A pseudovertical transmission model for the epidemiology of tuberculosis in New Zealand possums

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Introduction

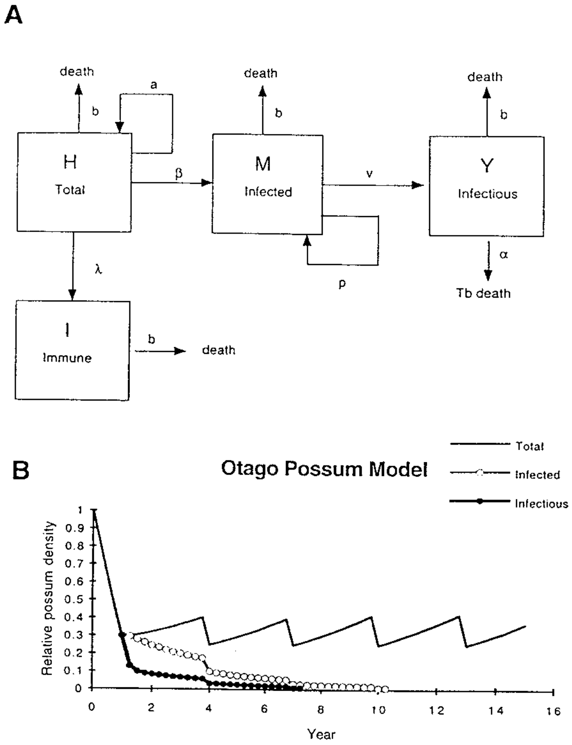
This paper describes modifications to the Barlow model (Barlow, 1995) in which a high degree of pseudovertical transmission is used instead of spatial aggregation to explain disease clustering. Our model is better able to explain the field observations in regard to reemergence, disease latency, the infectious period and the high subclinical prevalence of Tb in possums. For ease of comparison to the Barlow model, the same notation and parameters have been used in this paper.

The main modification to the models of Barlow is the introduction of the pseudovertical transmission factor (p) into the Tb infected possum population (M in Panel A). The assumption is that the primary way by which Tb is spread in possums is by pseudovertical transmission from mother to 'joey' while nursing in the mother's pouch for the 120-200 days before weaning and followed by a period of back riding. This occurs in the latent (infected but not infectious) period in the Barlow model.

The other main assumption of our model is that there is a long latency period from pseudovertical infection to the clinically overt infectious stage of about two years. The period of latency is the time between infection either by pseudovertical or by horizontal contact and overt signs of disease such as enlarged and/or pustulating lymph nodes. The infectious period is brief (2 to 3 months) being the time between overt disease and death.

Model Parameters

The values used in our model reflect the biological situation in the field. The starting possum population was 10 possums/ha (the carrying capacity) and the infected and infectious densities of possums were 20% and 5% respectively. The latency and infectious periods were 24 months and 6 months respectively and the pseudovertical transmission factor was 50% (p = 0.5). In our model the densities of infected and infectious possums are stably maintained at 14.8% and 1.2% respectively. Using these values in the Barlow model, the density of infected and infectious possums declined to undetectable levels relatively rapidly and the disease could not be maintained in possums. It should be noted that Tb has little effect on the total possum population and is not a major mortality factor to possums. The value for pseudovertical transmission used here is 50%, however this may be higher given the unique interaction of mother and 'joey'. If higher values



***Panel A**: Modification to the Barlow model. Pseudovertical transmission (**p**) was added to the infected population, **M**. For the vaccination model, the immune population, **I** was added and the rate of vaccination was λ. **Panel B**: The effects of poisoning (75% followed by 3 yearly maintenance poisoning) on the possum population using the pseudovertical transmission model.*

are used, the pattern is similar to that shown in Panel B except that the values for the densities of infected and infectious are increased by a small amount.

The values of 2 years for latency and 2 months for the infectious period are supported by the observed values of 2 to 2.5 years and 3 months respectively (Pfeiffer, pers. comm.). The average age of a possum dying from Tb is about 2.5 years and once possums become overtly ill they rarely live for more than 3 months. The Otago model predicts that there will be a >14% infected possum population, that a temporary reduction of possums population by poisoning will not eliminate Tb and pseudovertical transmission is the mechanism by which the disease is clustered in the environment.

Comparison of control strategies

One of the control strategies proposed is to reduce the population of possums to below a hypothetical threshold level of 4 possums/ha. The current control strategy is to reduce the population by a 75% using poisoning, followed by a maintenance poisoning every three years. As shown in Panel B, this results in the elimination of Tb as in the Barlow model, except there is a longer persistence of the infected population.

It has been proposed (Barlow, 1994) that viral-vectored immuno-contraception can be used to control Tb in possums. If a 50% reduction in possum density could be achieved this would be below the threshold for Tb transmission. However, even when using the most optimistic values for the parameters, it is unlikely that the virus could spread quickly enough or be efficacious to sterilise females (.ie. it would take more than 20 years to control possum populations).

An alternative control strategy is that of vaccination. Our estimates for the reproductive rate (R) of Tb in possums is about 1.47. It has been shown by Anderson *et al.* (1981) that if the reproductive rate of a pathogen is about 1.5 then an immunisation rate of 33% is sufficient to control the spread of the pathogen. A model for vaccination and pseudovertical transmission of Tb in possums is shown in Panel A. Using the values for the latent and infectious periods given above, the model predicts an elimination of the infectious and the infected population in a 5 and 10 year period respectively. This would have similar results to the results obtained by culling without the disadvantages of poisoning over such an extended period of time.

The vaccination of foxes for rabies using oral bait has been very successful in Europe and the USA and we can see no difficulty in achieving a similar rate of vaccination for Tb in possums.

Bibliography

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