

PLENARY SPEAKER

MODELLING THE WANING AND BOOSTING OF IMMUNITY

MIRJAM KRETZSCHMAR

m.e.e.kretzschmar@umcutrecht.nl

Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht,
Heidelberglaan 100, 3584CX Utrecht, The Netherlands

Joint work with Odo Diekmann (Utrecht University), Wilfred de Graaf (Utrecht University) and
Peter Teunis (RIVM).

Keywords: Mathematical model, Waning immunity.

ABSTRACT

The immune status of an individual host is determined by the increase of immunity during infection, waning of immunity after clearing the infection, and boosting by renewed exposure to the pathogen. The process of boosting, the rate at which immunity wanes, and the level of protection it confers, all influence the transmission dynamics of the pathogen. Information about the immune status of a population is often available from serological studies, but it may be unclear what this means for the level of protection against infection or symptomatic disease. We would like to understand how an intervention changes a population's immune status and the incidence of symptomatic infection for an infectious disease with waning immunity.

In this talk I will introduce a mathematical model for the waning and boosting of immunity. The model is defined on two levels. On the within-host level we defined a model that distinguishes between episodes of infection and time periods of waning of immunity (De Graaf et al. 2014). During infection, a simple 2-dimensional system of ODE's describes the time evolution of pathogens and immunity within the host. Between infection episodes immunity wanes until a new exposure triggers the next infection episode. We then lift the model to the population level by studying the distribution of immune states in a population under the assumption of a constant force of infection. The events of exposure and infection are described by a time-homogeneous Poisson process, between exposures immune status wanes deterministically. This model can be formulated in terms of a renewal equation, for which a stable stationary distribution can be derived.

The modelling framework will be illustrated with applications to pertussis epidemiology. For pertussis, longitudinal and cross-sectional serological data are available, which can be used to parameterize the model. We were interested in obtaining estimates for the incidence of symptomatic infections, the ratio of symptomatic to asymptomatic infections, and the immune level at which protection from symptomatic infection occurs. We found remarkable correspondence between predictions of the within-host model with observations reported in the literature concerning the serological correlate of protection. The modelling framework has strong links with a statistical model used for estimating incidence from serological data.

References

- [1] de Graaf WF, Kretzschmar ME, Teunis PF, Diekmann O. (2014). *A two-phase within-host model for immune response and its application to serological profiles of pertussis*, *Epidemics* 9:1-7.