

Brachytherapy: Applications and Importance

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Abstract

Background: This review aims to highlight the importance of brachytherapy in medical physics, specifically, cancer treatment and dosimetry. This type of therapy uses radionuclide irradiation in or in contact with the tumor surface. Based on the target organ, various applicators can be used.

Materials and methods: Both clinical and Monte Carlo methods are able to obtain the organ and the neighboring tissues' dose rates.

Results: The findings reveal that the Monte Carlo method can only predict the dose range and ranges of dose in organs at risk, and does not give us precise results.

Conclusion: In summary, after evaluation of doses in the Monte Carlo method, we should validate them with clinical results.

1. Overview

Recently, the eye and skin have become common organs to be at risk of tumor malignancies. Hence, brachytherapy is suitable equipment due to its targeting the tumor and minimizing the probability of normal tissue complications. Beta emitters such as ⁹⁰Y and ¹⁰⁶Rh-¹⁰⁶Ru are the best choices [1,2]. The sharp dose falloffs of electron particles, beta emitters, and a short range of electrons in comparison with photons. Diverse radionuclides, each paired with distinctive applicators, offer a viable option for selectively targeting specific tumors. The selection of the radiation source depends on the dimensions and depth of the tumor, thereby influencing the most suitable utilization.

¹⁹²Iridium brachytherapy using a Leipzig applicator is a highly precise form of contact radiotherapy specifically designed for treating small, superficial skin lesions. This technique involves placing the flat surface of the Leipzig applicator directly onto the target area, such as a skin cancer on the nose or eyelid. The applicator itself is a shielded device that collimates the gamma radiation emitted from a High-Dose-Rate (HDR) ¹⁹²Ir source housed within an afterloader machine. This shielding is crucial, as it focuses the radiation beam onto a well-defined field while protecting the surrounding healthy tissue and

deeper organs. The treatment is typically delivered in a few brief outpatient sessions, offering a high chance of cure with excellent cosmetic results by minimizing damage to adjacent skin. This makes the Leipzig applicator an ideal tool for delivering a concentrated, localized, and effective dose to superficial tumors where surgical excision may be difficult or undesirable [3-7].

2. Materials and Methods

In brachytherapy, Monte Carlo codes like MCNPX, FLUKA, and PHITS can simulate radionuclides, phantoms, and applicator geometry. For instance, in ocular melanoma treatment, a disk source is used. Radionuclides such as ⁹⁰Y and ¹⁰⁶Ru/¹⁰⁶Rh are suitable due to their sharp dose falloff. Figure 1 shows such an applicator, developed by Liberty Vision (LV) of NH, USA [5-7]. The ¹⁹²Ir Leipzig applicator is suitable for superficial skin treatments. Figure 2 illustrates the applicator and the involved tissue types (skin, adipose, and bone) [4].



Figure 1 A commercially available disk source.

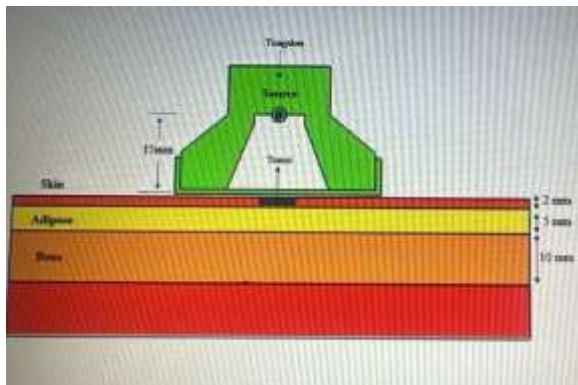


Figure 2. ^{192}Ir Leipzig setup utilizing MCNPX monte carlo code.

3. Results and discussion

The analysis indicates that the overall behavior of the dose distribution is consistent between clinical measurements and Monte Carlo simulations. This suggests that the Monte Carlo model successfully captures the fundamental physics of the radiation transport, including the general pattern of dose fall-off and penetration. However, despite this qualitative agreement, a significant quantitative discrepancy exists in the absolute dose values. Due to these differences, the Monte Carlo simulations in their current form cannot be relied upon to provide numerically accurate dosimetric results that match the real-world clinical data. This indicates a need for further refinement of the simulation parameters to improve its quantitative accuracy.

4. Conclusion

In conclusion, both the Leipzig applicator for skin cancer and the disk source for ocular melanoma exemplify the core principle of brachytherapy: delivering a highly conformal radiation dose to a targeted lesion while minimizing exposure to surrounding healthy tissues. The Leipzig applicator achieves this through its specialized design, which optimizes surface dose and penumbra for superficial

skin diseases, making it a valuable tool for treating complex contours on the skin. Similarly, the customized disk source used in ocular brachytherapy, often loaded with beta-emitting isotopes like $^{106}\text{Ru}/^{106}\text{Rh}$, is engineered to fit the orbital anatomy, ensuring precise dose delivery to the tumor while critically sparing sensitive structures like the lens and optic nerve. The efficacy of both techniques is profoundly dependent on accurate applicator positioning and sophisticated treatment planning. Looking forward, the role of advanced Monte Carlo simulations is poised to become increasingly critical in refining these treatments. While current studies show that simulations can reliably replicate the behavior of dose distributions from applicators like the Leipzig and ocular disks, there remains a need to enhance their absolute numerical accuracy. Further development and validation of these computational models will enable even more precise pre-treatment planning and dose verification, ultimately pushing the boundaries of treatment personalization. Therefore, the continued synergy between innovative applicator design and high-fidelity dosimetric calculations promises to further improve local control rates and patient quality of life for those battling skin and ocular cancers.

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5. References

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