Mathematical modeling and optimal control analysis of epidemic models

Anuj Kumar*

School of Mathematics, Thapar Institute of Engineering and Technology, Patiala, India
College of Science and Engineering, Department of Mathematical Sciences,
Aoyama Gakuin University, Kanagawa 252-5258, Japan

ABSTRACT

It is well recognized nowadays that the infectious diseases (SARS, Influenza, Zika, COVID-19 etc.) not only broach challenges on social health but also potentially damage the economic well-being of communities due to high morbidity and mortality and various disease related costs (such as expenditures on health care, diagnosis and medical treatment etc. as well as productivity loss due to disease) during the course of epidemic. Therefore, control the disease spread with minimal damage and associated costs should be the primary goal of policy makers and governments. It has been encountered that there is always a trade-off between the execution of available control measures like vaccination, screening and treatment. Mathematical modeling and optimal control study are successful mechanisms to tackle such type of cost optimization problems related with execution of controls arise during epidemic outbreaks. Thus, the present study accounts for the dynamics of infectious diseases via proposing and analyzing different nonlinear compartmental models. In these mathematical models, the effect of different control aspects is quantified such as effect of information on self-protection and on vaccination coverage. In addition, a saturated treatment policy is also incorporated on the infective population due to the limited medical resources. Model analysis is performed to explore the complex and nonlinear properties of models such as: existence of multiple stability switches, Hopf, Hopf-Hopf (two Hopf), Transcritical and Backward bifurcations etc. Our study experiences that the different model systems give rise to the rich and complex dynamics due to saturation effect considered in medical treatment. Further, considering different time dynamical controls such as information-induced vaccination, behavioral changes, usage of pesticides and medical treatment, the associated optimal control problems are also proposed and analyzed which minimize costs incurred due to the disease burden and applied controls with the help of Pontryagin's Maximum Principle. A comparative study is conducted by choosing various control strategies. We observe that the comprehensive use of control interventions reduces the severity of the disease burden and also minimizes the economic burden.

References:

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*E-mail: anujdubey17@gmail.com