Modelling the time-dependent transmission rate for porcine circovirus type 2 in pigs

M. Andraud, B. Grasland, B. Durand, R. Cariolet, A. Jestin, F. Madec, J.S. Pierre, N. Rose

French Agency for Food Safety (AFSSA)
Epidemiology Unit
BP 53 – 22440 PLOUFRAGAN
FRANCE

Objectives

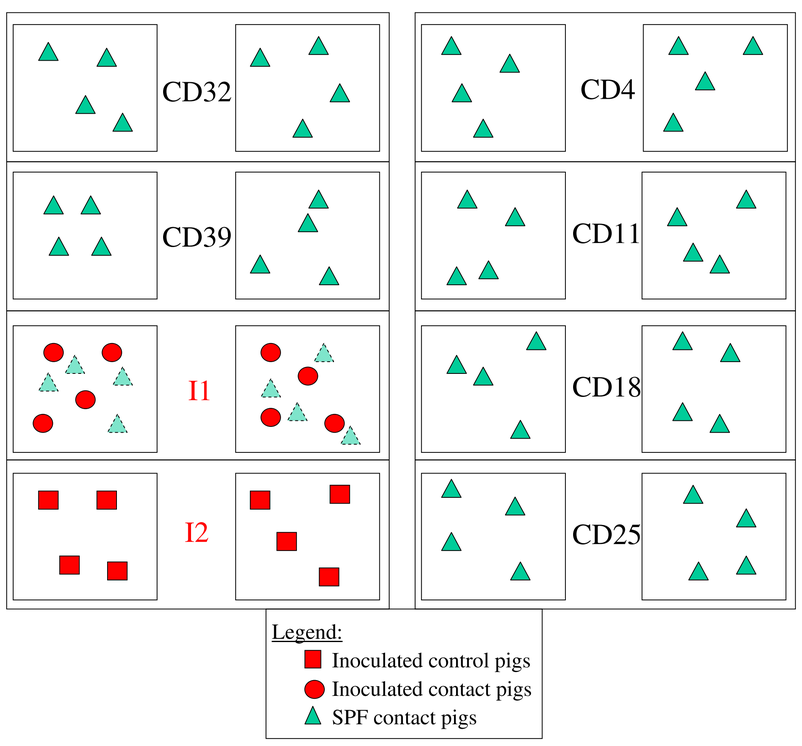
• Develop a method to assess PCV2 time-dependent transmission rate in pigs.

•Implementation of a time-dependent SEIR Model

•comparison with external data from a previous transmission experiment (Andraud *et al.*, *Vet. Res.,* submitted)

Material and methods

⇨ Experimental design



⇨ Contact characteristics

➢ Occurrence: Weekly from the 4th to the 39th day post inoculation

➢ Duration: 2 days for each contact group

⇨ Time-dependent transmission rate estimation: β(τ)

✓Number of new cases during a time-interval

$$\int_{t_0}^{t1} \beta(\tau)d\tau$$

✓Probability to escape from infection during a two-day contact

$$q_i = \exp(-I\int_{t_i}^{t_{i+1}} \beta(\tau)d\tau)$$

✓Basic Reproduction Ratio :

$$R_0 = \int_0^{\infty} \beta(\tau)d\tau$$

✓ The number of new cases follows a binomial distribution B(8,1-q_i)

✓ Log-Likelihood expression

$$\sum_{i=1}^{6}\left[C_i \log\left(1-\exp\left(-I\int_{t_i}^{t_{i+1}}\beta(\tau)d\tau\right)\right)-I(S_i-C_i)\int_{t_i}^{t_{i+1}}\beta(\tau)d\tau\right]$$

⇨ Time-dependent SEIR model

Hypothesis:

✓ The transmission rate was neglected if $\beta(x)<0.001$

✓"Exposed" class was implicitly represented by setting $\beta(\tau)$ to 0 throughout the period of latency.

✓"Removed" class represented all animals no more infectious

Model description

$$\begin{cases} \frac{dS}{dt} = -\frac{S(t)}{N}\int_0^{\infty}\beta(\tau)I(t,\tau)d\tau \\ \frac{\partial I}{\partial t}+\frac{\partial I}{\partial \tau} = -\delta_x(\tau)I(t,\tau) \\ \frac{dR}{dt} = \int_0^{\infty}\delta_x(\tau)I(t,\tau)d\tau \end{cases}$$

Boundary conditions

$$I(t,0) = \frac{S(t)}{N}\int_0^{\infty}\beta(\tau)I(t,\tau)d\tau$$

Initial conditions

$I(0,a)$: initial distribution of infectious individuals over age at infection

Results

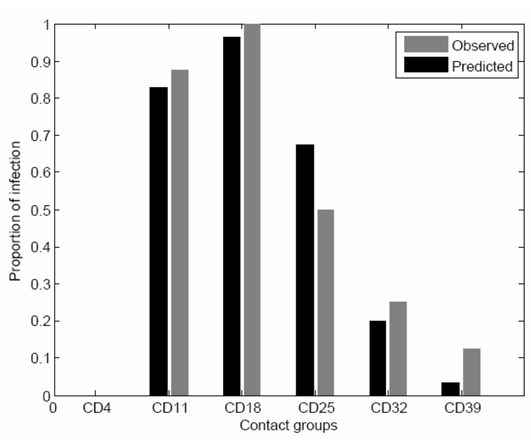


Figure 1.
Proportion of observed and predicted infections per contact group

➢ Transmission rate function

✓Unimodal

✓Left skewed

✓Lower- and upper-bounded

⇒ Gamma-like function

$$\beta(\tau) = \frac{(\tau - Lat)^{(k-1)}\, e^{(\tau-Lat)/\theta}}{\theta^k}$$

➢ Estimations of *k* and θ

(Maximum likelihood estimates)

k (CI)	θ (CI)	R_0 (CI)
4.0 (3.6,4.4)	2.7 (2.0,3.3)	5.7 (3.2,10.5)

➢ Latency duration: 8 days.

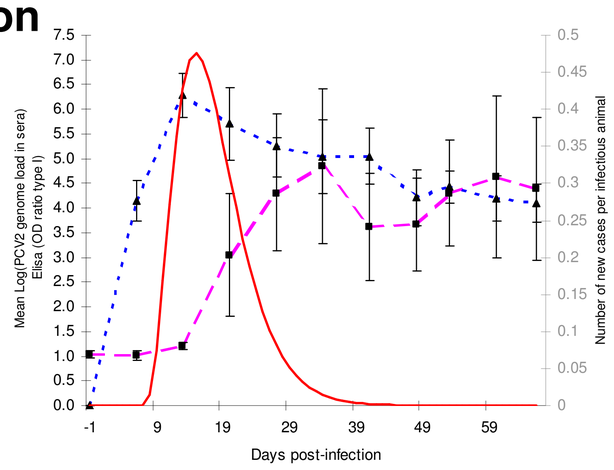


Figure 2.
Transmission rate function (red curve) in relation with serological response (purple curve) and genome load (blue curve)

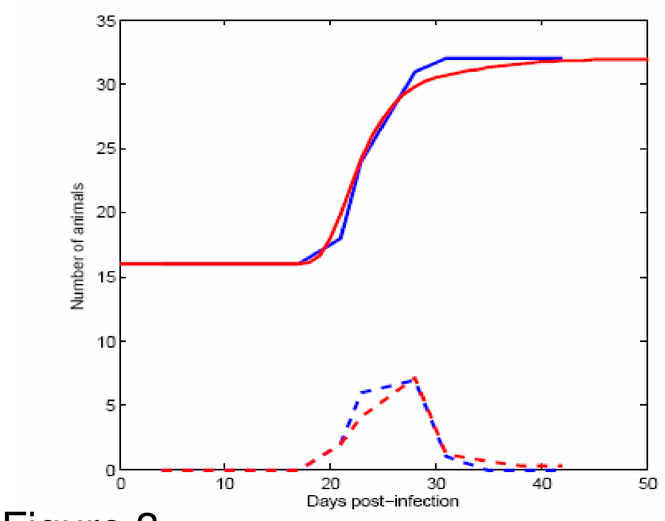


Figure 3.
Prevalence (continuous line) and incidence (dashed line) derived from a previous transmission experiment (blue) and outputs of the time-dependent SEIR model (red)

Discussion

In this study, serial transmission experiments were carried out to determine the shape of the transmission rate in terms of time since infection. Virus transmission occurred from inoculated pigs to SPF ones but was not constant according to time since inoculation (Figure 1).

The time-dependent transmission rate was supposed to be unimodal. This assumption reflected both the increase of genome load, which coincided with the increasing phase of the transmission rate, and the activation of the immune response, after what the infectious potential decreased (Figure 2).

The estimate of the transmission rate was inserted into a deterministic SEIR model to compare the outputs with the results of a previous transmission trial. Observed prevalence and incidence were correctly fitted by model outputs, showing that infectious dynamics could be fully explained by the time-dependent transmission rate in experimental conditions (Figure 3).

Contact: m.andraud@afssa.fr