Wait or Vaccinate? Behavioural Dynamics of Competing Vaccine Strategies in a Compartmental Epidemic Model with Prevalence-Dependent Hesitancy

Sarkhel Akbar Mahmood, Attila Dénes
University of Szeged, Szeged, Hungary

As emerging pathogens frequently share biological similarities with previously circulating diseases, pre-existing vaccines may provide valuable yet imperfect protection during the early stages of an outbreak, before disease-specific vaccines become available.

In this work, we present a compartmental model that integrates two types of vaccines: a partially protective one, and a more efficient onw which only becomes available after a given time corresponding to vaccine development. Our model includes a hesitant population consisting of individuals who lack confidence in the newly developed vaccine. Both hesitancy and vaccine uptake are included as a function of disease prevalence.

By constructing appropriate Lyapunov functions, we show that the disease-free equilibrium is globally asymptotically stable when $R_0 < 1$, while a unique endemic equilibrium exists and is globally asymptotically stable when $R_0 > 1$. A transcritical forward bifurcation is shown to occure at $R_0 = 1$.

Numerical simulations are provided for scenario analysis considering various situations differing in severity of the new disease, efficacy of the old vaccine and the time needed for development of the new vaccine.

Critically, delayed introduction of a superior vaccine even with a high efficacy allows uncontrolled viral proliferation during the waiting period, producing a markedly higher infection peak and greater cumulative mortality compared to immediate deployment of a moderately effective vaccine. Elevated hesitancy amplifies transmission and delays epidemic control, whereas declining hesitancy enhances vaccination campaign effectiveness.