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POPULATION DYNAMICS OF NORMAL AND CANCER CELLS UNDER RADIOTHERAPY

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RESEARCH HIGHLIGHTS

- The use of the improved cancer treatment model predicted the population changes in the normal and cancer cells during radiotherapy.
- The simulated radiation doses are 15 Gy, 18 Gy, 20 Gy and 24 Gy administered 5 times for each dose.
- The population of the cancer cells reduced from 40 % of the carrying capacity to 10.72%, 23.25 %, 1.61 % and 3.72 % of the carrying capacity for the respective doses.
- The population of the normal cells reduced from 70% of the carrying capacity to 65.50%, 62.48%, 68.49% and 67.59% of the carrying capacity for the respective doses.
- During the no treatment stage (0 Gy), the model predicted an increase in the population of cancer cells and a decrease in the population of normal cells.

Keywords: *Radiotherapy, Caputo-Fabrizio Fractional Derivative, Linear-Quadratic Model*

GRAPHICAL ABSTRACT

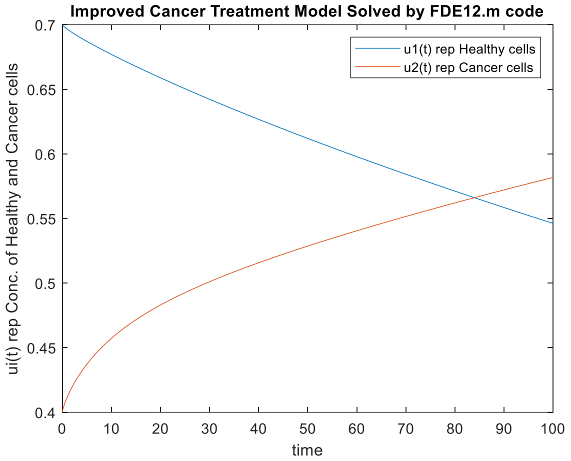

Figure 1a. Population changes in normal and cancer cells: No Treatment Stage

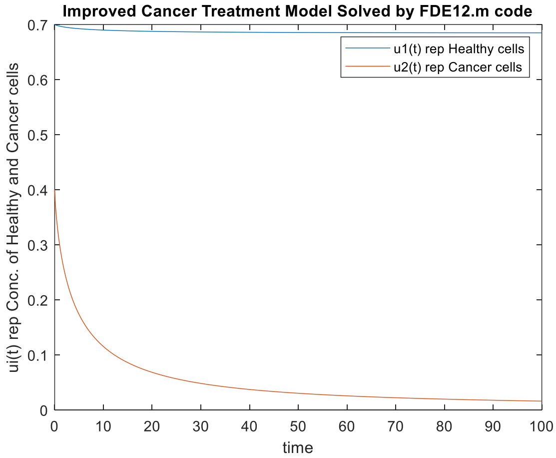

Figure 1b. Population changes in normal and cancer cells: Treatment Stage (20 Gy)

RESEARCH OBJECTIVES

This research is aimed at simulating the population dynamics of the normal and cancer cells in a tumor region of a cancer patient during radiotherapy. The treatment of cancer, using radiotherapy or any other treatment procedures, implies the reduction of the population of the cancer cells. However, the population of the normal cells is also affected during radiotherapy. These population changes, which constitute the cancer treatment process, is always monitored to check the health status of the patient. This treatment process will be simulated in this research by using an improved cancer treatment model.

Also, during radiotherapy, the strategy of radiation involves the administration of doses of irradiation over a period of time in a constant or fractionated pattern. As a result, these doses of irradiation decreases the populations of the normal and cancer cells. It is important to measure the populations of eliminated normal and cancer cells with respect to delivered doses during treatment. This research is also aimed at predicting the populations of the eliminated cells with four different radiation doses.

Finally, the knowledge of the population dynamics of cells of cancer patients gives an indication of the progress of treatment and side effects during radiotherapy.

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MATERIALS AND METHODS

The simulation of the normal and cancer cells' population changes was done with the improved cancer treatment model. The improved model couples the Caputo-Fabrizio fractional cancer treatment model (1) with the linear-quadratic model (2, 3). The parameters for the cells population dynamics include the proliferation rates, carrying capacities and competitive coefficients. The values for proliferation rates of the normal and cancer cells were obtained from previous literature (4). The values for carrying capacities were assumed to be 1 (100%). Therefore, the initial values for the cells' populations were chosen to be fractions of the carrying capacities. For the normal cells, 0.7 (70%) was chosen while for the cancer cells, 0.4 (40%) was chosen.

The values for competitive coefficients were obtained by using assumptions in previous literature (4, 5). The cells' population decay due to radiation was modeled with the coupled linear-quadratic model. The values for the radiation parameters were obtained from data collated during the treatment of some cancer patients with stereotactic radiotherapy (2). The computer simulation was done in MATLAB with the use of fractional differential code (FDE12.m) (6-10). The power of the fractional derivative was chosen to be 0.8.

RESULTS

The results of the computer simulation show that when there is no treatment (0 Gy), the population of the cancer cells increased from 40% to 58.18% and the population of the normal cells decreased from 70% to 54.62%. For the first treatment (15 Gy), the population of the cancer cells decreased from 40% to 10.72% while the population of the normal cells decreased from 70% to 65.50%. For the second treatment (18 Gy), the population of the cancer cells decreased from 40% to 23.25% while the population of the normal cells decreased from 70% to 62.48%.

For the third treatment (20 Gy), the population of the cancer cells decreased from 40% to 1.61% while the population of the normal cells decreased from 70% to 68.49%. Finally, for the fourth treatment (24 Gy), the population of the cancer cells decreased from 40% to 3.72% while the population of the normal cells decreased from 70% to 67.59%. The percentages are based on the respective carrying capacities. The assumed carrying capacities for the normal and cancer cells were 100% each.

FINDINGS

The simulated results showed that the best treatment was the third treatment. This treatment guaranteed destruction of more cancer cells and less normal cells. This implies better treatment with fewer side effects. The worst treatment was the second treatment. In this case, fewer cancer cells were destroyed and more normal cells were damaged. The no treatment stage implies a cancer win solution where the patient might end up dying. It follows that the improved cancer treatment model can be used to simulate an appropriate radiotherapy procedure for cancer patients.

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