activities (blue lines, Figure 1). The third scenario is continued suppression

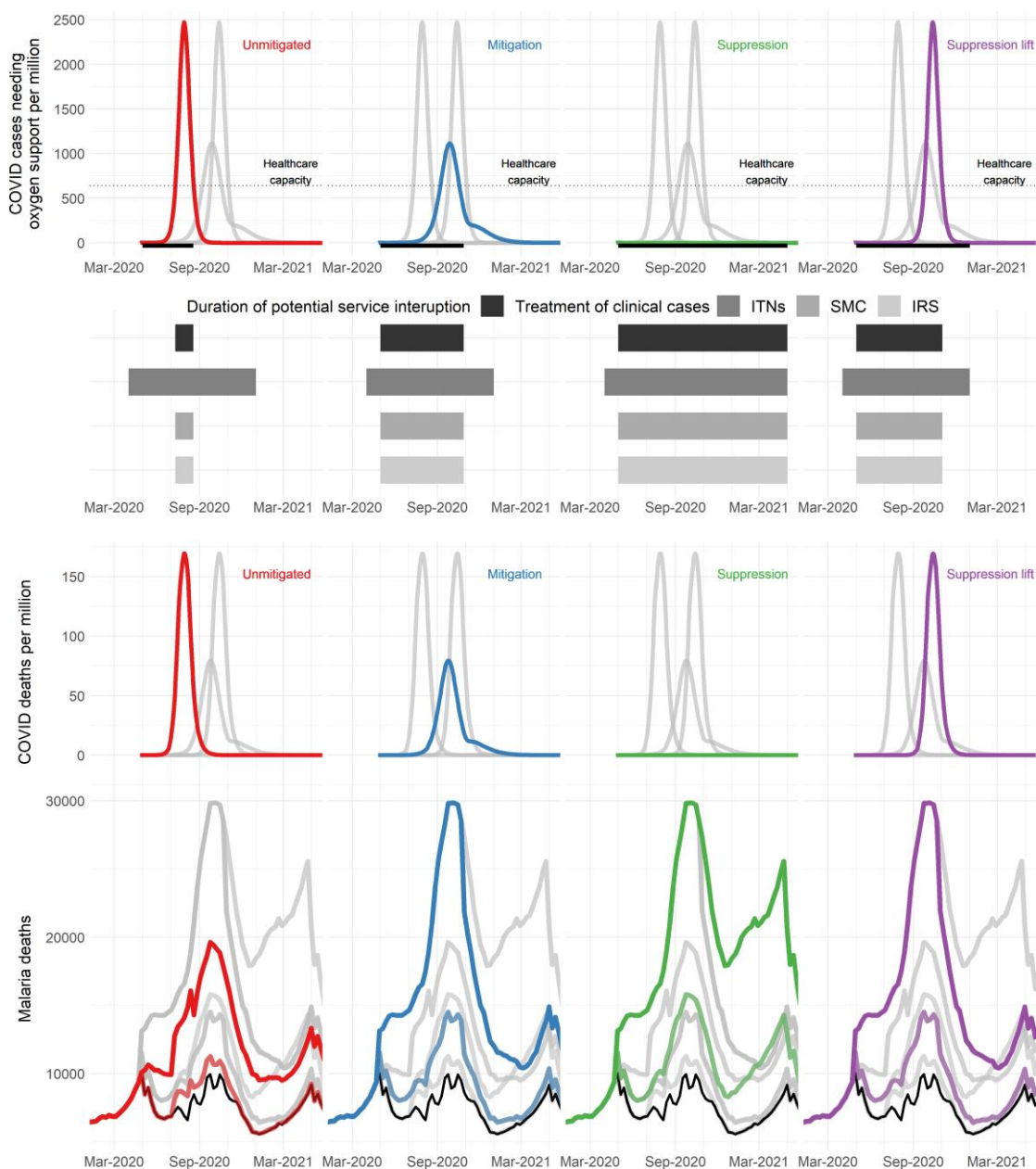


Figure 1. Projected number of deaths due to COVID-19 and malaria in sub Saharan Africa (SSA) over time according to different COVID-19 scenarios. Top panel shows the COVID-19 epidemic and the number of people needing oxygen support per week for four different COVID-19 scenarios – an unmitigated epidemic (whereby contact rates are reduced by only 20%, red lines in 1st column), mitigation (contact rates are reduced and slow transmission but insufficiently to prevent an epidemic, blue lines in 2nd column), suppression (contact rates reduced low enough that numbers of deaths fall and are kept low for 12 months, green lines in 3rd column) and suppression lift (same as suppression but restrictions lifted after 2 months, purple lines in righthand column)). Thin dotted horizontal grey line indicates estimated healthcare capacity for a typical African country. Thick black horizontal line beneath the figure show the period when COVID-19 mitigation or suppression activities are assumed to be in operation. The upper middle row indicates the assumed duration of interruption where COVID-19 interventions affect different malaria prevention activities (IRS = indoor residual spraying, LLINs = mass distribution of long-lasting insecticide treated nets, SMC = Seasonal Malaria Chemoprevention) or case management of clinical cases with the level of this disruption is presented in Table 1. Middle bottom row indicates the predicted number of deaths due to COVID-19 per week for the different scenarios. The bottom row shows predicted malaria deaths per week for the different COVID-19 scenarios (coloured lines) and for the counter-factual where there was no COVID-19 induced disruption (black lines). Top coloured lines indicates worst-case scenario when all services cease (Table 1, row 1 highlighted by ‡) whereas bottom coloured line shows the most well-managed scenario (Table 1, row 7, highlighted by ¶). Grey lines in all panels show alternative scenarios whilst in the suppression scenario COVID-19 remains low throughout.

19 are available (likely a vaccine). We assume that under this scenario, malaria prevention remains disrupted throughout the year and whilst treatment services are disrupted through shortage of staff, the health system itself is not overwhelmed by COVID-19 patients because the disease is suppressed throughout (green lines, Figure 1). The fourth scenario assumes a shorter period of suppression is sustained but then subsequently lifted – resulting in a second epidemic that overwhelms the health system (purple lines, Figure 1).

Under all four COVID-19 scenarios considered, we estimate that the disruption to prevention activities coupled with reduced availability of treatment are likely to result in substantial numbers of additional deaths from malaria (Table 1). The scale of this increase depends critically on the overlap between the period of disruption due to the COVID-19 epidemic and the malaria seasons. As shown in the bottom panels of Figure 1, the majority of malaria cases across SSA occur in the latter half of this year, although the timing of the malaria peak varies considerably across the region. We expect the greatest degree of overlap with the malaria season and COVID-19 related disruption of services to occur under either mitigation or suppression scenarios. These strategies remain the most likely trajectories for countries to follow given that many countries have already implemented partial or full lockdowns.

Table 1. Projected COVID-19 and malaria deaths between 1 May 2020 and 30 April 2021 for different COVID-19 scenarios in malaria endemic countries in SSA. Different combinations of malaria interventions are considered on each row, with the colour denoting whether they were halted for the period of health system interruption (red), reduced to 50% of the normal coverage level (light green) or continued as normal (dark green). *LLINs* = distribution of long-lasting insecticide treated nets in countries due for mass campaigns in 2020, *SMC* = seasonal malaria chemoprevention in SMC target areas in the Sahel and, *Treatment* = treatment of clinical cases. *LLINs* and *SMC* campaigns are only disrupted in regions where they were previously planned. Values rounded to nearest hundred. Symbols ‡ and ¶ highlight malaria scenarios plotted in Figure 1.

			COVID-19 Scenario			
			Unmitigated	Mitigated	Suppression	Suppression lift
Projected COVID-19 deaths			3,324,100	2,414,800	4,000	3,320,600
Malaria scenario			Additional malaria deaths			
LLINs	SMC	Treatment	(compared to a baseline estimate of 387,800 deaths in this period without malaria service interruption)			
‡			268,600	471,900	684,500	473,000
			50,200	167,100	294,300	168,600
			246,300	442,000	684,500	443,100
			224,400	413,000	654,000	413,900
			253,200	384,500	456,100	385,000
			239,400	302,600	347,400	302,600
¶			25,000	97,000	189,000	97,400
			33,900	145,900	271,900	147,400
			40,800	115,400	170,400	115,500
			231,400	359,400	506,700	359,800
			18,000	125,000	271,900	126,600

Our results indicate that the provision of LLINs is particularly important. Twenty-seven out of 47 malaria endemic countries in SSA were due to hold LLIN campaigns in 2020. Not all regions within these countries were due to receive LLINs this year but where information is available it was included within the model. This means a high percentage of LLINs currently in circulation in SSA will be three

years old and their efficacy will have been diminished due to the decay of the insecticide and physical wear and tear. Their use is also likely to have dropped since the last campaign. It is unclear to what extent these campaigns will be impeded by COVID-19 but if those campaigns due in quarters two and three of 2020 are delayed until after an unmitigated COVID-19 epidemic (whilst maintaining reduced SMC and existing case management) we estimate that malaria deaths could increase by 231,400. Conversely, if LLIN distribution is maintained then this would substantially reduce the number of malaria cases, reducing any additional burden on the health system that could arise from rebound malaria epidemics.

The disruption to routine treatment of clinical cases is predicted to have the second largest impact on additional malaria deaths. SMC is only currently undertaken in the Sahel region of West Africa and hence at a continental scale is predicted to have less impact; however, the potential effect of interrupting these campaigns in the countries that use SMC may be large.

Implementing COVID-19 mitigation strategies can delay the peak in COVID-19 mortality though the lack of health system infrastructure in low income countries considered here means that deaths associated with COVID-19 are still likely to be high. The prolonged period of health system disruption caused by the mitigation scenario is predicted to substantially increase malaria deaths depending on the level of disruption caused. For example, if all malaria prevention and treatment activities are halted, under the mitigation scenario we estimate that malaria deaths would increase by 471,900 compared to a normal year. If the level of disruption can be minimised, with only SMC and treatment of clinical cases being reduced to 50% of their normal levels whilst LLINs are distributed as planned, the number of additional malaria deaths is predicted to be just ~100,000. This illustrates the benefits of ensuring that malaria services are managed as best as possible whilst acknowledging that the COVID-19 epidemic is likely to be overwhelming.

Many countries are pursuing strategies to suppress COVID-19 so that deaths associated with the disease are minimised. One of the challenges with this approach is to maintain other essential services for what could be a considerable period of time. Our results illustrate that, even if suppression is well-managed and LLIN distribution continues unaffected, reducing SMC and case management by 50% compared to the normal level could increase malaria deaths by 189,000 because of the long duration of disruption. Furthermore, failure to maintain suppression is likely to lead to a large second wave of COVID-19 that would overlap with the malaria season in many countries, resulting in worse outcomes for both COVID-19 and malaria.

3. Conclusion

The rapid global spread of the SARS-CoV-2 virus in the last two months has demonstrated the vulnerability of all populations to new infectious diseases. Whilst the direct health threat of the disease is clear, the broader societal and economic impact of the strategies required to control its spread are not yet fully realised. The disruption to other health services is likely to be one of the primary effects and will have wide-ranging ramifications for other diseases. Furthermore, in resource-poor settings, the disruption to daily life is also likely to have broader health effects including on food supply and hence malnutrition [4]. Many of those who suffer the most from diseases like malaria are also those who are most susceptible to the wider economic shocks. Communities will therefore need to work to combat both COVID-19 and a range of other public health threats simultaneously.

Our results demonstrate that prevention of malaria – particularly through the distribution of LLINs – is key to counter-acting any resurgence in malaria due to an interruption in other services. Unfortunately, the average age of an LLIN in Africa is now relatively old as more LLINs were scheduled to be distributed in 2020 than ever before. In addition, the increase in insecticide resistance in recent years may exacerbate this problem as resistant mosquitoes are more likely to survive exposure to older LLINs. Given that the majority of the LLINs due to be distributed in 2020 are already in country, NMCPs should prioritise widespread distribution of existing stock so that communities have the most effective vector control available. This will reduce the number of malaria cases at the time that health systems are most likely to be disrupted. The best option to reduce any impact of COVID-19 disruptions on malaria will depend on the local setting, their available resources and the timing of the COVID-19 epidemic relative to the transmission season. A wide range of additional preventative measures such as SMC and mass drug administration should additionally be considered to help reduce the resurgence of malaria in the coming months.

4. Methodology

Potential COVID-19 trajectories were produced through a modelling framework adapted from that previously developed as part of Report 12 of the Imperial College COVID-19 Response team: “The Global Impact of COVID-19 and Strategies for Mitigation and Suppression” [2]. We used an adapted age-structured SEIR model of transmission with age-specific patterns of disease severity captured according to age-dependent probabilities that infection leads to disease requiring hospitalisation (and the need for treatment with high-pressure oxygen), more severe disease requiring intensive care and subsequently mortality. Model parameters are based on analysis of age-specific severity and infection-mortality ratios observed in China and the UK [2, 5, 6]. To produce simulations representative of a malaria endemic setting, the model was calibrated to typical social contact patterns observed within surveys in SSA, which show less substantial declines in contact rates by age [7-9], and the demography of Nigeria, the country with the highest burden of malaria globally [10]. As a result, our projections incorporate a lower per-infection demand for healthcare such as oxygen and mechanical ventilation driven by the younger populations within malaria endemic settings.

To capture the likely constraints within a health system we contrasted this demand for healthcare with a representative level of supply using the median estimated provision of hospital beds and intensive care units for a low-income country from Report 12 [2]. This threshold was chosen on the basis that, although many countries in sub-Saharan Africa are lower-middle-income and therefore likely to have a higher total number of hospital beds and intensive care units, access to high pressure oxygen and mechanical ventilation within hospitals is lower than within equivalent high income settings [11]. During the course of a projected scenario, as healthcare capacity is exceeded, individuals requiring either mechanical ventilation or high pressure oxygen who are not able to receive these interventions are then subject to a substantially higher degree of mortality, leading to excess mortality during time-periods in which health systems are overwhelmed (see [12]) for full details, code and parameterisation.

Representative scenarios were simulated using a basic reproduction number of 3 representing a 3.5 doubling time in cases and deaths reflective of many trajectories currently observed globally [13]. Once a threshold of 0.1 deaths per million (approximately reflecting the COVID-19 level of mortality

observed in many countries in Africa to date) is exceeded, the pandemic trajectory follows four potential scenarios:

- *“No action”*. Here no direct action is taken but contact rates are reduced by 20% relative to baseline according to assumed behaviour change in the face of the pandemic even in the absence of specific, coordinated public health interventions.
- *“Mitigation”*. Here through combinations of isolation and social distancing contact rates are reduced by 45% for a period of 6 months after which infections fall to low levels and contact rates return to pre-pandemic levels. This scenario approximates the maximum reduction in the final size of the epidemic that can be achieved whilst generating sufficient levels of immunity capable of preventing a second wave once measures are lifted (assuming infection leads to high levels of immunity from reinfection) and thus produces the lowest final numbers of COVID-19 infections of the three strategies that do not involve indefinite suppression.
- *“Indefinite suppression”*: Here stringent suppression-targeting interventions are implemented to reduce contact rates by 75% and these are maintained indefinitely in the hope that a pharmaceutical intervention (e.g. effective vaccine) can be developed and deployed. We run this scenario for 12 months but note that at the end of this period lifting suppression, in the absence of such a pharmaceutical intervention, would lead to a second wave of equivalent size as in the *“Suppression and lift scenario”*.
- *“Suppression and lift”*: Here the stringent ‘lockdown’ type interventions implemented by many countries are represented by a reduction in contact rates of 75%. This reduction is maintained for two months at which point it is lifted and contact rates return to 80% of their pre-pandemic levels (i.e. the levels simulated within our “no action” scenario) for the remainder of the epidemic.

A previously published model of malaria transmission dynamics was used to predict the number of malaria deaths resulting from different COVID-19 scenarios [14]. Simulations were run at the administrative 1 unit (where each the model is calibrated to capture the seasonality, prevalence, vector composition, treatment coverage and vector control coverage in each unit) and results summed across the African continent according to size of the population at risk of malaria. Models were parameterised using 2017 malaria prevalence and the LLIN usage estimated at the administrative 1 unit level from the Malaria Atlas Project [17] with LLIN usage expected to remain at the same level at the next LLIN mass campaign. Malaria control depends on the level of insecticide resistance in the local mosquito population which diminishes the effectiveness of LLINs. This was estimated for each administrative unit from discriminating dose bioassays collated by the World Health Organization and combined with results from experimental hut trials to estimate LLINs epidemiological impact [15, 16]. Seasonality in malaria transmission was determined by local rainfall. It is assumed that the proportion of clinical cases receiving prompt treatment remains at 2017 levels. The number of deaths due to malaria was estimated using the modelled number of severe cases, scaled by the assumed proportion of severe cases resulting in mortality both in and outside the hospital setting, and adjusted by the location-specific proportion of clinical cases receiving treatment [14]. Pan-Africa estimates of the number of malaria deaths in 2018 were scaled to align with World Malaria Report median deaths for 2018 for the same region [10].

Different levels of malaria prevention and treatment interruption are considered together. The impact of COVID-19 will depend on the time since the last LLIN campaign as older nets are likely to be less

effective due to the loss of insecticide. This aging of LLINs may be exacerbated by the spread of insecticide resistant mosquitoes as they may overcome the concentrations of insecticide on the LLIN earlier than susceptible mosquitoes [16]. All LLINs are assumed to be standard pyrethroid-only LLINs. Alliance for Malaria Prevention estimates were used to calculate the proportion of LLINs distributed in 2018, 2019 and due in 2020 by country as it is unclear when the different campaigns were at a sub-national level. Different simulations were run for each administrative unit distributing LLINs at the appropriate year and season. Overall estimates of clinical cases in the administrative unit were weighted by the proportion of LLINs given out that year. The proposed timings of SSA LLIN distribution campaigns in 2020 were collated at the country level and reported to the quarter where available. LLIN campaigns due to occur prior to April 2020 were assumed to have occurred as normal. Those campaigns which were due at a time of COVID-19 induced disruption either went ahead as planned (achieving the same population coverage) or were delayed until a year after they were originally due. SMC was assumed to be undertaken in the same administrative units covered in 2019 at a population coverage of 70% in the target age group of children under five years of age, except in Senegal where children up to ten years of age are covered. The normal proportion of clinical cases of malaria receiving the appropriate prompt treatment outside the COVID-19 epidemic was estimated based on data extracted from the Demographic and Health Surveys (DHS) on the proportion of febrile children who were given medical treatment, and the type of treatment administered [18]. Indoor residual spraying was assumed to take place annually in the same administrative units covered in 2018 [19]. During the period of health system interruption SMC and clinical treatment of cases can either reduce to zero, reduce to 50% of the normal level (35% of the target age group are covered), or continue as before. IRS is assumed to be cancelled.

We simulated the number of deaths for the period 1 May 2020 to 30 April 2021, for both the non-COVID-19 scenario, and the four COVID-19 scenarios, as well as for a range of malaria intervention combination strategies. The number of projected deaths was aggregated across SSA and presented as the increase in deaths predicted for the different COVID-19 and malaria scenarios.

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