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Advanced Radiation Treatment against Brain Cancer

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Introduction

Boron Neutron Capture Therapy is an advanced radiation treatment that shows promise in the fight against brain cancer. BNCT utilizes the interaction between thermal neutrons and boron-10 atoms, selectively targeting cancer cells while sparing surrounding healthy tissue. Accurate dosimetry, the measurement and calculation of absorbed radiation doses, is crucial for optimizing BNCT efficacy and minimizing adverse effects. Recent advancements in BNCT dosimetry, involving the NUR nuclear research reactor and a modified Medical Internal Radiation Dose phantom incorporating the eye lens, are revolutionizing the way we approach brain cancer treatment. This review explores the innovative techniques and their implications for the future of BNCT in brain cancer therapy. Which is preferentially taken up by cancer cells and thermal neutrons, which trigger the boron-10 capture reaction, releasing high-energy alpha particles and lithium nuclei that selectively damage cancerous cells. One of the challenges in BNCT lies in ensuring an optimal dose to the tumor while minimizing damage to adjacent healthy tissues, especially critical organs like the eye lens, which is highly sensitive to radiation. The NUR nuclear research reactor, located at the National Centre for Nuclear Research in Poland, has significantly contributed to BNCT dosimetry. Its high neutron flux allows for efficient irradiation, increasing the precision and efficacy of BNCT.

Description

The reactor's controlled environment enables researchers to study neutron interactions and optimize BNCT protocols, ensuring the delivery of therapeutic doses to brain tumors. Traditional MIRD phantoms are anthropomorphic models used for internal radiation dosimetry calculations. To enhance the accuracy of BNCT dosimetry, researchers have developed a modified MIRD phantom that incorporates the eye lens. This innovation is crucial for brain cancer patients, as radiation exposure to the eye lens can lead to cataracts, affecting the patient's quality of life post-treatment. By accounting for the eye lens in dosimetry calculations, BNCT procedures can be refined to minimize radiation exposure to this sensitive organ. Monte Carlo Simulations: Monte Carlo simulations, sophisticated mathematical models that replicate particle interactions, have become invaluable in BNCT dosimetry. These simulations enable researchers to predict radiation doses with high accuracy, considering factors such as tissue composition, neutron energy spectra, and boron-10 distribution within tumors. Accurate quantification of boron-10 concentrations within tumors is vital for BNCT dosimetry [1].

Advanced imaging techniques, such as Positron Emission Tomography and Single Photon Emission Computed Tomography coupled with boron-10 radiopharmaceuticals, allow researchers to precisely map boron-10 distribution, optimizing treatment planning. Real-time in vivo dosimetry techniques have been developed to monitor the actual radiation doses received by patients during BNCT. These methods, including thermoluminescent dosimeters and ionization chambers, provide immediate feedback, enabling clinicians to adjust treatment parameters for individual patients, ensuring safe and effective therapy. Accurate dosimetry allows for the development of personalized treatment plans tailored to each patient's unique tumor characteristics and physiological factors. This individualized approach maximizes the therapeutic effect while minimizing damage to surrounding healthy tissues. Precise dosimetry ensures that radiation exposure to critical organs like the eye lens is minimized, reducing the risk of cataract formation and other radiation-related side effects. Patients experience improved post-treatment quality of life, enhancing overall treatment outcomes. By optimizing the radiation dose delivered to tumors, BNCT becomes more effective in eradicating cancer cells [2].

This enhanced efficacy is particularly significant in recurrent or aggressive brain cancers, where BNCT can offer a viable treatment option. The integration of BNCT with cutting-edge dosimetry techniques opens avenues for research into novel radiopharmaceuticals, boron carriers and neutron sources. These explorations may lead to the development of more potent and targeted BNCT therapies, expanding its applicability to various cancer types. Collaborative efforts between institutions, facilitated by advancements in dosimetry, enable the global dissemination of BNCT expertise. Knowledge sharing and standardized dosimetry protocols ensure that BNCT becomes more accessible to patients worldwide, particularly in regions where advanced cancer treatment options are limited. The recent advancements in BNCT dosimetry, driven by innovations in neutron sources like the NUR nuclear research reactor and the incorporation of the eye lens into modified MIRD phantoms, mark a significant milestone in the fight against brain cancer. These developments enhance the precision, safety, and efficacy of BNCT, positioning it as a promising therapeutic approach for brain cancer patients [3].

As research continues to evolve, the synergy between advanced dosimetry techniques and BNCT technologies holds the potential to transform cancer treatment paradigms. With personalized treatment plans, reduced side effects, enhanced efficacy, and global accessibility, BNCT stands poised to make a profound impact on the lives of patients, offering hope and a path towards a future where brain cancer is no longer an insurmountable challenge. Through ongoing collaboration, research, and technological innovation, the potential of BNCT in the realm of oncology is boundless, ushering in a new era of cancer care and patient outcomes. Boron Neutron Capture Therapy is an innovative radiation therapy modality with the potential to treat various types of cancer, particularly brain tumors, by selectively delivering a highly localized dose of radiation to cancer cells while sparing surrounding healthy tissue. This therapeutic approach relies on the nuclear capture of thermal neutrons by stable. The success of BNCT hinges on precise dosimetry, which ensures that the intended radiation dose is administered to the tumor while minimizing damage to adjacent healthy brain tissue. In this review, we explore the role of BNCT dosimetry for brain cancer treatment, focusing on its implementation with the Nuclear Research Reactor NUR and the modification of the Medical Internal Radiation Dose phantom to incorporate the eye lens, a crucial structure often implicated in brain cancer therapy [4].

BNCT relies on the unique properties of boron-10, which has a high thermal neutron capture cross-section. When boron-10 atoms are selectively delivered to tumor cells, such as through the administration of boron-containing compounds, and irradiated with thermal neutrons. This reaction releases high-energy alpha particles and lithium-7 nuclei, which have a very short range in tissue, typically less than the diameter of a single cell. By concentrating

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boron-10 within tumor cells and delivering thermal neutrons, BNCT exploits the preferential destruction of cancerous tissue while sparing healthy cells. BNCT dosimetry is a complex and multidimensional task that requires the precise quantification of radiation dose distributions within the tumor and surrounding tissues. The concentration of boron-10 in tumor tissue is a critical parameter. It determines the number of thermal neutron captures and, consequently, the production of high-energy particles within the tumor. The energy spectrum and intensity of the neutron beam used in BNCT affect the depth of penetration and distribution of thermal neutrons within the tumor and surrounding regions [5].

The elemental composition and density of the tissues involved influence the energy deposition of alpha particles, lithium nuclei, and gamma radiation. Heterogeneities in tissue composition can complicate dose calculations. The spatial distribution of boron-10 within the tumor, as well as the tumor's geometry and size, play a crucial role in BNCT dosimetry. Accurate characterization of the radiation field produced by including the range and energy of alpha particles and lithium nuclei. The biological effectiveness of alpha particles and gamma radiation must be considered when determining the therapeutic dose. Alpha particles are highly effective at inducing cell death due to their high linear energy transfer. Nuclear reactors, such as the Nuclear Research Reactor NUR, are often used as neutron sources for BNCT due to their capacity to produce a high flux of thermal neutrons.

Conclusion

These reactors generate a controlled and stable neutron beam that can be directed toward the patient's tumor site. The neutron beam's characteristics, including its energy spectrum and intensity, are critical for accurate BNCT dosimetry. The NUR reactor, like other BNCT research reactors, plays a pivotal role in optimizing BNCT dosimetry by providing the necessary neutron irradiation conditions. Researchers can characterize the neutron beam, assess its interactions with different materials, and develop treatment protocols to achieve the desired therapeutic effect while minimizing radiation exposure to healthy tissues. When it comes to brain cancer treatment with BNCT, the eye lens is a crucial structure to consider. Brain tumors can be located in close proximity to the eye, and the eye lens is highly sensitive to radiation. Therefore, precise dosimetry of the eye lens is essential to prevent radiation-induced cataracts and other ocular complications. Developing effective radiation shielding strategies to protect the eye lens while still delivering a therapeutic dose to the tumor is a delicate balance. Each patient's anatomy and tumor location are unique, necessitating personalized dosimetry calculations. The development of modified dosimetric phantoms that accurately represent the eye lens and surrounding structures is crucial for BNCT planning.

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Conflict of Interest

None.

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