Cureus

Open Access
Abstract

# A Parametric Study of Reoxygenation After Single-Fraction Stereotactic Radiosurgery by Cellular Automata Simulation

Daisuke Kawahara [1] , Lin Wu [2] , Yoichi Watanabe [3]

1. Physicist, Hiroshima University, Hiroshima, JPN 2. Radiation Oncology, University of Minnesota-Twin Cities, Minneapolis, USA 3. Radiation Oncology, University of Minnesota, Minneapolis, USA

**Corresponding author:** Daisuke Kawahara, daika99@hiroshima-u.ac.jp

**Categories:** Radiation Oncology, Other
**Keywords:** reoxygenation, stereotactic radiosurgery, cellular automata simulation

**How to cite this abstract**
Kawahara D, Wu L, Watanabe Y (January 01, 0001) A Parametric Study of Reoxygenation After Single-Fraction Stereotactic Radiosurgery by Cellular Automata Simulation. Cureus -2007(1): a555

## Abstract

Objectives: To study the effects of biologic parameters on the reoxygenation occurring after stereotactic radiosurgery (SRS) by an improved cellular automata (CA) model.

Methods: A CA simulation model was created to simulate the tumor growth and the radiation response by including blood vessels, which supplied oxygen and nutrient required for cell growth. Cancer cells died by the radiation-induced mitotic death process, which was quantified by the LQ-model. The radiation caused increased oxygen permeation through the blood vessel or the breakdown of the vasculature resulting in a decrease of oxygen and nutrient. Consequently, these changes affected tumor growth after irradiation. Cells were classified into five types: proliferating cancer cells, arrested cells, which were dying cancer cells due to the lack of nutrient, doomed cancer cells, which were dying cancer cells due to the direct radiation death process, dead cancer cells, and normal healthy cells. In this study, we selected three time-related constants among many parameters used in the current CA model. Those were the tumor volume doubling time (Tcd), the meantime of a doomed cell transiting to a dead cell (Tdd), and the meantime of a dead cell to disappear (Tclear). The sensitivity of the reoxygenation to the biologic parameters was evaluated by varying the values in specific ranges as follows: Tcd (0.1-10 days), Tdd (0.1-20 days), and Tclear (0.1-20 days). All simulations were done for a single uniform dose of 20 Gy delivered on the 100-th day after the start of simulation. The default model parameters were determined by matching the simulation results with experimental data of the mice tumor volume for various doses. The a/ß value of the LQ model was set to 5.

Results: The model parameters, which reproduced the experimental curves of the mice tumor volume, were 0.6 days, 5 days, and 6 days for the Tcd, Tdd, and Tclear., respectively. The simulation showed that the number of proliferating cancer cells after SRS was larger for shorter Tcd, Tdd, and Tclear because more opportunities for cancer cells to grow in terms of space as dead cells disappeared and were replaced by healthy cells faster. The number of hypoxic cancer cells, which were cells with below 2% oxygen level of the standard atmospheric pressure, increased immediately after irradiation due to the radiation-induced death of blood vessels. For several days after the radiation, more hypoxic cells turned to oxic for longer Tcd and Tclear by reoxygenation. This observation can be explained as follows. When dead cells were cleared more rapidly, cancer cells grow faster. Hence, there was no opportunity for reoxygenation to occur. Moreover, the number of dead cells was smaller for the smaller Tcd, which decreased the chance for reoxygenation. Additionally, we noted that the shorter Tdd resulted in faster

**Open Access**
**Abstract**
**Published 01/01/0001**

increase of the dead cells after irradiation, resulting in the reoxygenation occurring with a shorter delay after irradiation than a longer Tdd.

Conclusions: The current study showed that the tumor proliferation rate, the meantime of doomed cancer cells to dead cells, and the mean clearance time of dead cells strongly influenced post-SRS tumor volume and reoxygenation. For example, the tumor volume after SRS increased with decreasing Tcd, Tdd, and Tclear. The reoxygenation after a single fraction SRS was more pronounced for longer Tcd and Tclear. The reoxygenation occurred sooner after irradiation for a shorter Tdd.