Chapter 6
Analyzing Interval Systems of Human T-Cell Lymphotropic Virus Type I Infection of CD4$^+$ T-Cells

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ABSTRACT

Human T-cell lymphotropic virus type I (HTLV-I) infects a type of white blood cell called a T lymphocyte. HTLV-I infection is seen in diverse region of the world such as the Caribbean Islands, southwestern Japan, southeastern United States, and Mashhad (Iran). This virus is the etiological agent of two main types of disease: HTLV-I-associated myelopathy/tropical spastic paraparesis and adult T cell leukemia. Also, the role of HTLV-I in the pathogenesis of autoimmune diseases such as HTLV-I associated arthropathy and systemic lupus erythematosus is under investigation. In this chapter, the author considers an ODE model of T-cell dynamics in HTLV-I infection which was proposed by Stilianakis and Seydel in 1999. Mathematical analysis of the model with fixed parameters has been done by many researchers. The author studies dynamical behavior (local stability) of this model with interval uncertainties, called interval system. Also, effective parameters in the local dynamics of model are found. For this study, interval analysis and particularly of Kharitonov's stability theorem are used.

INTRODUCTION

Recently, attention of many researchers has been attracted to the study of population dynamics of infectious diseases, such as human immunodeficiency virus (HIV), hepatitis B virus (HBV), and human T cell lymphotropic virus type I (HTLV-I) (Arafa, Rida, & Khalil, 2011; Asquith & Bangham, 2008; Asquith et al., 2005; Atay, Başbük, & Eryılmaz, 2016; Bangham, 2000; Bangham & Osame, 2005; Bangham et al., 2009; Blattner et al., 1982; Blattner et al., 1983; Bofill et al., 1992; Cai, Li, & Ghosh, 2011; Cann & Chen, 1996; Chiavetta et al., 2003; Dadi & Alizade, 2016; DeBoer & Perelson, 1998; Elaiw, 2010; Eshima

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et al., 2009; Eshima, Tabata, Okada, & Karukaya, 2003; Gokdogan & Merdan, 2011; Gómez-Acevedo & Li, 2005; Katri & Ruan, 2004; Lang, 2009; Lang & Li, 2012; Lim & Maini, 2014; Mortreux, Gabet, & Wattel, 2003; Mortreux, Kazanji, Gabet, de Thoisy, & Wattel, 2001; Murphy et al., 1991; Nelson, Murray, & Perelson, 2000; Nowak & Bangham, 1996; Oguma, 1990; Olavarria, Gomes, Kruschewsky, Galvão-Castro & Grassi, 2012; Perelson & Nelson, 1999; Poiesz, 1980; Ramirez, Cartier, Torres, & Barria, 2007; Ribeiro, Mohri, Ho, & Perelson, 2002; Richardson et al., 1997; Richardson, Edwards, Cruickshank, Rudge, & Dalgleish, 1990; Robbins, 2010; Seigel, Nash, Poiesz, Moore, & O'Brien, 1986; Seydel, & Kramer, 1996; Seydel & Stilianakis, 2000; Shirdel et al., 2013; Song & Li, 2006; Stilianakis & Seydel, 1999; Sun & Wei, 2013; Tortevoye, Tuppin, Carles, Peneau, & Gessain, 2005; Vieira, Cheng, Harper, & Senna, 2010; Wang, Fan, & Torres, 2010; Wang, Li, & Kirschner, 2002; Wattel, Vartanian, Pannetier, &Wain-Hobson, 1995; Williams, Fang, & Slamon, 1988; Yamamoto, Okada, Koyanagi, Kannagi, & Hinuma, 1982; Yu, Nieto, Torres, & Wang, 2009).

The discovery of HTLV-I as the first human retrovirus in 1980 has had several notable implications, (Poiesz et al., 1980). First, clear proof of existence a relationship between viruses and cancer. Second, making an opportunity to investigate the mechanisms what lead to chronic demyelinating disease. There exists an obvious association of HTLV-I with a neurologic disease similar to multiple sclerosis (MS). Finally, the discovery and isolation of human immunodeficiency virus (HIV) was facilitated. HIV has caused a global epidemic of a rapidly progressive fatal illness: acquired immune deficiency syndrome, AIDS.

In fact, HTLV-I as a C-type retrovirus is the etiological agent of two main types of disease (Cann & Chen, 1996);

- HTLV-I associated myelopathy/tropical spastic paraparesis (HAM/TSP) and
- Adult T cell leukemia (ATL).

The virus not only induces HAM/TSP in a small proportion of HTLV-I carriers, but also is associated with other autoimmune diseases such as HTLV-I associated arthropathy (HAAP). In addition, the role of HTLV-I in the pathogenesis of systemic lupus erythematosus (SLE) has been discussed extensively, (Shirdel et al., 2013). The infection is also associated with an increasing occurrence of infectious diseases such as infective dermatitis in children, tuberculosis, disseminated strongyloidiasis, and scabies (Olavarria, Gomes, Kruschewsky, Galvão-Castro, & Grassi, 2012).

Infection with this virus is now a global epidemic, affecting 20 million to 40 million people. In the areas where HTLV-I is endemic, significant causes of mortality and morbidity are HAM/TSP and ATL. The highest prevalence of this infection is found mainly in the tropics and subtropics: the Caribbean Islands, southwestern Japan, Central and South Africa, South America and the Middle East. The virus is also present in USA, especially in southeastern United States, and Mashhad in the northeast of Iran which the prevalence of HTLV-I infection is estimated to be 2-3% in the whole population, (Shirdel et al., 2013).

HTLV-I is transmitted by four major routes:

- Sexual transmission,
- Vertical transmission from mother to child,
- Infection by blood transfusion,
- Needle-sharing among drug users.