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Agent-Based Simulation Patient Model for Colon and Colorectal Cancer Care Trajectory

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Abstract

Colon and Colorectal cancer are a diagnosis of particular concern for older Canadians. They are the second cancer in terms of rate of incidence and mortality among Canadians after lung cancer. Treatment of colon and colorectal cancer requires a complex decision-making process of treatment. These treatments may involve surgery and either pre- or post-operative radiation or chemotherapy, which can have a great impact on the quality of life of patients due to the rigorous requirements of treatment and the inconvenient side effects. This paper is the first developmental step of an agent-based simulation platform aiming at simulating colon and colorectal cancer patient care trajectories in a hospital. In this study, we describe a virtual patient agent, which includes a cancer evolution model, capable of replicating cancer behavior in response to treatment. Simulation results show promising interpolation results with respect to chemotherapy dosage and radiotherapy dosage. However, the model ability to interpolate different administration protocols is still limited, and therefore require calibration for each protocol.

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Keywords: Agent-based simulation; cancer evolution model; virtual patient.

1. Introduction and Motivation

Almost half Canadians (41 % women and 46 % men) will develop cancer during their lifetime and 88 % of them are older than fifty [1]. Lung, breast, colon, colorectal and prostate cancers represent more than half of all new cancer cases (52 %). Breast cancer is the leading type of cancer among women, while colon and colorectal cancer are the third most common

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cancer among men and women. Cancer is the leading cause of death in Canada and in the world [2] with 29.8 % of the population affected, compared to 26.6 % for cardiovascular diseases. Furthermore, in 2000, cancer was the fourth most expensive disease in Canada with $ 17.4 billions spent. Colon and Colorectal cancer are considered the second leading cause of cancer death among men and the third among women.

Cancer treatment is characterized by the convergence of many services including ambulatory, hospitals, clinical, nutritional, psychological, and sports medicine, which coordination and integration condition treatment success and patient quality of life. In order to reduce the impact of this disease and increase the cure rate and the patient quality of life, it is necessary to develop and evaluate new therapeutic and organizational approaches.

The general objective requires the modeling and simulation of complex behaviors, decision-making processes and interactions between hospital staff and patients, therefore to create and validate the patient agent model, which includes a physiological model of how the cancer evolves in time in response to specific treatments. This study deals with this goal and is the first methodological step toward creating a simulation platform of care trajectories of colon and colorectal cancer patients. This simulation platform aims at simulating many elements of the hospital environment, from care resources to patient physiology and psychology profiles, in order to evaluate the many impacts of organizational changes of care trajectories. Also, the simulation model will include: the physical health of the patient; the cognitive state of the patient; the psychosocial state of the patients; the hospital resources, staff and physicians. In other words, factors such as socio-demographic and environmental characteristics, as well as the characteristics of the organizational and decision-making systems, will be used to simulate patient care trajectories, from their diagnosis to the end of the treatment. This simulation environment will support the simultaneous optimization of resources utilization and care quality by assessing the performance of multiple patient care trajectories in a virtual hospital based on reengineered organizational and medical procedure of the Montreal General Jewish Hospital. In this study, agent-based simulation is used as the main modeling paradigm, because it allows the researcher to model the actors (e.g., patient, physician, nurse, and support staff) involved in the care trajectory and their interactions in a natural and anthropomorphic manner.

In order to achieve this specific objective, several challenges must be addressed. The first methodological challenge concerns the development of the cancer evolution model. Cancer evolution in time, and particularly during treatment, is an important part of this study. It is the central model of proposed the simulation environment, because (a) it has an impact on resource utilization and decision processes, and (b) it is impacted by all medical and organizational decisions and resource availability, as well as the patient condition, environment and support. Therefore, having a representative cancer model is essential to this project.

This paper focuses specifically on the first developmental step of this simulation model, which concerns the development of an agent-based model of colon and colorectal cancer patients. This includes a general conceptual model and a cancer evolution model under different kinds of treatment. The next section presents a state-of-the-art of simulation application to the medical domain.

2. State of art

Simulation is a proven methodological tool to study the intrinsic complexity of dynamic systems, which behavior emerges from the interactions of a multitude of elements. Artificial, biological, as well as psychosocial systems involved in healthcare-related issues are complex in nature. Most simulation technics have been used to study and analyze these systems, including Monte Carlo simulation, Discrete-Event Simulation, System Dynamics and Agent-Based Simulation. In general, computer simulations are used to better understand the impacts of specific decisions, policies, or systems configurations through the use of virtual computer emulation of real systems. Computer simulations can also be used in educational settings in order to develop specific skills, in which students control part of the computer variables through user interfaces. This section presents different simulation applications in the medical domain as a tool to improve care quality and services.

2.1. Simulation technics and applications in the medical domain

As briefly mentioned, several simulation technics have being used in the medical domain. Each technic has its pros and cons and are appropriate for specific contexts. First, Monte Carlo simulation uses, repeatedly, random sets of numbers from known probability distribution of different sources of uncertainty (i.e., the environment), in order to compute the results of a mathematical model or algorithm (i.e., the system's model), from which we can infer the general behavior or performance of that system. It is used in practice when the behavior of the system cannot be easily calculated analytically. Discrete-Event