Determining the transmission route of the Buruli Ulcer using a mathematical model

Tiffany Lam, Robert Smith?, Alison Kealey, Department of Mathematics, University of Ottawa

Introduction

The Buruli Ulcer (BU) is a necrotizing skin disease caused by the environmental microbial pathogen, *Mycobacterium ulcerans*, reported in over 30 countries in tropical and subtropical climates. In earlier stages, the disease results in painless subcutaneous nodules or skin papules that can spontaneously heal as a lesion. However, 60% of patients develop severe cases of tissue necrosis, in which the destruction of bones and joints leads to disfigurement and disability. This morbidity is often associated with stigma and a socioeconomic disadvantage.

It is the third most common mycobacterial infection, after tuberculosis and leprosy, having the highest incidence rates in the African continent. Treatment is costly and difficult, requiring surgical excision or amputation of the infected tissue, which can be performed alongside the administration of antibiotic therapy. The transmission mechanism of the BU remains unknown.

Figure 1. Severe Buruli ulcer on the shoulder join of a 12-year-old Angolan boy .

Objective

To create a mathematical model accounting for the various modes of transmission of the Buruli Ulcer, in order to devise an economically favourable treatment and prevention plan.

Hypothesis

The primary route of transmission of Buruli Ulcer to humans is direct physical contact with the bacterium by bathing in contaminated water bodies, while aquatic bug vectors and an animal reservoir may also play a minor role in the transmission of the disease.

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Methods

A broad search was performed in the Google Scholar and PubMed databases, using the following search terms: “Buruli ulcer”, “transmission”, “geographic distribution and prevalence”. Data and statistics from relevant articles about risk factors and transmission dynamics will be interpreted in Matlab in an attempt to match the parameters of the hypothesized mathematical model.

Results

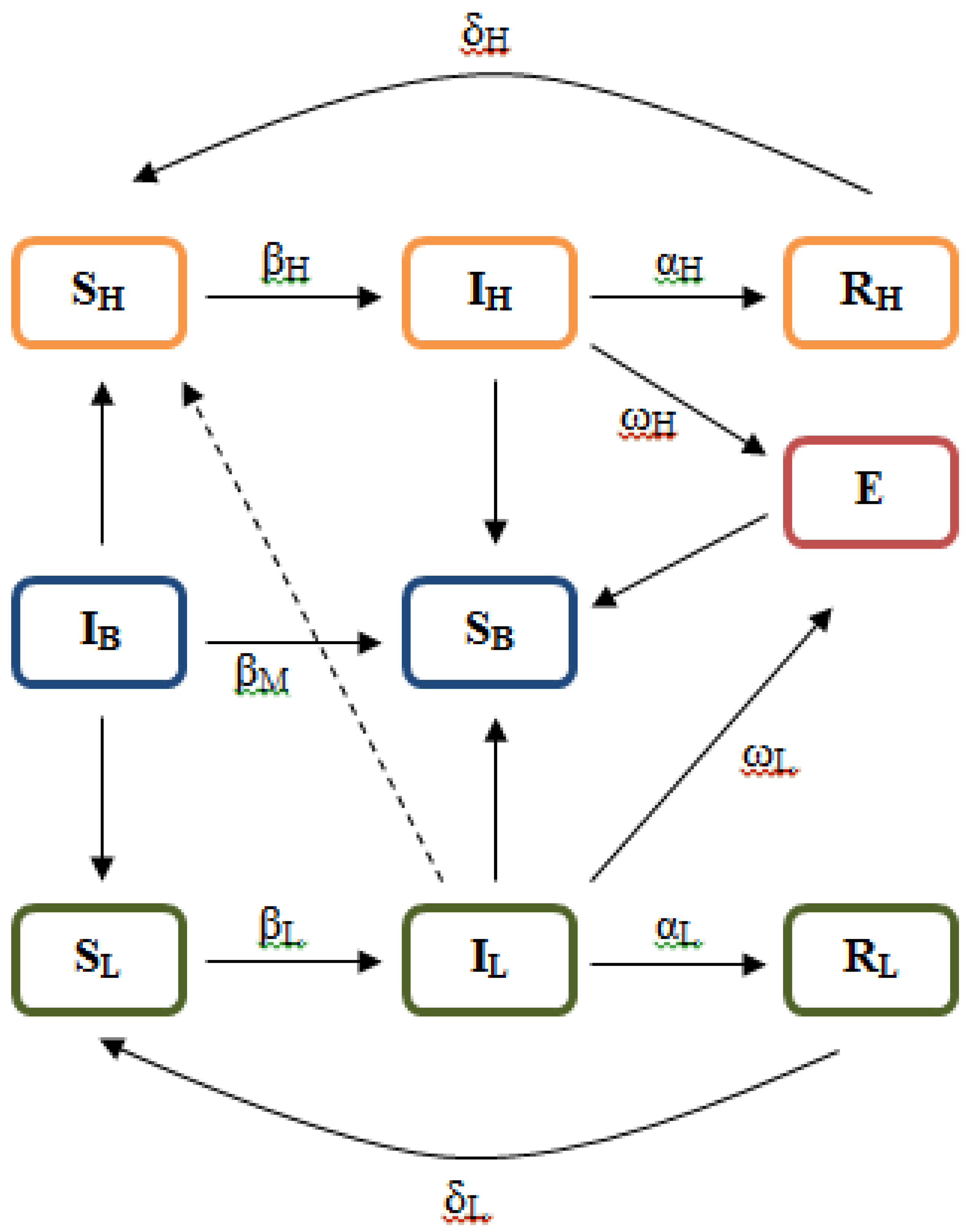

Figure 2. Schematic diagram of interrelations between human, aquatic bug, and livestock population.

S = susceptible population
I = infected population
R = recovered population
$_H$ = humans
$_B$ = aquatic bugs
$_L$ = livestock

β = rate of infection
α = rate of recovery
δ = rate of loss of immunity from recovery-state
ω = rate of bacteria transmission to environment

Assumptions:

- All population include the following two variables, not shown in Fig.1:
  Π = birth rate
  μ = background death rate (not due to disease)
- Death rate in recovered population is equal to death rate in susceptible population.

For more information, please contact tlam094@uottawa.ca or visit http://mysite.science.uottawa.ca/rsmith43/.

Discussion

Since BU is a water-related disease, various risk factors were accounted for in the schematic diagram of possible transmission routes in Fig.1. Statistics have shown that proximity to rural wetland ecosystems increases the prevalence of the disease; it is likely directly contracted through the skin by bathing or swimming in the contaminated water. Potential routes of infection in humans include direct contact with the bacterium in water, inoculation through the bite of an aquatic bug (vector), or the eating of infected livestock. This model also shows that the waste that infected livestock and human produce can also increase the rate of infection by re-releasing the bacterium into the environment.

Figure 3. (A) Major Buruli ulcer surgically excised from abdomen of 9-year-old Tongolese girl.
(B) Skin graft over the abdominal lesion.

Conclusion

More data must be gathered in order to determine the transmission route of BU in humans, whether through direct contact with contaminated water ecosystems, interaction with aquatic bug vectors or an animal reservoir. A variety of numerical simulations will be performed for possible scenarios, to determine the parameter that bears the greatest effect on the incidence of the disease. Next, an economic model evaluating the cost-effectiveness of treatment and prevention will be developed. This model will also be analysed with numerical simulations to determine the most practical, economically-favoured, and viable plan of eradicating the disease.

References

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