Surprising effectiveness of vaccines

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Using a modified version of my previously developed chlamydia vaccine model, Andrew Craig has developed a model for gonococcal vaccines. His investigations of the potential effectiveness of such a vaccine has shown a suprisingly low efficacy is required to eliminate gonorrhea from a population. Initially I thought this was due to the sexual behaviour and partnershhip network in the model. As most individuals form long-term monogmous partnerships they are effectively protected for long time period. However, using a simple SIS model we can show these results are unsuprising. This Rmarkdown produced document describes the theoretical and numerical calculations to demonstrate this.

### Theorectical calculations

We use a simple SIS model with 100% effective vaccine and no waning.

Let be the proportion of the population infected. Then , and the number of people infected is

where is the infectivity, is vaccine efficacy (with if there is no vaccine) and is the rate of recovery. Letting be the value of where , we have

and either (the disease-free equilibrium) or

Setting describes the no-vaccine scenario. Calling the no-vaccine equilibrium prevalence , we have

. Susbstituting this into the equation for gives

which is equal to or less than zero when . This means the vaccine will remove the infection from the population if its efficacy is equal to or greater than the no-vaccine prevalence.

### Numerical demonstration

The theoretical calculations show that a partially efficacious vaccine can elimitate an infection from a population if the efficacy is greater than the endemic prevalence. The time taken for the infection extinction to occur is not shown. To investigate the change in prevalence over time we simulated the simple SIS model described above numerically.The model requires three input parameters to run. Table 1 shows the values we use for the simulations.

**Table 1** - Model input parameters

|  |  |
| --- | --- |
| Parameter | Value |
|  | 0.029/yr |
|  | 0.029/yr |
|  | 0-20% |

The parameter values in Table 1 are set to give a prevalence of 1.5% in the population of adults who are sexually active for 35 years (equivalent to 15-50 year olds). Figure 1 shows how introducing a partially efficacous vaccine (10 years into the simulation) effects the prevalence in the population over time. The R code for this figure is available in the associated Rmarkdown file.

**Figure 1** - Change in prevalence for different vaccine efficacies

