Radiobiological effects of the interruption time in radiation therapy with photon beams based on the microdosimetric kinetic model

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Abstract

Background: We investigated the effect of the interruption time on the radiobiological effectiveness with photon beams based on a modified microdosimetric kinetic model.

Background: The interruption time is used is that irradiation interruption occurs at sites and operations such as the gantry, collimator, couch rotation, and patient set-up in radiotherapy. However, the effect of interruption time on photon beams for tumor cells is little evaluated.

Methods: The dose-mean lineal energy y_D (keV/ μm) of 6 MV photon beams was calculated by the particle and heavy ion transport system (PHITS). We set the absorbed dose to 2 or 8 Gy, and the interruption time (τ) was set to 1, 3, 5, or 10 min. The biological parameters values were acquired from a human non-small cell lung cancer cell line (NCI-H460) for the mMK model. We used two-field and four-field irradiation with a constant dose rate (3 Gy/min); the photon beams were paused for interruption time τ . We calculated the relative biological effectiveness (RBE) to evaluate the interruption time's effect compared with photon beams that were not interrupted as a reference.

Results: The RBE with four-field irradiation for 8 Gy was decreased to 0.997, 0.992, 0.987, and 0.975 for $\tau = 1, 3, 5$, and 10 min, respectively. The decrease in the RBE was within 3% compared with the non-interrupted photon beams.

Conclusions: The effect of RBE was decreased by increasing the interruption time, indicating that an escalation of the prescribed dose might be necessary when the interruption time was large.

Full-text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed.

However, the manuscript can be downloaded and accessed as a PDF.

Figures

Figure 1

Diagram of the mMK model, taking into consideration the interruption time of photon beams.

Figure 2

Irradiation geometry for the Monte Carlo calculations with 6 MV photon beams. The radius of the domain was set to $0.5 \text{ }\mu\text{m}$ in the 3-cm-wide measurement region with the water-equivalent phantom.

Figure 3

The microdosimetric energy distributions y_D as a function of y - $y_d(y)$ for 6 MV photon beams at a depth of 10 cm in a water-equivalent phantom (a). The relationship between the depth (which was 3 cm from the measurement point in the water equivalent phantom) and the dose-mean lineal energy y_D for the 6 MV photon beams (b).

(a)

(b)

Fig. 4.

Figure 4

The effect of the interruption time on the SF for 6 MV photon beams with two-field (a) and four-field (b) irradiation for the various interruption times.

Figure 5

The effect of the interruption time on the RBE with two-field (a) and four-field (b) irradiation for the various interruption times.

Figure 6

The effect of prolonging the interruption time (1 to 60 min) on the RBE when two-field irradiation was used.

Fig. 7.

Figure 7

The effect of RBE as a function of the cell-specific repair rate ($a + c$) with $\tau = 1$ min (a) and $\tau = 10$ min (b) using two-field irradiation.