LETTER

Epidemiological evidence for herd immunity induced by acellular pertussis vaccines

In a series of elegant experiments on baboons, Warfel et al. conclude that acellular pertussis vaccines (aP) prevent disease but fail to protect against transmissible infection (1). The authors speculate that this fact may explain the resurgence of pertussis in some countries (2). Although the animal model of Warfel et al. is a true breakthrough, we question the soundness of their extrapolation to transmission in human populations. Indeed, much available epidemiological evidence argues against it.

The precise nature of vaccine-induced protection is both controversial and consequential. Vaccines that protect against transmissible infection protect those vaccinated directly, but also protect the unvaccinated who benefit from decreased infection risk: so-called herd immunity. In contrast, vaccines that protect against disease but not transmission benefit only the vaccinated. Although experimental evidence on the transmission impacts of pertussis vaccination is lacking, available incidence data provide evidence for vaccine-induced herd immunity.

For example, Rohani et al. demonstrated an increase in the interepidemic period and in the number and duration of epidemic fadeouts after the initiation of whole-cell vaccination in England and Wales, an indication of reduced transmission and strong herd immunity (ref. 2 and references therein). Broutin et al., using aggregated incidence data from multiple countries, demonstrated a 1.3-y increase in the interepidemic period following the inception of vaccination programs (3). These studies, and others, afford strong evidence that whole-cell vaccination reduces not only disease, but also transmission.

Similar epidemiological evidence exists for aP. In Sweden, following a 17-y hiatus in vaccination, the 1996 introduction of aP prompted a 10-fold drop in the number of reported cases. The drop was pronounced in infants too young to be vaccinated (Fig. 1*A*), itself a clear indication of herd immunity. Moreover, Rohani et al. were able to show that careful accounting for age differences in contact rates was sufficient to explain the full pattern of age-specific incidence, under the assumption that vaccination blocks both infection and transmission (4).

We modified the model of Rohani et al. (4) to examine the empirical findings of Warfel et al. (1): We assumed aP prevents disease, with variable effects on transmission. Our results are unambiguous: a model with no vaccine effect on transmission cannot reproduce the observed epidemiological patterns after vaccination (Fig. 1*B*). In particular, the model predicts a decline in young-infant cases if—and only if—aP blocks transmission.

The baboon model pioneered by Warfel et al. (1) is without question a game-changer, shedding light on the impact of vaccination on disease and infection. However, the view it affords is clearer with respect to immunity and pathology than with respect to transmission. We point out that the extrapolation of the possibility of transmission from vaccinated baboons in the laboratory to the probability of transmission from vaccinated humans in the population is unwarranted. More work is needed to elucidate the relative transmissibility of infections in vaccinated vs. unvaccinated hosts. The evidence adduced above suggests, however, that vaccination with aP must have a strong effect on transmission as well as disease.

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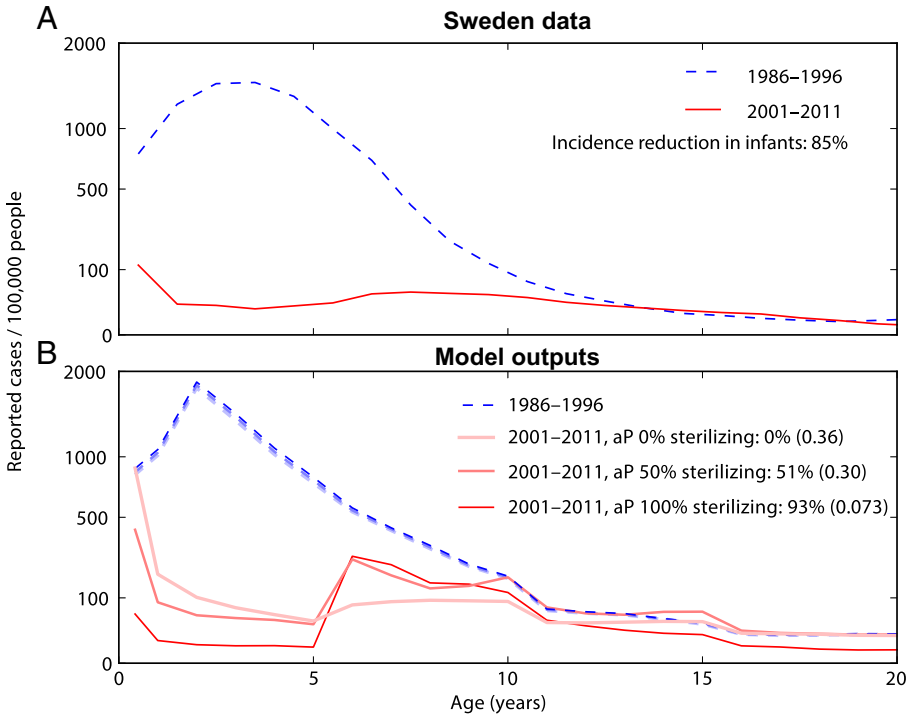

Fig. 1. Observed (*A*) and simulated (*B*) pertussis case reports in Sweden, before (years 1986–1996, dashed blue lines) and after (years 2001–2011, continuous red lines) inception of vaccination with acellular vaccines. In both panels, the *y* axis is square root-transformed. In *B*, the red lines correspond to different assumptions on the acellular vaccine's efficacy to reduce transmission (0%, 50%, or 100% efficacious); the numbers in the caption give the mean (SE) predicted percent incidence reduction in infants <1 y old from 20 model runs. The model used was adapted from Riolo et al. (5), with Sweden-specific parameters used in Rohani et al. (4). Briefly, this was an age-stratified stochastic compartmental model of pertussis dynamics, assuming no primary vaccine failure and lifelong immunity following vaccination and natural infection. Vaccine uptake data were fixed as described in the supplementary material of ref. 4.