Design of a Module-Type Radioactive Applicator Using Monte-Carlo Simulation for Skin Cancer

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Purpose: This study aims to design a module-type radioactive applicator for patient specific brachytherapy.

Methods: Dose distributions were evaluated by a Monte Carlo method to optimize the structure and materials of a module type sealed source applicator. Monte Carlo simulations were performed using MCNP6. Both cylindrical and hexagonal geometries were considered as basic design of applicator. P-32, V-48, and Sr/Y-90 isotope were selected as pure beta source. The inner part of the applicator consists of 3 layers, source, acrylate plate for beta shielding and aluminum plate for x-ray shielding. The inner components were encapsulated by stainless steel with various wall thicknesses (0.5, 1, 2 mm). Six applicators were configured to evaluate the effect of gap in each applicator. The dose distribution and uniformity for each applicator design were calculated in a flat water phantom that was placed at a depth of 2.5 mm. the dose uniformity was defined as a ratio of area bounded by 90% isodose curve to that by over the 90% dose. To achieve statistical accuracy (error $< 2\%$) in the dose profile, 10^9 histories of the transported particles were considered.

Results: The minimum percent doses caused by the gaps between the neighboring applicators for the hexagonal model with 0.5 mm wall thickness were 96.7% (P-32), 85.8% (V-48), and 93.9% (Sr/Y-90). For the cylindrical model, the minimum percent doses were 69.3% (P-32), 57.3% (V-48), and 68.1% (Sr/Y-90). The dose uniformity for hexagonal model (P-32) with various wall thickness was 0.854 (0.5 mm), 0.613 (1 mm) and 0.473 (2 mm), respectively. For the cylindrical model, the dose uniformity was 0.379 (0.5 mm), 0.304 (1 mm) and 0.240 (2 mm), respectively. In all cases, the hexagonal models showed a better dose distribution. Furthermore, as the thickness of encapsulation decreased, the dose uniformity increased because of decreased gaps between neighboring applicators.

Conclusions: In terms of dose uniformity, a hexagonal geometry with thin wall thicksness turned out to be superior to cylindrical geometry.