CHAPTER 1

Hepatitis C Virus Epidemic Control Using a Nonlinear Adaptive Strategy

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1. INTRODUCTION

The hepatitis C virus (HCV) is a blood-borne virus identified as the main cause of liver diseases [1–3]. Globally, about 3% of the world population (170 million) are dealing with HCV and 71 million people have chronic hepatitis C infection [1, 4–6]. Several studies showed that the chronic stage of HCV will develop cirrhosis and liver cancer in the case of no treatment and approximately 339,000 people die every year due to these diseases [1, 7]. Despite previously mentioned statistics which makes HCV infection one of the important health threats, this disease received little attention especially in the regions with a higher rate of infectiousness [4].

Although fatigue and jaundice were mentioned as symptoms of the HCV, this disease often has no considerable symptom, even in the advanced stages. This is the reason that the HCV outbreak is called "the silent epidemic" [4, 8]. Several different ways were reported for HCV prevalence, which includes sharing injection equipment, unsafe sexual contacts, inadequately sterilization of syringes and needles especially for health-care personnel, and transfusion of polluted blood [1, 9]. Even though these are the main causes of the HCV epidemic, but some other reasons may also be critical in some societies based on special conditions. For instance in the developed countries, since there is precise control on the blood transfusion, the importance of injecting drug use in transmission of the disease has increased compared to the transfusion of polluted blood and its products [2, 9].

Natural cure at the chronic stage of HCV is not common, but it can happen for about 10%–15% of patients that the RNA of HCV is indistinguishable in their serum [5, 6]. For the rest of the patients (80%–85%) that the HCV could not be healed by their immune system response, some drug therapy regimes should be employed. Hepatitis C drugs have recently had some developments. Available safe, highly effective, and endurable combinations of oral antivirals that act directly have currently developed for this disease [4, 10]. Although vaccination is the most vital way of controlling different viral diseases, but unfortunately there is no vaccine for the HCV yet [5]. Therefore, preventing this disease has an important role in stopping the extension of its epidemic.

In the present study, a nonlinear adaptive method is developed for treatment and control of the HCV epidemic. For this purpose, the recently published nonlinear HCV epidemiological model in [4] is employed and different parametric uncertainties are taken into account, despite the previous optimal strategies [4]. The main goal of the proposed control scheme is the population decrease in the unaware susceptible and chronically infected compartments in the existence of parametric uncertainties. Accordingly, two control inputs (efforts to inform susceptible individuals and treatment rate) are employed to track descending desired populations of the previously mentioned compartments. The asymptotic stability and tracking convergence of the closed-loop system having uncertainties are proven using the Lyapunov stability theorem and Barbalat's lemma. Innovations of this research are as follows:

- For the first time, a nonlinear adaptive method is developed to control the HCV epidemic by defining a novel Lyapunov function candidate that provides the tracking convergence proof.
- Due to the lack of accurate information about HCV model parameters in each society, parametric uncertainty is taken into account in this research for the first time, and the defined control objectives are achieved in the presence of these inaccuracies.
- In all of the previous studies that have been conducted on the control of the HCV outbreak,

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