Transmission Assumptions in Paratuberculosis Models

Clara Marcé[1,2], Pauline Ezanno[1], Maarten Weber[3], Henri Seegers[1], Dirk Pfeiffer[2], Christine Fourichon[1]

[1]UMR 1300 BioEpAR, Veterinary School, INRA, BP 40706, 44307 Nantes Cedex 3, France.
[2] Veterinary Epidemiology & Public Health Group, Royal Veterinary College, Hatfield AL9 7TA, Hertfordshire, United Kingdom
[3]Animal Health Service, PO Box 9, 7400 AA Deventer, The Netherlands

Introduction

Paratuberculosis is a disease in cattle and other ruminants caused by *Mycobacterium avium* subsp. *paratuberculosis* (*Map*). Worldwide, it has great economic importance for dairy producers. Understanding the transmission of the disease will allow the development of improved control programs. Models are particularly relevant as they allow simplified representations of our knowledge and exploration of hypotheses in relation to epidemiology and control. Various models have been developed in order to study *Map* transmission within a herd.

OBJECTIVE: to review published models on *Map* transmission within cattle herds with particular emphasis on routes of transmission, and to provide recommendations for future modelling studies.

Selected papers

Peer-reviewed papers and conference proceedings describing paratuberculosis transmission models within a cattle herd were systematically selected using electronic search engines in January, 2009 accessing literature databases (CAB, Medline, and ISI web of knowledge) and proceedings (such as the proceedings of the International Colloquia on Paratuberculosis). 6 models were selected from peer-reviewed papers and 2 from conference proceedings [1-8].

Transmission pathways

KNOWLEDGE: Only young animals are susceptible to *Map*. The main infection route is by ingestion of faeces. Other routes have been shown to exist: *in utero* transmission, or transmission by ingestion of colostrum or milk.

IN MODELS: see Table 1.

	[1]	[3]	[4]	[5]	[2]	[7]	[6]	[8]
Overall transmission	●	●	●	●				
In utero transmission					●	●	●	●
Adult-to-calf transmission					●	●	●	●
Milk and colostrum ingestion					○	○		
Faeces ingestion – through contacts					○	○		○
Faeces ingestion – through the environment							○	
Calf-to-calf transmission								●

Table 1: Transmission pathways considered in the models.

Assumptions in relation to faecal-oral horizontal transmission

	Probability of infection[a]	Reed-Frost exponent
[1]	$1-(1-\frac{k}{N_c})^{I_a}$	Number of infected adults (I_a)
[2,5]	$1-\left(1-\frac{k(age)}{N_a}s(age)\right)^{I_a}$	Number of infected adults in the last 6 months (I_a)
[3]	$\int_a \beta(age)\frac{I(age)}{N}$	Not applicable
[4]	$1-(1-\tau_x)^{I_x}(1-\tau_y)^{I_y}(1-\tau_z)^{I_z}$	Number of infected cows (I)
[6]	$1-(1-p(age))^{b(I_a,t)}$	Bacterial density in the environment (b)
[7]	$1-\left(1-\frac{k(age)}{N_a}s(age)\rho\right)^{I_a}$	Number of infectious cows (I_a)
[8]	$\sum_i \beta(i)\frac{I_i}{N}$	Not applicable

Table 2: Probability of infection and underlying assumptions used to model *Map* horizontal transmission (transmission via milk and colostrum ingestion excluded).

[a] β: transmission parameter (contact + transmission), I: number of infected adults, k: number of effective contacts, N: number of animals (Nc for calves, Na for adults), p: probability of infection, ρ: weighting factor depending on calf age, s: calf susceptibility, τ_i: disease transmission probability related to adult infectious status i.

Most publications use a Reed-Frost function (see Table 2), composed of probability of contact and probability of transmission given contact between infected and susceptible animals.

The probability of contact can be constant [1] or vary with age [2,3,5,6] and/or infectious statuses [4,8].

The probability of transmission if an infectious contact occurs can be equal to 1 [1] or can vary with calf susceptibility [2,5,7], age [2,5,6,7], and/or infectious statuses [3,4,8].

In all models, an underlying assumption is the random mixing of infectious and susceptible individuals, which may not be appropriate for all cow-calf contacts. The models do not take into account the influence of herd management on contact structure. Only one model takes into account *Map* survival in the environment [6].

Existing models could be improved by including:

- **Calf-to-calf transmission**
- **The contact structure between animals in a herd**
- ***Map* survival by considering indirect transmission of the bacteria via the environment.**

REFERENCES

1. Collins MT, Morgan IR. 1991. Prev Vet Med.
2. Groenendaal H, *et al.* 2002. Prev Vet Med.
3. Van Roermund HJW, *et al.* 2002. 7th Intl. Coll. Paratuberculosis.
4. Pouillot R, *et al.* 2004. Vet Res.
5. Van Roermund HJW, *et al.* 2005. 8th Intl. Coll. Paratuberculosis.
6. Humphry RW, *et al.* 2006. Vet J.
7. Kudahl AB, *et al.* 2007. Prev Vet Med.
8. Mitchell RM, *et al.* 2008. Prev Vet Med.