

## Review Article

### Does malaria protect against COVID-19?

#### Abstract

The majority of persons in malaria-endemic areas have acquired malaria immunity. This acquired immunity in endemic areas may protect against severe Coronavirus Disease 2019 (COVID-19). This review highlights the low COVID-19 disease incidence in malaria-endemic areas. It also provides a comprehensive summary of the **existed** suggested explanations for this protection.

keywords: malaria; COVID-19; *Plasmodium spp.*; SARS-CoV-2

#### 1. Introduction

Malaria-endemic regions have recorded fewer cases of Coronavirus disease 2019 (COVID-19) and deaths from COVID-19, indicating probable protection from the poor outcome of COVID-19.

Since the first official cases of COVID-19 were recorded on the 31st of December, 2019, till February 28, 2023, the cumulative number of COVID-19 deaths in Africa which is the highest malaria-burden region in the world was 175,295 out of 6,859,093 global COVID-19 deaths. This represents approximately 2.55% of global cumulative COVID-19 deaths.<sup>1</sup> Meanwhile, COVID-19 cases in Africa accounted for 9,497,673 out of 758,390,564 global confirmed cases representing approximately 1.25% of global confirmed cases.<sup>1</sup>

Analytical analyses, ecological, retrospective cohort, immunological; and genetic studies suggested that malaria has been attributed to the low incidence and mortality of COVID-19 in the endemic regions. This article reviews this evidence and highlights the existing underlying explanations and theories explaining such findings.

#### 1.2. Statistical Evidence

World regions that are malaria-free or recorded limited malarial infections reported a large number of COVID-19 cases.<sup>2,3</sup>

As of April 6, 2023 deaths per million population mortality statistics indicate that the global figure is 877.1. Africa records 146.39 deaths whilst Europe records 2,733.72 deaths and the United States records 3,307.22 deaths per million population.<sup>4</sup> In the WHO African Region during 2021, malaria caused an estimated 95% of global malaria deaths<sup>5</sup>

Within the same country, COVID-19 cases have been reported to be low in regions where malaria incidence is high. For example, Rusminiet *al.* reported that the lowest incidence of COVID-19 cases was seen in areas with the highest malaria cases in Italy.<sup>6</sup>

Incidences of H1N1 and coronavirus infections other than severe acute respiratory syndrome coronavirus 2 ( SARS-CoV2) such as Middle East Respiratory Syndrome Coronavirus (MERS-CoV) and SARS indicated that regions with high malaria burden report low MERS-CoV and SARS incidences.<sup>7,8</sup>

## 2.1. Epidemiological studies

Few epidemiological studies showed a disproportionate spread of COVID-19 in malaria endemic regions.

### 2.1.1 Association of COVID-19 incidence and malaria elimination time

Malaria elimination is defined as the interruption of local transmission of a specified malaria parasite species in a defined geographical area as a result of deliberate activities.

In 2021, 35 countries reported fewer than 1000 indigenous cases of the disease, up from 33 countries in 2020 and just 13 countries in 2000. Since 2015, 9 countries have been certified by the WHO Director-General as malaria-free, including Maldives (2015), Sri Lanka (2016), Kyrgyzstan (2016), Paraguay (2018), Uzbekistan (2018), Argentina (2019). A study on sixty-nine malaria-free countries with a total population of 1 million or more showed that there was a significant positive association between COVID-19 mortality and elapsed time since malaria elimination. countries not recording malaria cases in the last 15 years had high rates of COVID-19 mortality.<sup>9</sup>

### 2.1.2 Association of COVID-19 and malaria prevalence

The following papers published since 2020 suggest a relationship between a low incidence of COVID-19 with malaria incidence and explained the COVID-19 poor prognosis in malaria-free regions and vice versa:

- a- A preprint posted on May 26, 2020, by Banerjee *et al.*<sup>10</sup> showed that the percentage of the population affected with COVID-19 is inversely related to the incidence of malaria in that population ( $r = 0.28$ ).
- b- As of 25 /3 2020 Napoli PE *et al.*<sup>11</sup> examined (COVID-19) cases per country vs malaria endemicity with the assumption that malaria has a protective effect against the recent epidemic. This epidemiological study in the early stages of the COVID-19 pandemic indicated that malaria-endemic regions had a low prevalence of COVID-19.<sup>11</sup>
- c- Muneer A *et al.*<sup>12</sup> studied COVID-19 spread in 108 countries till 18<sup>th</sup> April 2020. The number of COVID-19 cases per million population and case fatality rates were significantly negatively correlated with malaria endemicity.
- d- Anyanwu *et. al.* ecological analysis was conducted on 20<sup>th</sup> April 2021. COVID-19 mortality from 195 countries was negatively correlated with malaria prevalence.<sup>13</sup>
- e- Raham studied covid-19 mortality till August 31, 2020. Hierarchical multiple regression analyses revealed that a highly significant association was observed for malaria incidence in reducing COVID-19 mortality in 80 malaria-endemic countries<sup>14</sup>
- f- In December 2020 Arshad A *Ret al* reported a strong negative correlation between SARS-CoV-2 fatality and the top 20 most affected countries by COVID-19 endemicity of malaria.<sup>15</sup>

### 3. SARS-CoV-2 seroprevalence studies

The SARS-CoV-2 seroprevalence in Africa was 65% by September 2021. This indicates a high proportion of undetected asymptomatic or mild infections and protection against severe or fatal COVID-19 infections.<sup>16,17,18,19</sup>

### 4. A retrospective cohort study

Achan J *et. Al* enrolled 597 people with PCR-confirmed SARS-CoV-2 infection from April 15, to Oct 30, 2020. They reported a low previous malaria exposure was associated with severe

COVID-19 and higher adverse outcomes. Furthermore, they confirmed that patients with medium and high previous malaria exposure had significantly lower concentrations of IL-7.<sup>20</sup>

## 5. Coinfection

Potential of COVID-19 mortality was observed among people who are co-infected with malaria.<sup>21,22,23</sup> Coinfection can lead to excess pro-inflammatory responses and results in severe manifestations and poor prognosis. In non-endemic areas co-infection could be deleterious due to the excessive pro-inflammatory responses with the lack of immunity to COVID-19 and malaria.<sup>24,25</sup>

This has been explained by the increased incidence of cytokine storm and increased level of oxidative stress biomarker 8-isoprostaglandin F2 alpha, the occurrence of T-cell co-inhibitory receptors; and increased atypical memory B cells and plasma-blasts.<sup>26,27</sup>

A systematic review published on Oct 1, 2021, demonstrated a 5% prevalence of co-infection in India, 1% in the Democratic Republic of Congo, and 4% in Nigeria.<sup>21</sup> The prevalence of malaria and COVID-19 in malaria-endemic regions may be underreported because of the limited testing capacity and high prevalence of asymptomatic infections. Additionally, malaria is prevalent among children below 5 years is high, while COVID-19 prevalence is low.

Experimental incubation of a *P. falciparum* culture with SARS-CoV-2 virus done by López-Farfán et al suggested that *P. falciparum* would not facilitate the entry of SARS-CoV-2 virus into malaria-infected erythrocytes and vice versa.<sup>28</sup>

6. Theories that explain the low incidence of severe COVID-19 in countries with high malaria burden:

The percentage of natural resistance to SARS-CoV-2 infection by humans is not known. It is now well known that a considerable percentage of adults are not infected even when exposed to the SARS-CoV-2 however, the following may explain a protective role of malaria exposure in either the reduced risk of infection and/or severity of SARS-CoV-2 disease:

### 6.1. Cross immunity

There are three possible mechanisms of malaria cross immunity effects on COVID-19 incidence and mortality including heterologous immunity, trained immunity, and anti-inflammatory effect.

#### 6.1.1. Trained immunity:

Certain vaccines and infections can induce extra protection against other than the target pathogens through the innate immune system. This “trained immunity” can exhibit adaptive immune system-like characteristics.<sup>29</sup> Trained immunity fulfils the same principal function of adaptive immunity which is : a quicker and stronger response against subsequent pathogens improving the survival of the host.<sup>29</sup>

The innate immune response against *Plasmodium* species (spp.) involves natural monocyte, macrophages ; and natural killer (NK) cells, proinflammatory cytokines; and anti-inflammatory cytokines<sup>30,31</sup>. The pro-inflammatory cytokines must be regulated by anti-inflammatory ones , when unregulated the infection can progress to a severe squally.<sup>32</sup> Innate immune response to different *Plasmodium* spp activate immunological memory . This trained immunity acts as immunological memory and is capable to produce a prompt immune response against subsequent infections<sup>29,33</sup> that can also cross –protects against SARS-Cov2 infection . Effective cytokines and antibodies are produced without passing to a case of cytokine storm and severe condition leading to a lower proportion of severe COVID-19 cases.<sup>32</sup>

#### 6.1.2. Glycosylphosphatidylinositol (GPI) antibodies (immunoglobulin G) against *Plasmodium* - specific antigens were also speculated to cross-react with SARS-CoV-2 antibodies.<sup>34</sup>

6.1.3. M A M Iesa et al . identified potential shared targets providing immunity against virus infection to those previously infected with *Plasmodium* by immune determinants' shared identities with *P. falciparum*. These shared epitopes lie within antigens that aid in the establishment of the *P. falciparum* erythrocyte invasion HLA-A\*02:01 and subsequent CD8<sup>+</sup> T-cell activation were suggested to play part in this cross-reactivity. The apparent immunodominant epitope conservation between N and open reading frame (ORF) 1ab from SARS-CoV-2 virus and thrombospondin-related anonymous protein (TRAP) from *P.falciparum*. they also hypothesize that these shared epitopes may be an alternative route for SARS-CoV-2 invasion via the erythrocyte CD147 receptor, <sup>35</sup>

## 6.2. ACE2

ACE2 acts as an entry receptor for SARS-CoV-2 through its spike glycoproteins. The pathogenesis of COVID-19 depends on the relative interplay between different ACE2 elevating and lowering factors. ACE2 mutations that downregulate ACE2 tends to protect such populations from SARS-CoV-2 infection , decrease the prevalence of infection and explain lower COVID-19 burden in malaria-endemic areas .<sup>36</sup>The variable distribution of the ACEI/D and the ACE2 polymorphisms has been hypothesized to explain the low COVID-19 burden in certain stings. <sup>37</sup>a genetic deletion or insertion polymorphism leads to a reduced expression of ACE2 .<sup>38</sup>Reduced plasma levels of ACE2 are observed within populations of African descent.<sup>39</sup> Although deficiency or downregulation of ACE2 may be protective against entry of SARS-CoV2 to human cells, once acquired infection, an unfavorable outcome may result . Downregulation of ACE2 contributes to the over-activation of the renin-angiotensin-aldosterone system (RAAS) system increasing the severity of the disease <sup>40,41</sup>The pathogenesis of COVID-19 in malaria-endemic countries is suggested to be dependent on the interplay of the host genetics and other related factors.<sup>42</sup>

## 6.3. Blood group O :

A low incidence of COVID-19 has been reported in individuals with blood group O .<sup>6,43,44</sup> Studies revealed a reduction in severe malaria and in vitro reduction in *P.falciparum* rosetting among blood group O children .<sup>45</sup>

## 6.4. Antimalarial drugs

In the first months of COVID-19 pandemic, Certain routinely-used malaria drugs such as hydroxychloroquine were suggested to have anti-viral activity and accounted for the low mortality rate of SARS-CoV-2 infection in malaria-endemic regions.<sup>11,46,47,48,49</sup>

#### 6.5. Tuberculosis (TB) immunity:

TB and BCG can induce lifelong immunity and may provide immunological protection against COVID-19. Hierarchical multiple regression analyses for 80 malaria-endemic countries showed that, although TB prevalence correlated to a reduction in COVID-19 mortality, an additional effect of reducing COVID-19 mortality with a highly significant association was observed for malaria. Since immunity against TB can reduce COVID-19 mortality, malaria association with COVID-19 mortality can be easily confounded by LTBI prevalence and BCG status.<sup>14,50</sup> Geographically, in 2020, TB cases were 43% in the WHO regions of South-East Asia (43%), 25% in Africa, 18% in the WHO Western Pacific with 18%, 8.3% in the Eastern Mediterranean; and the least reported cases were in Americas and Europe (3.0%) and (2.3%) respectively.<sup>51</sup> This makes confounding effect of TB more likely.

#### 6.6. Vitamin D deficiency

Vitamin D deficiency may be related to regional incidence variance COVID-19.<sup>52</sup> A meta-analysis showed that low vitamin D serum levels people are more likely to contract COVID-19.<sup>53</sup> COVID-19 infection individuals with low serum vitamin D levels were 1.64 times (95% confidence interval [CI], 1.32 to 2.04;  $p < 0.001$ ) more likely to contract COVID-19.<sup>53</sup> Vitamin D deficiency prevalence varies globally with a prevalence of 34% in Africa<sup>54</sup>, 23–30% in the USA,<sup>55,56</sup> 30–90% in the Middle East, 20% in Australia, 56% in China.<sup>57,58,59</sup> Data reported that African ancestry people living in temperate regions have lower vitamin D status,<sup>60</sup> compared with African people living in sub-Saharan and compared other ethnicities.<sup>60,61</sup> This could explain high COVID-19 mortality among African Americans.

#### 6.7. Age structure:

The lower population mean age and lower life expectancy may attribute to a lower COVID-19 mortality rate in Africa.<sup>62</sup> The population consists of a predominantly young population in Africa and a predominantly older population in Western countries. This may be explained by the high

birth rates in African countries. SARS-CoV-2 infection is less aggressive in children while children under 5 years of age are the most affected<sup>38</sup> This makes young structure communities in Africa suffer less from COVID-19. According to one study, a high population growth rate was shown inversely related to COVID-19 mortality in a too highly significant association (p-value 0.000).<sup>63</sup>

#### 6.8. Weak surveillance:

Surveillance data indicated the under-assertiveness of confirmed infections in Africa and the weak laboratory testing capacity in Africa to detect COVID-19 cases<sup>26</sup> and accounted for the low number of confirmed cases and associated deaths.<sup>64</sup>

### 7. Conclusions and recommendations

One weak point in reviewed malaria- COVID-19 researches is that the malaria incidence reflects future malaria immunity among survivors and does not reflect the current malaria immunity.

Although this review partially fills the knowledge gap concerning COVID-19 lower risk in Africa and other malaria-endemic regions, it addresses the need for further testing of research conclusions. Further research is especially important to identify tools for antigens that can be used for trained immunity-based vaccines.

In summary, malaria prevalence possibly contributes to less severe COVID-19 in malaria-endemic areas. The malaria immunity through previous exposure (s) possibly explains these findings. Further research is recommended.

#### Abbreviations

COVID-19: severe Coronavirus disease 2019

NK : Natural killer

RAAS : Renin-angiotensin-aldosterone

SARS-CoV2 : severe acute respiratory syndrome coronavirus 2

spp.: species

Declarations:

- Ethics approval and consent to participate 'Not applicable'
- Consent for publication: 'Not applicable'
- Availability of data and materials: 'Not applicable'

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