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Helium and Oxygen beam models in TRiP98: implementation, treatment planning tests and experimental verification

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Since some of the most modern ion therapy facilities are offering or considering the irradiation with alternative ion beams, beyond proton and carbon, it has raised new attention the need for a proper description of these beams, in order to exploit their use for specific applications. In particular, helium and oxygen beams are presently available in the research cave of the Heidelberg Ion therapy facility (HIT).
We developed and integrated in TRiP98, our research treatment planning system, specific beam models for these ions, which have been validated experimentally on different levels.
For the Helium beam a semiempirical model for dose deposition and fragmentation was implemented, by modification of algorithms conventionally used in space radiation transport studies, translated to the typical therapeutic range of energies [1].
For Oxygen beam, the standard transport model of TRiP98 was tuned on recent attenuation experiments and the fragmentation cascade has been improved using the latest beam models of the low-lying ions.
Several treatment planning tests have been performed, showing no universal indications but rather selective advantages of the different beams, and revealing for example a considerable convenience of using Helium beams in specific configurations [2], or proposing combination of different ions [3].
Experimental verification has been performed for both ion beams at the experimental room of HIT, analyzing different endpoints: basics physics data, delivered 3D physical dose distribution and biological effect. Monoenergetic and extended target irradiations of different extensions with single and double opposed fields have been verified. In the case of oxygen beams, considering that its main importance is related to a possible indication for partially hypoxic tumors, the biological verification was extended beyond the RBE weighted dose effect, but also including the OER effect. As previously obtained with carbon ions [4], the kill-painting method, allowing to restore an homogeneous survival level on a differently oxygenated target, was verified with oxygen beams. It is found that with the latter ion beams, for a partially hypoxic target an inversion of the relative profile occurs, as compared to a normoxic case, with a slightly reduced normal tissue damage for same cell killing in the target than with the carbon irradiation.

Keywords: Particle Therapy, Adaptive Treatment Planning, Helium beams, Oxygen beams, Hypoxia

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Medical isotope production at TRIUMF and future collaboration with MEDICIS-PROMED

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The demand for personalized medicine is increasing, and considering that the population suffering from chronic diseases (i.e. cancer, Alzeihmer) is continuously growing it is expected that the consumption of molecular diagnostic products and radiotherapeutics will continue to increase. In this scenario, TRIUMF and its fleet of proton accelerators ranging from 13 to 500 MeV is offering a unique environment for scientists to enable the production of isotopes with potential applications in molecular imaging or radiotherapy. A multidisciplinary program involving target design, isotope production and radiopharmaceutical chemistry has emerged in the Division of Life Sciences to facilitate and accelerate the translation from bench-to-bedside.
A brief overview of the recent efforts related to the production and applications of medical isotopes at TRIUMF will be presented. Comprehensive studies have been conducted to improve the production of conventional PET isotopes by a better understanding of the physical phenomenon occurring inside the target during beam irradiation. Feasibility of the production, from liquid targets, of radiometals (i.e. ^{44}Sc, ^{68}Ga, ^{86}Y and ^{89}Zr) used in medical imaging has also been demonstrated. The results of the ITAP project, led by TRIUMF and including a consortium of institutions, on accelerator-based production of ^{99m}Tc will be discussed. It has been shown that a reliable commercial scale (TBq) production of ^{99m}Tc is achievable by using ^{100}Mo coated tantalum targets at energies up to 24 MeV. Investigations on the production and isolation of the therapeutic isotope ^{211}At and its imaging companion ^{209}At will be mentioned.
Novel radiolabeling strategies and technologies have recently emerged to prepare radiopharmaceuticals and will be discussed. Isotopic exchange reactions are getting popular to rapidly and efficiently synthesize PET imaging probes. Click chemistry is also representing an attractive approach to radiolabel molecules because of its simple process, short reaction times and clean product synthesis. Microfluidic devices bear great promises in the field of radiochemistry as it is expected that they will allow faster reaction rate, exquisite reaction selectivity, reduced reagent consumption, and possibly revisit the hot-lab concept. An overview of the tracer development performed at TRIUMF (e.g. cysteine transporter, angiogenesis) will be presented.
Finally, within the framework of the MEDICIS-PROMED consortium, a collaboration between TRIUMF and the Institute of Translational Molecular Imaging (ITMI) at the University Hospital of Geneva and the Laboratory of Bioorganic Chemistry and Molecular Imaging at EPFL will soon take place. This presentation will conclude with a short summary of our ambitious project on the development of dual modality molecular probes for ovarian cancer and their preclinical validations in animal models.

Keywords: medical isotope, radiochemistry, radiopharmaceuticals

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Size dependence of GNPs dose enhancement effects in cancer treatment – Geant4 and MCNP code

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Purpose: The main purpose of the present work is to evaluate the effects of gold nanoparticles (GNPs) in different sizes and concentrations on cancer cells which undergo treatment with photon therapy.

Material and Method: This work was carried out with MCNP and Geant4 codes. The 10x10x10 cm3 cubic water phantom and a tumor region with a size of 1x1x1 cm3 were simulated. Factors such as different concentrations and GNP sizes were implemented into the simulation, so as to obtain the optimum results, specifying the maximum absorbed dose within the tumor while sparing healthy tissue. In a certain concentration, different sizes of GNPs including 30, 50, 70 and 100 nm were defined within the tumor and the absorbed dose by the GNPs-loaded tumor were calculated for different sizes. Similarly, the absorbed dose was calculated for different concentrations of 7, 10, 18 and 30 (mg Au/ gram of tumor) in a certain size of GNPs. The dose enhancement factor which is defined as the ratio of the absorbed dose by the tumor in the presence of nanoparticles to the absorbed dose by the same organ in the absence of nanoparticles was estimated for different concentrations and sizes of GNPs.
Results and Conclusion: The calculations show results for different sizes and concentrations and a comparison is made between the two Monte Carlo codes (MCNP and Geant4). In a certain diameter of GNPs the higher concentration made more increase in absorbed does by the tumor. In a certain concentration, higher size of GNPs made higher absorbed dose by the tumor. Given the fact that therapeutic applications of GNPs in acquiring the proper DEF have demanded much attention in recent years, defining the proper size and concentration would be considered extremely vital for pre-treatment plans.

Keywords: Geant4, Size and Dimension, GNPs, Radiotherapy

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Therapeutical Dose to Thyroid Remnants Determination for Low-risk Thyroid Carcinoma Patient Treated with rhTSH and 1.1 GBq 131I

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Purpose: Aim of this study was to investigate, practically prove contribution, and verify dosimetry possibilities for low-risk patients (rhTSH stimulation and 1.1 GBq 131I administration) undergoing first Radioiodine therapy (RAIT). Furthermore, it was intended to verify whether the administered activity deliver sufficient dose to thyroid remnants so it can be called "thyreo-ablative".
Materials and methods: Siemens Symbia S gamma camera was used for quantitative imaging of 131I accumulation in remnants of patients thyroid and 131I accumulating nods. Vials with known activity of 131I were used to calibrate the system. Verification of activity determination was done by measuring the vial together with patient for comparison, if necessary. All of the patient-volunteers were around 3 months after thyreoablation due to thyroid carcinoma. As a low-risk indicated patients, they were prepared by injections of rhTSH during two days before therapy. Weight of the accumulating remnants or nods was established using ultrasound, if visible or roughly estimated using phantom measurements causing serious uncertainties.
17 patients (15 women, 2 men) participating the study undergone up to 6 quantitative imaging by the gamma camera during 70 hours after administration. Minimum of the gamma camera examination was 4. General time schedule of examination was 5, 24, 30, 48, 70 hours after administration.

Results: Absorbed doses within remnants or nodes vary from tens of Gy up to several hundred Gy with uncertainty from 25% up to 100% depending mainly on mass of the remnants estimation. For 5 of the patient the administered therapeutic activity caused absorbed dose which was considered to be rather insufficient in terms of thyreo-elimination (at least for one of accumulating remnants). For 4 patients the absorbed dose was considered to be particularly thyreo-eliminative. Measurements for 5 patients confirmed thyreo-eliminative dose and in case of 3 patients no accumulation was detected. Consequent follow-up for all patients is being done.
Conclusions: Though in nearly 30% of all patients absorbed dose did not reach 300 Gy in thyroid remnants and 80 Gy in nods, due to low-risk staging it is probable that the treatment was successful. However, it is necessary to do consequent follow up and include all data for annual treatment evaluation. Based on the results appropriate grant for further investigation will be seek out.

Keywords: dosimetry, iodine therapy, 1.1 GBq

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Augmented reality supporting innovation and accuracy in advanced radiation therapy facilities

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Purpose: Particle therapy cancer treatments require a work flow that involve several professional figures, working with a complex hardware and software set up. Each professional role needs access to a considerable set of information in the everyday clinical practice. In particular quality assurance protocols demand checking a sensible amount of data.
The drawback is that often required information are physically accessible outside the treatment room, being distributed on several computer in different places.
Integrate and display needed information in an organic and easily accessible way can speed up the clinical practice, reducing potential time loss and providing a better continuous quality control.
Methods: We propose an innovative tool based on Augmented Reality (AR). In AR a view of the physical world is augmented with computer generated elements. Our AR tool could be installed on a modern mobile device, a tablet or a cellphone. Users gets information in real-time about any equipment in the *treatment room* simply pointing the device at it.
The AR client recognizes medical equipment using the device camera, then gathers corresponding information from a cloud server, where all data stored.
The access to the data server is secured with different level of privileges: a user can visualize and use only predetermined kind of relevant information, according to his role. Moreover, all information related to the patient and the medical environment are hosted in a private cloud, not accessible without proper authentication.
Results: We present a prototype of AR application for particle therapy centre that improves and speeds up the whole work flow, making the access to information easier and more centralized.
Here we present a three different use cases that illustrate the use of our AR application: medical doctor, medical physicists and technical engineer.
Conclusion: Augmented Reality is the perfect candidate to help healthcare organizations make their existing processes more precise and efficient. Using AR tools, useful information can be provided and related in real-time to the specific need of the different systematic tasks that are daily checked accurately in an advance radiation therapy facility.

Keywords: e-heathcare, augmented reality, particle therapy

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Manufacturing and Nuclear Medicine Applications of the Novel Isotope Sn-117m

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Sn-117m has unique characteristics that make it ideal for a variety of nuclear medicine applications. The $t_{1/2}$=14d isotope emits a primary 159 keV imaging photon (86%) that is easily detectable with any SPECT camera system. The accompanying mono-energetic conversion electrons (~140 keV; 110%) have a therapeutic effect limited to a range of ~300 µm which also minimizes any shipping and handling issues. Together these characteristics make this theranostic