Cancer Treatment Modeling: Overlooking the Discrete Event Simulation Model throughout the Cancer Treatment Phase

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Abstract

The cure for cancer has always been elusive. There is no doubt that one of the crowning achievements for humanity would be the ability to find an exact cure for cancer. Obtainable or not, physicians and scientists have come a long way to learn and tend to these chronic diseases. In the vast timeline of cancer research, many theories, models, and methods have been tested and utilized to get the best solution to those people who have been diagnosed with cancer the best treatment plan possible to increase their chances of survival. The use of computer modeling such as discrete event simulation (DES) will help find and decide the potential process the patient must go through in order to get from the diagnostic phase to the treatment phase. This review will simply go through my brief research on the consideration and selection of certain treatment processes including chemotherapy, radiation therapy, and immunotherapy along with a handful of DES models to visualize the different cases and outcomes of different treatment plans with the idea of eliminating wait time.

**Keywords**: Discrete event simulation, wait-time, process-modeling, patient flow, cancer care

Introduction

Looking back thousands of years ago, the one who was considered by many today to be “the father of medicine,” Greek physician Hippocrates would describe tumors found on the human body as either *karkinos* and *karkinoma*, both describing whether the tumor was seen to be an ulcerous or non-ulcerous tumor. During his examinations, Hippocrates compares these rough and sporadic tumors to an outline of a familiar crustacean: the crab [NCI]. Thus, the term *cancer* was born and has unsparingly marched on through humanity without prejudice nor hesitation. Fast-forwarding to today, cancer remain one of the leading causes of death worldwide. In only 2020, a bewildering 19 million new cancer cases emerged globally, and about 10 million cancer related deaths occurred consequently [Sung].

Generally, survival in any form of diagnosed cancer is dependent upon where the cancer was located and the amount of area and spread the tumor has gone starting from the point of origin. Whenever the tumor has grown past the point of origin, and onto an adjacent or distant organ, it is said to be malignant. These neoplasms (abnormal mass) are typically staged from low to high depending on the severity, size of the mass and the location of the tumor. The measurement of the average patient life expectancy is usually measured by the five-year survival rate, which is the percentage of people who are alive for the beginning 5-years whenever they were first diagnosed with the disease/started the treatment. For instance, the 5-year survival rate goes from 90% for patients with stage I colorectal cancer, a tumor found in the colon/rectal region of the body, to about 75% for stage II patients. It goes from 70% for stage III patients, but only 14% for stage IV patients [ACS]. The major difference between stage III and stage IV (in the case of colon cancer) is whether or not the tumor has travelled to another part of the body, such as the liver or lungs and have turned malignant. So how is cancer generally treated? It is by halting the spread of the cancerous cells during the early stages of its mutation before it grows out of control. The early detection and diagnoses of the tumor is vitally important as time plays a big role in deciding the life and death of a patient.

One of the biggest factors in the success of cancer treatment is essentially time, the faster you can detect and eliminate the mutated cells to travel, the better the odds of survival. This is where the modeling technique of discrete event simulation (DES) can come into play and assist with the removal of wait-time. Discrete event simulation is a method used to model systems that can be transformed into a set of logical processes that continues through time [Barrett]. It essentially shows a sequence of events in time and uses multiple simulations to see the ideal result to cut any wait-time and improves the patient flow throughout the treatment phase.

Literature Review

There are many paths and options one may select to get the best results for success. These includes knowing which therapy and most successful for which certain kind of tumor, the different side effects that might occurring when partaking in a certain plan, the availability of treatment and support options outside of the main hospital, even the reliability of doctor recommendations vs a certified oncologist. Many factors come into play whenever trying to figure out which route would result in the best outcome.

Having a computer model that can work with this process can provide benefits to patient outcome and comprehension of data. Bekisz and Geriz [Sophie] goes into depth to describe how mathematical models would allow for a better understanding for different types of tumors and that uses an *in silico* cancer model which takes a system and optimizes that system by looking at the variables and parameters and improve on them. On the flip side, Aggarwal *et al* [Aggarwal] gives us their perspective of the effectiveness of these models built throughout the years and how there are so many variables involved in cancer research that it is impossible to settle down on a few models and expect them to be successful.

Karnon *et al* [Karnon] explains the use of DES models in general in the medical field and Barrett *et al* [Barrett] introduces us to the idea of using DES models in field of oncology specifically, how the model has a timestamp for every event and even considers random variable wait-times that might occur and adapts to the environment real-time.

Going into specifics of utilizing DES models in various treatment types, Ju *et al* [Ju] gives a great visualization of how the discrete event simulation should be used throughout the lung cancer diagnosis-to-treatment process on surgical patients. The article gives us these six steps into the process of what a surgical patient must go through, but in a DES model. Each single event has its own separate category, such as the X-Ray/CT scan, the biopsy conducted, the type of imaging software selected, and the staging process used. A very concise and understandable article, showing how the model is trying to pick and weave out the best timeliness to reduce any wait-time, reducing and eliminating any “bottle-necking” that might occur to delay patient progression. Continuing, we will also be looking at Pham *et al* [Pham], Vieira *et al* [Vieira] and Tully *et al* [Tully] as each separate articles will look at using DES models to cut down on wait-time, increase patient flow, and improve treatment efficiently to chemotherapy, radiation therapy, and Immunotherapy/T-Cell therapy respectively.

Discussion/Limitation

At the beginning, my knowledge with this chronic disease was very limited and minute. Throughout my research, many of my curiosities and concerns about the fight against cancer slowly began to be answered. I slowly broke down each scenario for each type of neoplasm, I began to see how each type would behave and how effective it was to use non-surgical procedures to cure the infected site. Whenever a person is diagnosed with cancer, it might seem that modern medicine would have multiple solutions to tackle a strenuous problem. However, there has only been 3 non-surgical solutions that has a high enough success rate to be considered: chemo, radiation, and immune/t-cell therapy. Each one of these processes have an intricate method that one must follow to get to the best result. This includes every step and patient must take, starting from whenever they were diagnosed, to when they are done with therapy.

Viewing the studies from the pool of various treatments, the discrete event simulation seemed to have a positive effect in all categories and fields which dealt with patient interaction and the procedure that they had to go through to cut down the waiting time. An excellent example of cutting down wait-time was in the chemotherapy DES model study. Using this model (Figure 1), the patient could either be waiting based on their initial consultation to proceed to their next planned imaging (pull method) or to pick a day in between their treatment planning to their treatment start day. This DEC model was able to speed up the waiting time for patients for up to 1 day, creating availability for a much smoother experience and to allow additional patients to the resource, whether it be consulting, imaging, or staging.

Diagram

Description automatically generated  
(Figure 1. Pham)

Some limitations that I came across throughout my research was the lack of models used globally in other countries. Out of those models, a decent amount of discrete event simulations was used, but not enough examples of the “worst-case” scenario were used to truly see if the DES model was truly effective.

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