Transmission Dynamics and Vaccination Strategies for Chikungunya Virus (CHIKV): An Outbreak Simulation Study in Rome, Italy

Poster EPH15

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Introduction

Disease background

Chikungunya is an arboviral disease transmitted to humans by chikungunya virus (CHIKV)-infected mosquitoes, mainly the *Aedes albopictus* and *Aedes aegypti (1,2).* With common symptoms comprising fever, polyarthralgia (joint pain) and myalgia (muscle pain), the disease is characterized by high morbidity rates and potentially debilitating long-term effects (3,4).

Disease management and prevention

Treatment for chikungunya is mainly supportive and involves rest, pain and fever relief, and adequate hydration (5). Additional measures to prevent the spread of CHIKV or improve the treatment of chikungunya patients are needed. The VLA1553 vaccine candidate induced seroprotective antibody levels in 98.9% of patients in the Phase III randomized clinical trial (6). This vaccine could be a significant addition to the global fight against CHIKV outbreaks, as current preventive methods consist of reducing the mosquito population through vector control (7).

Objective

This study aimed to simulate and evaluate the transmission dynamics in the case of CHIKV importation to Rome in a scenario without vaccination and scenarios with VLA1553 vaccination at various coverage rates.

Method

Anzio outbreak

In 2017 an outbreak of chikungunya occurred in the town of Anzio, Italy. This marked the second occurrence of CHIKV in Italy, with outbreaks having been reported in other European countries as well (8,9).

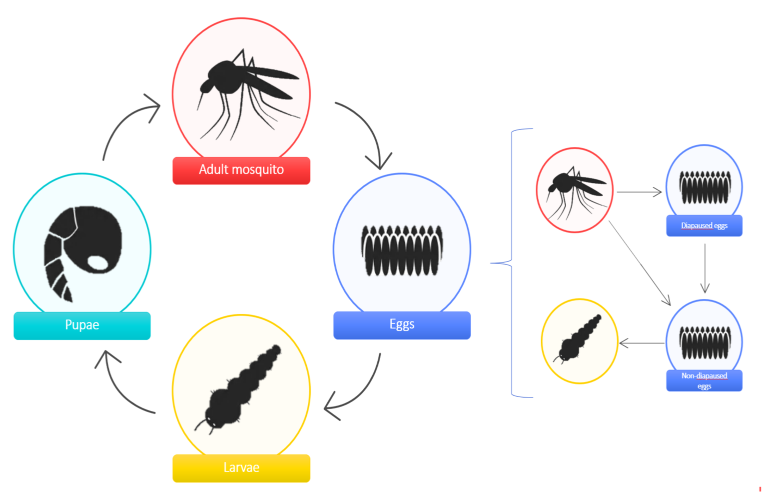
A Susceptible-Exposed-Infected-Recovered model was created to replicate the Anzio outbreak. The model included temperature-dependent population dynamics of the *Ae. albopictus* mosquito and human-mosquito disease transmission interactions. The initial case of CHIKV was assumed to be introduced by a person returning from an area where CHIKV is endemic.

Hypothetical outbreak in Rome

To estimate the impact of a potential future outbreak in a major European city, the model was adjusted to match the context of Rome. Differences in temperature, population density, and area were included to reflect differences in mosquito population dynamics and disease transmission between the two areas.

Figure 1. Mosquito lifecycle dynamics

Figure 1 shows the mosquito lifecycle stages: eggs, larvae, pupae, and adult. Eggs were allowed to enter diapause at low temperatures to improve survival probabilities.



Intervention

The impact on the outbreak of timely intervention through vaccination with VLA1553 was investigated.

It was assumed that the outbreak was identified when 10 patients has reached the recovered state. A two-week delay was applied before vaccines were implemented, with an additional delay of two weeks until the vaccine became effective.

Different levels of vaccine coverage were incorporated to investigate the impact of vaccination.

Results

Disease-related outputs

The base case scenario compared no vaccination to vaccination with a coverage rate of 40% employing the seroprotection data of VLA1553, using a vaccine effectiveness of 98.9%. Table 1 shows the impact of vaccination on the number of infections.

Without vaccination, the model predicts a total of 413,607 infections, which is approximately 15.05% of the population of Rome. Implementing vaccination reduces the number of infections by 363,218, resulting in a total number of infections of 50,390, approximately 1.83% of the population.

Table 1. Disease-related outcomes

	Without vaccination	With vaccination	Prevented
Number of infections	413,607	50,390	363,218
Percentage of the population	15.05%	1.83%	13.21%

Coverage-rate analysis

The 40% vaccination coverage rate was an assumption as there is no information available on the willingness to take a CHIKV vaccine during an outbreak. To assess the impact of the coverage rate, scenario analyses were performed for different coverage rates. Our findings showed that a vaccine coverage rate of 20% would already prevent approximately two-thirds of the infections.

Scenario analysis

Various mosquito-related parameters used within the model are temperature-dependent. Because of this, scenario analyses could be performed to assess the impact of climate change. Raising daily temperatures by 1 degree Celsius led to 81.38% of the Rome population being infected. Within this specific scenario, a vaccination coverage rate of 40% could prevent up to 1,862,833 cases.

Discussion of results

Increased human mobility and ongoing global warming are expected to increase the frequency and severity of CHIKV outbreaks. Because of global warming, CHIKV can spread to more temperate areas, such as Rome. The results show that an outbreak can already bring about severe consequences, but we anticipate that future outbreaks become even more severe.

Figure 2. Number of infections per coverage rate

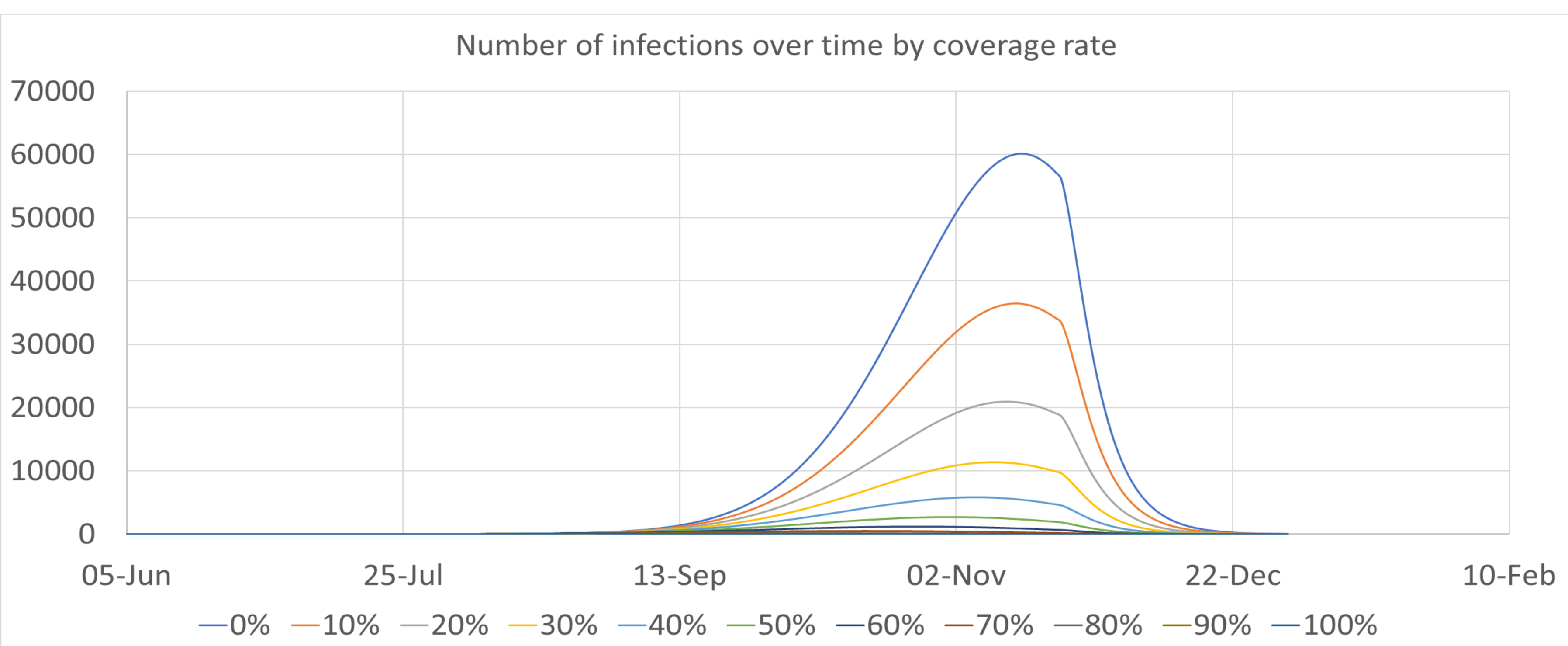


Figure 2 shows the impact of different rates of vaccine coverage on the number of infections caused by an outbreak of CHIKV occurring in Rome. A substantial diminishing effect on the number of infections is observed at low coverage rates, indicating that even with a limited willingness to get vaccinated the vaccine can provide protection against infection.

Conclusion

Outbreak risk

The model showed that a substantial portion of the population faces risk of infection when an outbreak is to occur in Rome.

Due to global warming and viral adaptation, *Aedes albopictus* is likely to become more prevalent in the future, resulting in more frequent and more severe outbreaks.

Vaccine effectiveness

Vaccination with VLA1553 provides protection against infection with CHIKV and can slow the spread of the disease during an outbreak.

Moderate vaccination uptake can already slow down infections and flatten the curve, resulting in the prevention of a substantial morbidity burden in those who would otherwise be infected.

Implementation

Active surveillance for early outbreak detection and timely vaccination can effectively mitigate the impact of future outbreaks.

Given the absence of effective treatments or preventative measures to the occurrence of CHIKV outbreaks, vaccination is ought to play a pivotal role in public health policy.

A CHIKV outbreak in a major city such as Rome can have considerable impact, especially in future global warming scenarios.

Proactive measures, such as vaccination, are crucial to prevent or control outbreaks in at-risk areas.

Future research should focus on exploring the effect of temperature on *Aedes albopictus*, the effectiveness of vector control measures, and the relationship between population density and biting rate.

CHIKV is expected to become a major global health burden and vaccination can be crucial to prevent major outbreaks.

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Disclosures

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