Contact lens-type ocular in vivo dosimeter for radiotherapy

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Background A cataract is the most common cause of vision loss and the leading cause of blindness worldwide. It can occur as a result of aging, trauma, eye surgery owing to other problems, and exposure to radiation. In terms of radiotherapy, radiation-induced cataract is 5% within/after 5 yr (TD5/5) for conventional prescription of 10 Gy. However, the tissue effect for the lens changed from the deterministic effect to the stochastic effect. In this respect, with a better understanding of the individual variation in response to radiation, the tolerance of normal tissues can be determined. To do this, the delivered dose to the lens should be accurately calculated or measured. However, current systems have limitations. First of all, the inaccurate calculation was caused by the charged particle equilibrium at lens located in a superficial region of the body. Second, the contoured lens volume was very small. Lastly, conventional in-vivo dosimetry tools were impossible to directly measure dose. Therefore, to overcome these matters, this study aimed to (a) develop a contact lens-type ocular in vivo dosimeter (CLOD) that can be worn directly on the eye and (b) assess its dosimetric characteristics and biological stability for radiation therapy.

Methods: The molder of a soft contact lens was directly used to create the dosimeter, which included a radiation-sensitive component — an active layer similar to a radiochromic film — to measure the delivered dose. A flatbed scanner with a reflection mode was used to measure the change in optical density due to irradiation. The sensitivity, energy, dose rate, and angular dependence were tested, and the uncertainty in determining the dose was calculated using error propagation analysis. Sequential biological stability tests, specifically, cytotoxicity and ocular irritation tests, were conducted to ensure the safe application of the CLOD to patients.

Results: The dosimeter demonstrated high sensitivity in the low dose region, and the sensitivity linearly decreased with the dose. The responses obtained for the 10 and 15 MV photon beams were 1.7% and 1.9% higher compared to the 6 MV photon beam. A strong dose rate dependence was not obtained for the CLOD. Angular dependence was observed from 90° to 180° with a difference in response from 1% to 2%. The total uncertainty in error propagation analysis decreased as a function of the dose in the red channel. For a dose range of 0 to 50 cGy, the total uncertainties for 5, 10, and 50 cGy were 14.2%, 8.9%, and 5%, respectively. Quantitative evaluation using the MTT (3-(4, 5- dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide) method presented no cytotoxicity. Further, no corneal opacity, iris reaction, or conjunctival inflammation was observed.

Conclusions: The CLOD is the first dosimeter that can be worn close to the eye. The results of cytotoxicity and irritation tests indicate that it is a stable medical device. The evaluation of dose characteristics in open field conditions shows that the CLOD can be applied to an in vivo dosimeter in radiotherapy.

Reference

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