Improving Make-ahead Chemotherapy Drug Policies in the Outpatient Infusion Center Pharmacy

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Introduction

Key Goal: Reduce patient waiting time by mixing chemotherapy drugs before patients arrive for their infusion appointment or at earlier stages in the process.

Cancer is the second leading cause of death in the U.S., with ~1.7 million cases estimated for 2016. Over 50% of cases require chemotherapy treatment. Increasing demand has led to increased patient waiting times and overworked staff. What if we could reduce these burdens by pre-mixing chemotherapy drugs?

What is Pre-mix?

Pre-mix is defined as the preparation of a drug before any patient is deemed ready to receive it. Generally, cancer center do not pre-mix chemotherapy drugs due to risk of a patient being unfit to receive treatment (i.e. defer) or not show. In our model, we consider the tradeoff between waste cost and saved patient waiting time.

Probability of Wasting a Drug

Let $Prob(\text{Deferral/no show}) = p$

Assume $m_d =$ patients scheduled to receive drug d on a given day

Then the probability of wasting the n^{th} dose of drug d is given by

$$P_d(\mathrm{n}) = \sum_{i=1}^{n} \binom{m_d}{m_d - i + 1} p^{m_d - i + 1}(1-p)^{i-1}$$

What if the probability of deferral or no show depended on age, sex, treatment, type of cancer, etc.?

Let $Prob(\text{Deferral/no show of patient } i) = p_i$

Let $S_d =$ set of patients scheduled to receive drug d

Therefore, $S_d = \{1,2,\dots,m_d\}$

$$Prob(\text{Wasting } 1^{\text{st}} \text{ dose}) = \prod_{i \in S_d} p_i$$

$$Prob(\text{Wasting } 2^{\text{nd}} \text{ dose}) = \sum_{i \in S_d} \left[(1-p_i) \prod_{j \in S_d \setminus i} (p_j)\right] + \prod_{i \in S_d} p_i$$

Model

Parameters

Δ_d	the reward or savings for mixing drug d
T	the total time units for the pre-mix period
c_d	the cost of drug d
p_d	the time it takes to mix drug d
N_d	the number of doses needed for each drug d
C	pre-mix capacity for any pre-mix period
M	a very large number

Sets

D: set of drugs d (e.g. 50 mg of Taxotere)

Variables

$$x_{nt}^d = \begin{cases} 1 & \text{if we mix the } n\text{th dose of drug } d \text{ at time } t \\ 0 & \text{o.w.} \end{cases}$$

$$y_n^d = \begin{cases} 1 & \text{if we don't mix the } n\text{th dose of drug } d \\ 0 & \text{o.w.} \end{cases}$$

$$z_{nt}^d = \begin{cases} 1 & \text{if mixing the } n\text{th dose of drug } d \text{ at time } t \\ 0 & \text{o.w.} \end{cases}$$

Objective

Maximize the difference between expected reward and waste cost

$$E_n^d[\text{waste cost}] = c_d P_d(n) \qquad E_n^d[\text{Reward}] = p_d \Delta_d [1 - P_d(n)]$$

$$\boldsymbol{max} \sum_d \sum_n \sum_t \left(E_n^d[\text{Reward}] - E_n^d[\text{waste cost}]\right) * x_{nt}^d$$

$$\sum_t x_{nt}^d + y_n^d = 1 \qquad \forall d, n$$

$$\sum_t z_{nt}^d + p_d * y_n^d = p_d \qquad \forall d, n$$

$$y_n^d \le y_{n+1}^d \qquad \forall d, n = 1, \dots, N_d - 1$$

$$\sum_t t x_{nt}^d \le \sum_t t x_{(n+1)t}^d + M * y_{n+1}^d \qquad \forall d, n$$

$$\sum_d \sum_n z_{nt}^d \le C \qquad \forall t$$

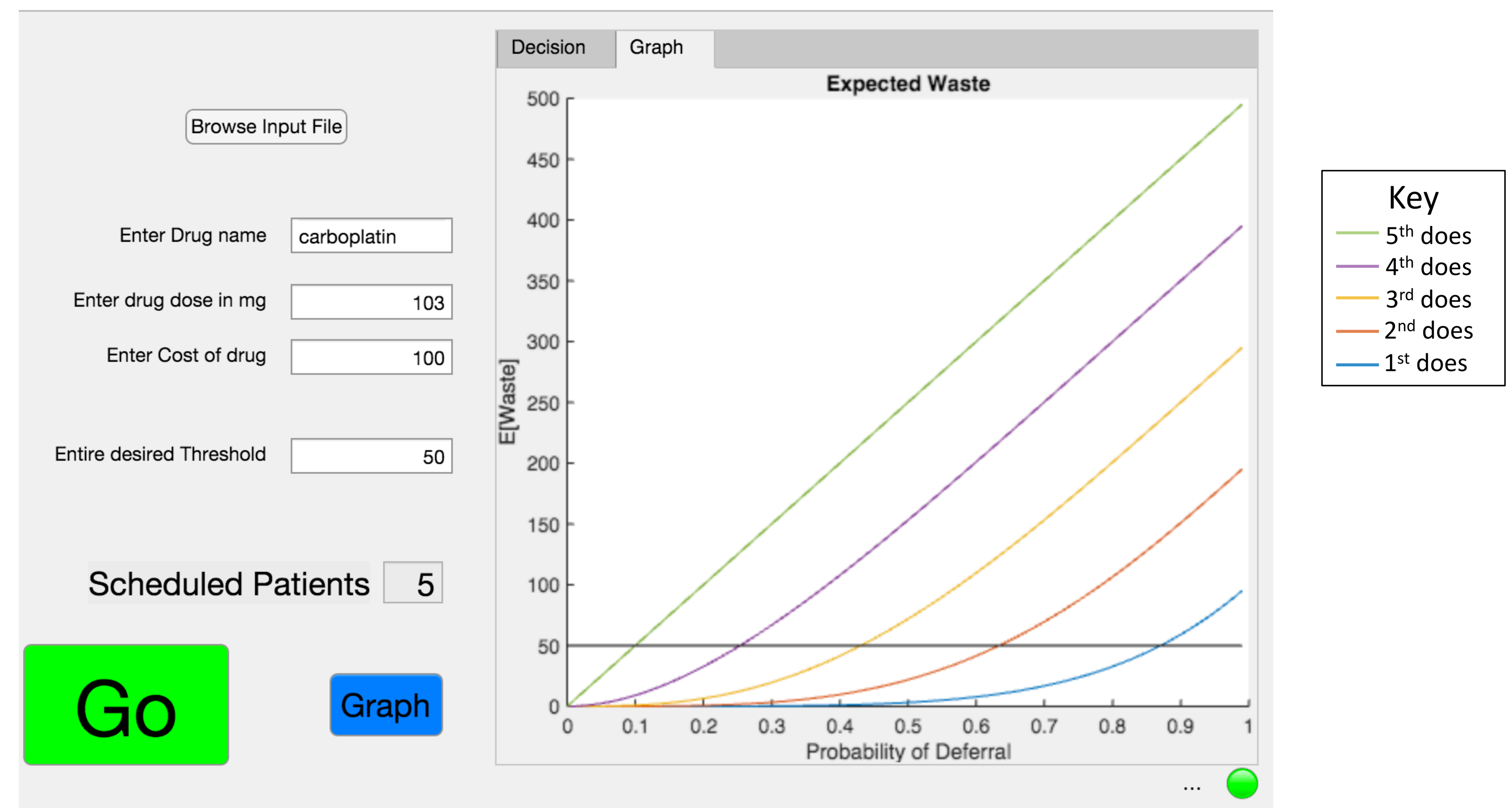
$$x_{nt}^d \le z_{n(t+i)}^d \qquad \forall d, n, t = 1 \dots (T - p_d + 1), i = 0 \dots (p_d - 1)$$

$$\sum_t t x_{nt}^d + p_d - 1 \le T \qquad \forall d, n$$

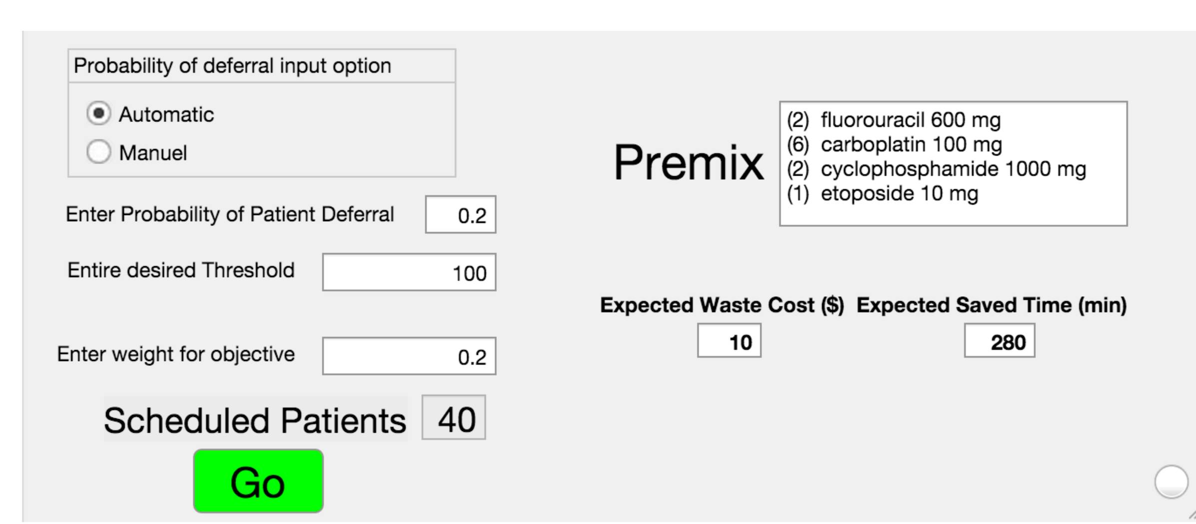
(1) Either pick a time to start a drug or don't make it at all
(2) Drug must be completed if mixed
(3) If you don't make the n^{th} dose you can't make the $(n+1)^{th}$ dose
(4) Must make doses in order
(5) Can only make C drugs at a time
(6) No preemptions allowed
(7) Cannot start a drug unless there is enough time

Pre-mix Application

1st Key Goal: Create a user friendly app to aid cancer center pharmacist in deciding which drugs are most advantageous to premix on a given day by relying on a threshold policy.



2nd Key Goal: Allow the pharmacist to input entire list of drugs on a given day and make decision on what is best to premix based on the objective of maximizing saved wait while minimizing waste cost



Here the user can manually input the patient probability of deferral or have it predicted based on historical patient data. Then the user will input the total waste cost threshold for all drugs. Lastly the user inputs how much they weight cost vs wait time.

Potential Impact

By making chemotherapy drugs ahead of time, we can potentially save the time it takes to make that drug for a given patient. While the goal is to have an hour turn around time for making drugs once the orders are received, the process can take up to 2 hours if the pharmacy is backed up. In this case pre-mixing a patient drugs becomes extremely valuable if they are scheduled during peak hours. This tool will also help pharmacist keep waste cost to a minimum.

Future Work

Static Model
- Relax assumptions for drug hang-by time, preparation times, and that all patients are scheduled to receive one drug
- Determine the most appropriate prediction model for patient deferrals/ no shows

Premix App
- Take an input of a list of drugs and utilize optimization model to make decision on what to premix
- Incorporate prediction model

Simulation Model
- Use to justify the expected saved wait time by following recommendations taken from the static premix model solution
- Test various policies for mixing chemotherapy drugs throughout the day

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