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Vaccination and waning immunity: An immuno-epidemiological model for measles

For infectious diseases where immunization can offer life-long protection, a variety of simple models can be used to analyze vaccination as a control method. However, for many diseases life-long immunity cannot be obtained from vaccination. Instead, immunity wanes over time and is subsequently boosted by asymptomatic encounters with infectious individuals. To study this type of epidemiological process a comprehensive model that captures both the within-host dynamics of the pathogen and immune system and the associated population-level transmission dynamics is needed. We have developed an immuno-epidemiological model (immunology and epidemiology—both carefully parameterized to match the available data) describing measles dynamics in terms of waning immunity and boosting in measles infection; although such ideas have been hypothesized before, it is only through the use of such immuno-epidemiological models that the impact can be quantitatively studied. The model predicts that moderate waning times and high levels of vaccination can induce large-scale oscillations with substantial numbers of symptomatic cases being generated at the epidemic/outbreak peaks. It also predicts that far larger epidemics than previously predicted by standard models will occur when infection is introduced after a long disease free periods. These results have clear implications for public health protocols. They also highlight that a sound understanding of the underlying immunological mechanisms of immunity and vaccination is needed to fully understand epidemiological dynamics.