

An opinion on mosquitoes' role in HIV transmission

Abstract

The number of new HIV infections in people aged ≥ 15 years worldwide was 2.3 million in 2000. After a two decades-long fight, the number of new infections was still 1.6 million in 2019.¹ These data indicate that HIV prevention has failed to a significant degree, and there are potential significant problems with our understanding of HIV transmission, and, therefore, our strategies for HIV prevention. The present paper shows that epidemiological data widely supports mosquitoes as an important transmission vector, and discusses why there were significant problems with the early studies used in developing the theory that mosquitoes do not transmit HIV.

Keywords: HIV prevention; HIV transmission; mosquito; insect; epidemiology; risk factor

Geographical distributions of HIV and mosquitoes

Fig. 1a shows the rates of diagnoses of HIV infection among adults and adolescents in the United States, 2018.² The prevalence of HIV infection in southern, eastern and western coastal states varied from 11 to 45 per 100,000 people, several times that in northern, central, and midwestern states (Fig. 1a).

Mosquitoes like humid and hot weather. Fig. 1b displays the estimated range of *Aedes aegypti* mosquitoes in the United States in 2017.³ showing that, their abundance in southern, eastern and western costal states was much higher than in northern, central, and midwestern states. This geographic distribution of the mosquito (Fig. 1b) closely paralleled that of HIV prevalence (Fig.1a). Distribution of *Aedes albopictus* mosquitoes is similar to that of *Aedes aegypti*.³

The weather in South Africa gradually changes from humid on the eastern coast to dry on the western coast where there is a desert. Thus, environmental suitability for mosquitoes decreases from east to west.

Consistently, HIV prevalence was highest in the eastern provinces, and gradually decreased from east to west.⁴ Studies conducted in the eastern provinces reported that, many types of mosquitoes including *Aedes aegypti* had the widest geographical distribution, and many other types were variably distributed.^{5,6}

Since research situations differed among the different countries in sub-Saharan Africa (SSA), and there are many species of mosquitoes, the data were not well suited for comparative analyses between the countries. Generally, the humid and hot weather in SSA is highly suitable for mosquitoes.

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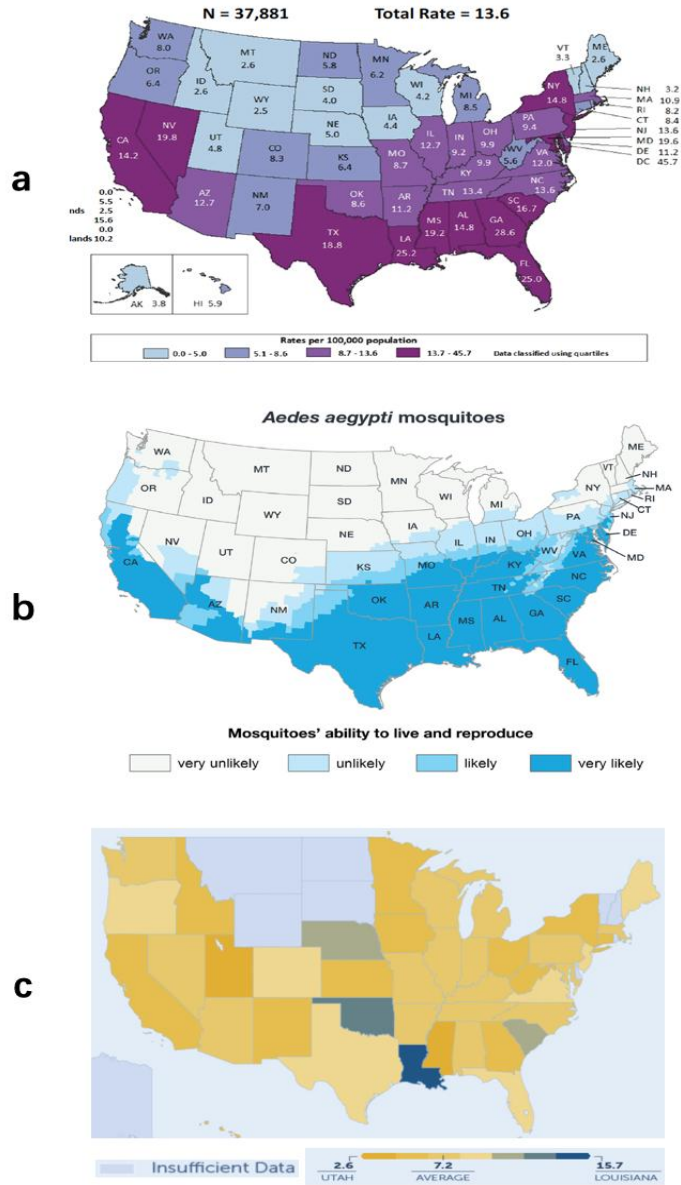


Fig. 1. a) Rates of diagnoses of HIV infection among adults and adolescents, in the United States, 2018. Source: CDC.² b) Estimated potential range of *Aedes aegypti* in the United States, 2017. Source: CDC.³ c) Mean number of sexual partners by state, in the United States. Source: Superdrug.¹³

Correlation between mosquitoes and HIV over a broad range of data

Partners often live and sleep together. Sleeping is an ideal circumstance for mosquitoes to bite; because, mosquitoes like dark and quiet environments. A sleeping person will flip over or scratch a bite site (e.g. face, arm, etc.). The interrupted mosquito may then move to bite his/her partner in bed.

In the United States, 3.4% of homeless people were HIV positive, compared to 0.4% of adults and adolescents in the general population.⁷ Homeless people are more often exposed to mosquitos.

In the United States, HIV prevalence among people with incomes at or below the poverty level was 2.3%, compared with 1.0% among those above the poverty level.⁸ No significant differences in HIV prevalence by race/ethnicity were observed in the survey.⁸ Impoverished people are much more likely to live in crowded living conditions; thus, some of them may live or sleep in close proximity, providing the chance for mosquitos to bite different peoples within a short interval.

Before the widespread use of highly active antiretroviral therapy, which greatly prolonged infected peoples' lives, there were two different patterns of age-specific mortality data due to HIV/AIDS.⁹ In the United States and other western countries, few deaths due to HIV/AIDS occurred among 15-24 year-olds in 1990s. Contrarily, deaths due to HIV/AIDS among 15-24 year-olds were very high in SSA in 1990s. We recently suggested that a large number of the infections in SSA occurred during childhood;⁹ because, few people who were infected during ages 15-24 died during those ages. It is also unlikely that, they acquired an infection in utero, or during delivery or breastfeeding; since, 80% of those infected during these three stages would have died by age 5 in the absence of effective treatment. In SSA, young children habitually sleep with parents, exposing them to the risk of mosquito mediated transmission. In contrast, in the United States and other western countries, most young children do not sleep with their parents; and the children who do sleep with parents usually cease to do so when they grow a little bigger.

In mortality data on people 15-24 years old in SSA, which showed large number of infections occurring during childhood as discussed above,⁹ and direct prevalence data on people 15-24 years old,¹⁰ females even

had a much higher prevalence than males. In SSA, the girls need to stay home to take care of HIV infected parents and family members, providing greater chances for mosquitoes to transmit HIV.

Antiretroviral therapy is claimed to be the main reason for the decrease in new HIV infections among children since 2000. The percentage of pregnant women with HIV receiving antiretroviral therapy in SSA changed little after 2014 (84.2% in 2015 to 86.5% in 2019).¹¹ However, the new HIV infections among young children in SSA kept declining from 2014 to 2020.¹¹ In SSA, the percent of women living with HIV who were aware of their status considerably increased from 2014 to 2020, suggesting that, mothers' behavioral changes due to awareness of their HIV status played an important role in prevention of mother-to-child transmission.¹¹ Studies reported many civilians still believe mosquitoes can transmit HIV.¹² Mothers could protect their children from mosquitoes, for example, by sleeping less with their children, etc.

Notably, a lot of epidemiological data which are not well explained by currently recognized risk factors are well explained by mosquitoes. For example, the data of much higher HIV prevalence in southern, eastern and western US coastal states than in northern, central, and midwestern states. No data have shown significant difference in the manner of sexual intercourse between the sets of regions. Moreover, there was not much difference in the number of sexual partners between the two sets of states (Fig. 1c).¹³ Injection drug use is another known risk factor for HIV transmission, but, there was insufficient data for an analytical comparison between the states. Generally, among the top 10 most drug addicted states, the two sets of regions each have five.¹⁴

Questions with studies developing the theory that mosquitos do not transmit HIV

Whether or not mosquitoes transmit HIV via a mechanical transmission mechanism was one of of most hotly debated issues in 1980s.^{15,16} The concept that mosquitos do not transmit HIV was established in the 1980s, and has had a profound impact on research since then, defining which ideas we judge to be right or not.

The mechanical transmission mechanism refers to when a mosquito feeds on an HIV infected person and is interrupted for some reason, then moves on to another uninfected person to complete its meal. To make a

successful transmission via this mechanism, the two persons need to be physically close. Because, HIV cannot live long outside its host cells. A review report published in 1987 concluded that insects did not transmit HIV.¹⁶ The following discusses problems with the studies cited in the report.

The review report cited research conducted by the CDC investigating 736 residents of Belle Glade, Florida, where a cluster of HIV infection had occurred.¹⁶ “Antibodies to HIV were found in: 1) none of 121 children ages 2-10 years; 2) 14 (8.9 percent) of 157 persons ages 18-29; 3) 7 (4.4 percent) of 160 persons ages 30-39; 4) 2 (1.8 percent) of 113 persons ages 40-49; 5) 3 (3.2 percent) of 91 persons ages 50-59; and 6) none of 94 persons over 60 years of age.” Because of the negative antibodies among the 121 children, the report stated that, these data supported the sexual intercourse route, but not the mosquitoes route, was the cause.

People sleeping together is an important condition for mosquitoes to complete a transmission. Even though partners sleep together, only a small proportion get infected. As mentioned above, young children in the United States usually do not sleep with parents, and children who do sleep with parents will sleep separately when they grow a little bigger. Moreover, parents who felt ill due to known or unknown diseases would be less likely to let children to sleep with them, in order to protect their children. Thus, negative antibodies among the 121 children actually also support mosquitoes as a risk factor.

The knowledge of HIV viral loads in blood made by the early studies was problematic. The review report stated that, “Most HIV-infected persons (70 to 80 percent) do not have detectable levels of infectious virus in their blood. Those that do have measurable HIV have very low levels.....” in the abstract section, and cited a series of detailed research data on Page 10.¹⁶ These early data were very different from current data, and downplayed the risk of transmission by mosquitoes. According to the United States national data on patients diagnosed in 2012-2016, the median viral load was 694,000, 125,022 and 43,473 copies/mL in week 1, 2 & 6 of infection stage 0, respectively; 15,412-17,495 copies/mL in stage 1; 44,973 and 38,497 copies/mL in week 1 & 6 of stage 2, respectively, and, 205,862 and 119,000 copies/mL in week 1 & 6 of stage 3, respectively.¹⁷

The review report cited the transmission rate of needle-stick injury for a prospective transmission by mosquitoes: HIV infections through needle-stick injuries occur in approximately 0.3 percent, and the volume of blood injected was about 0.001 ml, 100 times greater than that on mosquito's proboscis (0.00001 ml). However, the two circumstances are very different. In the event of a needle-stick accident, the blood automatically flows from inside-to-outside. The injury site will immediately be flushed with water, and often pressed to expel more blood. These practices greatly reduced the risk of infection. In contrast, there are no such protection measures practiced after a mosquitoes' bite. The proboscis consists of 6 needles. The mosquito uses 2 needles to break the skin, other 2 to hold the tissue, and the rest 2 to drool saliva into humans or suck the blood. The HIV on the needles gets directly into the bloodstream of the person. According to US national data on HIV viral load in blood among patients diagnosed in 2012-2016, the blood volume (0.00001ml) on mosquitoes' proboscises would contained 0.2 to 7 HIV copies. Therefore, after biting an infected partner, further biting of an uninfected person may lead to transmit of 0.2-7 copies of HIV. Moreover, different from the very rarely occurring needle stick injury, mosquito bites are very common in some of regions.

The review report argued that, only 2% of horse flies, after being interrupted while feeding on one animal, moved to bite another animal.^{16,18} Based on this data, the review report cited an experiment assuming the prevalence of HIV infection was 1%: "If a horse fly first bit an HIV infected person, the probability of its then completing feeding on an uninfected person would be: $0.01 \times 0.99 \times 0.02 = 0.000198$, or about 1 in 5,000." Afterwards, more experiments were made, assuming the prevalence was 5%, 10% and 50%, respectively. The authors concluded: "even if the prevalence of HIV infection was 50 percent, if horse flies are interrupted in their feeding," the possibility moving to bite a second person is "only" 0.5% (5/1,000). However, to assess the mechanical transmission, it would be more reasonable for experiments to be done by assuming an HIV prevalence of 25% and 50%, not "1%" or "5%"; because, for a pair of partners in bed or 4 persons in a small room with one positive, HIV prevalence is 50% or 25%, respectively. Moreover, although only 2% of horse flies, after being interrupted while feeding on one animal, moved to bite another animal, that number for some species of mosquitoes may be much higher than "2%".

Conclusion

HIV prevention has failed. It is time to reevaluate our understanding of HIV transmission and strategies in HIV prevention. The present paper showed a consistent correlation between mosquitoes and HIV over a broad range of data, and suggested, mosquitoes are a significant risk factor for HIV transmission.

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