Chapter 14

Optimization Model and Algorithm Help to Screen and Treat Sexually Transmitted Diseases

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ABSTRACT

Chlamydia trachomatis (CT) and Neisseria gonorrhoeae (GC) are two common sexually transmitted diseases among women in the United States. Publicly funded programs usually do not have enough money to screen and treat all patients. Therefore, the authors propose a new resource allocation model to assist clinical managers to make decisions on identifying at-risk population groups, as well as selecting a screening and treatment strategy for CT and GC patients under a fixed budget. At the same time, the authors also develop a two-step branch-and-bound algorithm tailor-made for our model. Running on real-life data, the algorithm calculates the optimal solution within a very short time. The new algorithm also improves the accuracy of an approximate solution obtained by Excel Solver. This study has shown that a resource allocation model and algorithm might have a significant impact on real clinical issues.

INTRODUCTION

Background on Sexually Transmitted Diseases in the United States

Chlamydia trachomatis (CT) and Neisseria gonorrhoeae (GC) are the two most commonly reported sexually transmitted diseases (STDs) in the United States. Most infections are asymptomatic and would not be detected without asymptomatic screening, especially for women. In 2008, 1,210,523 cases of chlamydia were reported to the Centers for Disease Control and Prevention (CDC) in the United States. This case count corresponds to a rate of 401.3 cases per 100,000 population, an increase of 9.2% com-
pared with the rate in 2007 (Centers for Disease Control and Prevention, 2010b). In 2008, 336,742 cases of gonorrhea were reported to CDC in the United States, corresponding to a rate of 111.6 per 100,000 population (Centers for Disease Control and Prevention, 2010b).

Many CT and GC infections are detected through screening and treatment in public clinics. In reality, these clinics may not have sufficient budgets to screen all eligible women with the most effective CT/GC tests and to offer patients more expensive, single-dose treatments that improve adherence. To use limited resources effectively, CT and GC control programs usually provide selective screening based on defined guidelines. For example, CDC and the U.S. Preventive Services Task Force (USPSTF) recommend annual screening for CT for all sexually active females 25 years and younger (Centers for Disease Control and Prevention, 2010a). In addition, USPSTF also recommends screening all sexually active women younger than 25 years, including those who are pregnant, for GC if they are at increased risk for infections (U.S. Preventive Services Task Force, 2005).

Identifying which subpopulations to screen for CT and GC is just one part of the real-life problem. The availability of several testing assays with various performance parameters and costs presents a challenge for screening strategies: newer diagnostic tests that are less invasive and more sensitive offer increased opportunities for screening, but at a greater cost. In other words, the problem is whether more infections can be diagnosed and treated using a more sensitive and expensive test to screen fewer patients, or to use a relatively cheaper and less sensitive test to screen a greater number of patients. To further complicate the issue, test manufacturers market combination tests or bundled tests at prices that are less expensive than the price of separate single-pathogen tests. This situation encourages the testing for GC even when its prevalence in the population is extremely low.

**Overview of Creating Resource Allocation Models for STDs**

There are not a lot of resource allocation (optimization) models regarding the control of CT and GC infections. But many efforts have been made to develop models to investigate and evaluate HIV prevention and control programs (Brandeau & Zaric, 2009; Kaplan & Pollack, 1998; Lasry, Zaric, & Carter, 2007; Sendi & Al, 2003). To correlate with the practical relevance to CT infections, researchers initially developed a resource allocation model to determine the optimal strategy for curing CT infections among asymptomatic women at clinics (Tao, Gift, Walsh, Irwin, & Kassler, 2002). Two years later, researchers proposed a mixed-integer program to model re-screening women who test positive for CT infections (Tao, Abban, Gift, Chen, & Irwin, 2004). These two optimization models are able to offer simple guidelines for clinics on the selection of test and treatment for certain populations. However, these models are not able to manage two or more infections (e.g. CT and GC) at the same time at given clinics.

**Overview of Algorithms for Solving STDs Resource Allocation Models**

Many health care researchers rely on existing resource allocation model software to solve their proposed models because some software applications are easy to use (Gift, Walsh, Haddix, & Irwin, 2002; Lasry, Carter, & Zaric, 2008; Tao et al., 2002, 2004). However, these applications sometimes may not provide the best outcomes due to the complexity of proposed models and the limitations of algorithms used in the software. For example, the resource allocation models used in the previous STD studies were nonlinear programming models and the optimal outcomes generated by the algorithm were never verified.

With respect to the nature of the resource allocation models that are typical nonlinear models, the algorithms for these models in general could