Prioritizing Hepatitis C Treatment in U.S. Prisons

1. Introduction and Motivation

More than 3 million persons in the United States (U.S.) have hepatitis C virus (HCV) infection. Chronic HCV infection is the leading cause of liver cirrhosis, liver failure, and liver cancer, the fastest-growing cause of cancer-related deaths in the U.S.

Recently, there have been major advancements in hepatitis C treatment, which could change the overall strategy in HCV management. In December 2013, the Food and Drug Administration (FDA) approved the first non-interferon-based, all-oral regimen HCV treatment drugs. This was followed by the development of several other all-oral new direct-acting agents (DAAs). Compared with the old drugs, the new treatment has much higher cure rates (>95% vs. <50%), shorter duration of treatment (8-12 weeks vs. 24-48 weeks), and significantly fewer side effects. These incredible advancements in treatment have made many experts and health organizations believe that the time has come for global HCV elimination (Hellard et al. 2016).

The criminal justice system is one of the areas with the highest concentration of HCV-infected people. This is because most HCV-infected people are current or past injection drug users (IDUs), and most Americans who inject drugs have been incarcerated at some point in their lives. Given that more than 10 million Americans cycle in and out of prisons and jails every year, including about one of every three HCV-infected patients, many experts have argued that the criminal justice system is one of the best places to focus for HCV management (He et al. 2015).

However, one of the biggest barriers against the plan of effectively treating infected inmates while in prison is the prohibitive cost of the new generation HCV drugs. With a list price of up to $1000 per pill, a single line of treatment with the new drugs can cost up to $84,000 per patient. The U.S. prisons operate under tight resource constraints, and healthcare budgets of state prisons are allocated by the state legislature a year in advance. As such, given that treating one HCV-infected inmate costs as much as the overall healthcare costs of about 17 prisoners, most correctional facilities do not have resources to treat all HCV infected inmates. Indeed, a recent study has shown that if all HCV-infected inmates were to get treatment, the cost would be about twice as high as the entire system’s annual total healthcare budget (Baker et al. 2015).
2. Research Questions and Key Results

Given that universal treatment is not affordable, the Federal Bureau of Prisons encourages correctional providers to prioritize inmates for HCV treatment (Federal Bureau of Prisons 2016). Current correctional system treatment prioritization guidelines and the published literature have suggested considering disease staging, remaining sentence length, and IDU status in prioritization decisions. However, there is controversy about how these factors should be incorporated because of the complicated tradeoffs, and to our knowledge such tradeoffs have not been evaluated while formulating prioritization guidelines. For instance, prioritizing IDUs can reduce the risk of spreading the disease to a larger population; however IDUs are more likely to be reinfected after treatment, hence prioritizing such patients may simply lead to a waste of scarce resources. Similarly, prioritizing patients with longer sentence lengths can maximize the life expectancy of the prison population, but prioritizing patients with shorter sentence lengths may be more effective in controlling the disease because of the reduced risk of spread in the general population.

Motivated by the above facts, we propose a data-driven mathematical modeling approach for prioritizing HCV treatment in state prison systems. In particular, we propose a restless multi-armed bandit (RMAB) modeling approach to systematically compare a large number of treatment prioritization rules and identify effective prioritization strategies. We consider Whittle’s index and other index-type policies. However, the implementation of Whittle’s index is nontrivial because i) Whittle’s index is only applicable to a restricted class of problems that satisfy the so-called indexability property, which is difficult to check in general (Whittle 1988, Glazebrook et al. 2006); ii) the computation of Whittle’s index involves repeated solution of single-bandit dynamic programs, which is difficult for our case since each single bandit has a multi-dimensional state space.

To address the above challenges, we first establish indexability of our problem through a novel approach. We then establish indexability and derive several structural properties of the Whittle’s index. Based on these results, we develop a closed-form expression of Whittle’s index for patients with advanced liver disease. This closed-form expression of Whittle’s index significantly expedites the computation, and more importantly, provides an intuitive interpretation allowing us to predict under what circumstances Whittle’s index would perform well or poorly for our problem. In particular, based on this closed-form expression, we anticipate that
the performance of the Whittle’s index would degrade as the treatment capacity increases (note that Whittle’s index is blind to the treatment capacity). Therefore, building upon this closed-form expression of Whittle’s index, we propose a capacity-adjusted closed-form index policy that explicitly captures the treatment capacity. We parameterize and validate our proposed RMAB model using real data from state prison systems and published studies. We further develop a detailed realistic agent-based simulation model to test the performance of our proposed capacity-adjusted index policy against Whittle’s index and other competitive benchmark policies such as myopic policy, and show that our proposed policy has a significant performance improvement.

Our research has important policy implications. First, we find that prioritization based on only liver health status, a commonly practiced policy, is suboptimal compared with many other policies we consider, and we show that simultaneously considering health state, remaining sentence length and IDU status in prioritization decisions can lead to a significant performance improvement. Second, we find that the decision of whether to prioritize patients with shorter or longer remaining sentence lengths depends on the treatment capacities inside and outside the prison system, and prioritizing inmates with shorter length of sentences may be preferable if the treatment capacity inside the prison system is not too tight compared with the linkage-to-care level outside. We remark that treatment capacity is also limited in the community, and a possibly higher average treatment capacity in the community does not necessarily translate to a higher treatment rate for released inmates due to lower linkage-to-care. Third, we shed light on the controversy surrounding the prioritization of IDUs and find that for patients with advanced liver disease, the decision is sensitive to reinfection rate, and IDUs should not be prioritized unless reinfection is well controlled.

References


