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P01

Abstarct

Nowadays, in order to improve the radiation therapy accuracy, there are many attempts to use online magnetic resonance imaging (MRI). On the other hand, carbon-ion (C-ion) radiation therapy is developing rapidly. The idea of applying MRI guidance in C-ion therapy involves challenges that dose distortion in the patient is one of the challenges ahead. For this purpose, this research was conducted in 3 steps. In the first step, the impact of the magnetic field inside a homogeneous water phantom on the total dose, dose equivalent and fluence profiles of C-ion beams in therapeutic energies were calculated. Moreover, the impact of the presence of tissue heterogeneities and geometric changes of heterogeneity layers on the magnitude of dose disturbances and deviation of C-ion beams were investigated. In the next step, the impact of anatomical changes on the radiation dose variation of the prostate and bladder was calculated for a potential scenario of MR-guided C-ion radiotherapy of prostate cancer (MRgCT). In the last step, to evaluate the water equivalency of possible materials used in C-ion dosimetry in both scenarios of presence and absence of the magnetic field, water equivalent ratio (WER) index was calculated. To achieve these goals, water equivalent beamline of the Heidelberg hospital, Germany, where its technical data was available, was simulated using the FLUKA Monte Carlo code. The impact of 0.5, 1.5 and 3 Tesla (T) perpendicular magnetic fields applied to a homogeneous water phantom on total dose, dose equivalent, and fluence profiles of C-ion beams at therapeutic energies of 100, 220 and 310 MeV/nucleon (MeV/n), were obtained. To investigate the effect of inhomogeneity and geometric changes of tissue layers, a multi-layer tissue phantom was simulated and the effect of a 1.5 T magnetic field, at 220 MeV/n energy, was assessed. To evaluate the impact of anatomical changes on dose variation, carbon beams with 250 MeV/n energy perpendicular to a pelvic phantom including the prostate, bladder, and rectum were simulated under the influence of a 1.5 T transverse magnetic field. Besides that, water equivalent ratio values of bladder, brain, prostate, muscle, bone, PMMA, POM, PET, Ti, Au, and Pt were evaluated in the presence and absence of a 3 T magnetic field. The results of this study showed that the total dose, dose equivalent, and fluence transverse profiles centers, in the range of the studied field strength and energy, are ranging from 0 to 10.5 mm. The maximum longitudinal displacement of the Bragg depth influenced by a 3 T field was equal to 0.8 mm reduction. The presence of heterogeneity, in particular air, leads to a magnitude of 30 % change in the central axis dose. The results of the effect of anatomical changes on dose variation showed that changing the bladder diameter from 10 to 5 cm reduces the bladder dose by 92 %. Changing the diameter of the rectum from 5 to 3 cm leads to a 20 and 26 % reduction in prostate and bladder dose, respectively. The WER value does not change significantly with magnetic field application.

Keywords: MR-guided carbon therapy, Dose distortion, Beam deviation, Multi-layer tissue phantom, Monte Carlo simulation

P02

SCATTERED RADIATION MORPHOLOGY AND SPECTRAL ANALYSES PRODUCED BY A PROTON BEAM FOR A HEAD AND NECK CASE WITH DENTAL IMPLANTS

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The investigation is focused on the impact of two dental implants in a head and neck cancer, using a collimated proton beam and an anthropomorphic phantom with human-like head density. Two dental inserts were placed in the centre of the target volume. With a hybrid design, based on semiconductor technology, Tiemepix3 detectors were used to measure and characterize the scattered radiation produced by the primary protons with the metallic inserts. With a high-resolution sensor, the stray radiation was analyzed using particle identification algorithms, creating real-time visualization of each type of particle and their spectral contribution to the final dose.

Based on an X-ray CT scan, a treatment plan was done using the anthropomorphic head phantom and those two metallic inserts placed in the phantom's upper jaw similar to those used in molar replacements. To highlight the difference induced by the metallic inserts in this kind of case, two irradiations were planned: one with two titanium implants, and one without them (replaced with two tissue-compatible inserts). Two cylindrical titanium inserts measuring 1 cm long and 0.33 cm in diameter were used in this experiment. Using a scattered fixed proton beam with a nominal energy of 170 MeV and a set of personalized collimators and boluses, the beam geometry was delivered according to the treatment plan. The scattered radiation was monitored with a Timepix3 detector placed 8 cm behind the target volume. Particle-specific morphology and spectral aspect were performed for the mixed radiation field resulting after the Bragg peak, highlighting the biological impact by measuring the linear energy transfer (LET).

The low intensity of the incident beam was maintained to be able to allow particle tracking. Based on a trained neuronal network infrastructure, three groups of particles were identified: scattered protons, electrons and photons, and ions. Placing the Ti implants into the field led to an increased number of scattered protons. The spectral fingerprint of each group of particles has a different contribution to the LET spectra. With the highest value of the LET, 6 keV/µm, ions with fast neutrons were detected in the scattered radiations. Directional maps of scattered high and low-energy protons show a more spread-out morphology when Ti implants are present.

Dental metallic implants' influences in a proton-based treatment are presented as a novel modality to study the morphology and spectral aspect of the scattered radiation. Further investigations will describe the contribution of each particle type to the deposited dose after the target volume.

P03

Abstract

The aim of this research was to develop an appropriate algorithm that can automatically detect and classify liver cancers. Digital image processing (DIP) provides different techniques for the segmentation and classification purposes. The sample was taken from 36 abdominal CT scans from Tikur Anbessa Specialized Hospital in DICOM stored in Addis Ababa. Semi-automatic techniques were used to segment liver images from the abdominal CT images then artificial neural network (ANN) was applied for classification of liver out of the given sample through nine texture features into 12 normal and 24 abnormal images. Then, liver tumors were segmented from the 24 abnormal liver images using the histogram-based Otsu method. The classification of liver tumors was performed by using ANN through six morphological features into 12 benign and 12 malignant. The classification results are presented in this paper using the confusion matrix, which shows 95.8 % maximum accuracy rate of tumor classification. However, the performance of the classifier could be improved by more sample images. The outcome of this work may help radiologists to identify tumors at early stages and to classify them as benign or malignant. The methodology proposed here might reduce the fatality rate of liver cancers in Ethiopia.

Key words: Digital image processing, ANN, liver cancers, CT images.

P04

Educational Utilization of MatRAD, an Open-Source Software, for Teaching Photon and Proton Treatment Planning in Kosovo

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MatRAD, an open-source treatment planning system based on MATLAB, was utilized in a pilot project to train aspiring medical physicists and postgraduate physics students in Kosovo in treatment planning and beam modeling techniques for both photon and proton therapy. Through four carefully designed exercises, students gained insights into modeling proton pencil beams, calculating doses in three-dimensional voxelized geometries, constructing pencil beam scanning plans (PBS), understanding spot spacing choices in patient plans, and discerning dosimetric variations between photon and proton PBS plans. The pilot project involved twenty students.

[1] Meyer J, Hartmann B, Kalet I. A ‘learning-by-doing’ treatment planning tutorial for medical physicists. Australas Phys Eng Sci Med.32,112 (2009).
[2] Sanchez-Parcerisa D, Kondrla M, Shaindlin A, Carabe A. FoCa: a modular treatment planning system for proton radiotherapy with research and educational purposes. Phys Med Biol. 59,7341–7360 (2014).
[3] Bridge P, Burrage S. Remote access to treatment planning software for pre-registration radiation therapy education: a single-case feasibility study. J Radiother Pract.14,180–186 (2015).
[4] Cisternas E., Mairani A, Ziegenhein P, Jeakel O, Bangert M. matRad-a multi-modality open source 3D treatment planning toolkit. In: World Congress on Medical Physics and Biomedical Engineering, June 7-12, 2015, Toronto, Canada. Cham: Springer; 1608–1611(2015).
[5] Tewell MA, Adams R. The PLUNC 3D treatment planning system: a dynamic alternative to commercially available systems. Med Dosim. 29,134–138 (2004).
[6] Clasie B, Depauw N, Fransen M, et al. Golden beam data for proton pencil-beam scanning. Phys Med Biol. 57,1147 (2012).
[7] Kreamer M, Jeakel O, Haberer T, Kraft G, Schardt D, Weber U. Treatment planning for heavy-ion radiotherapy: physical beam model and dose optimization. Phys Med Biol.45,3299(2000).

P05

Radiobiological Significance of Spot and Energy Layer Parameter Selection in Intensity-Modulated Proton Therapy

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Evaluating the Linear Energy Transfer (LET) distribution could provide crucial insights into the biological effects of Intensity-Modulated Proton therapy (IMPT). While it has been proven that the quality and robustness of IMPT plans depend on spot and energy layer (EL) selection [1], the impact of these factors on LET distribution remains unexplored in the existing literature. This study investigates the influence of spot and EL selection on the LET distribution and plan quality for clinical IMPT plans. IMPT plans were retrospectively generated for five HN patients in the RayStation Treatment Planning System. For each case, 21 treatment plans were generated by systematically varying parameters, including the distance between EL, spots and the number of proximal and distal EL. The LVH (LET Volume Histogram) was evaluated for different structures and LVH parameters such as volume of the high LET region (volume above 6 keV/µm ($V_{>6\,LET}$)), LET in 1% volume ($LET_{1\%}$) was evaluated. The Plan robustness, target and Organ at Risk (OAR) doses, target homogeneity index (HI) and conformity index (CI) were assessed for each case. Multilinear Regression analysis examined correlations between variables. The increase in ELs due to reduced EL separation led to higher $V_{>6\,LET}$ ($p = 0.00015$, $r = 0.74$) and $LET_{1\%}$ ($p = 0.0032$, $r = 0.71$). However, increasing the number of spots by reducing the spot separation does not correlate with the LET distribution ($p = 0.3$, $r = -0.05$). The target CI and HI positively correlated with the number of spots ($p = 0.01$, $r = 0.52$) rather than ELs ($p = 0.83$, $r = 0.23$). More spots increased treatment time and plan complexity. The OAR doses negatively correlated with the number of spots and ELs. The plan robustness reduced as the distance between EL and spots increased. Adding extra distal ELs has increased plan robustness with reduced $V_{>6\,LET}$. EL selection affects LET distribution and plan quality in PBS treatment planning. Even if the spot separation doesn't correlate with the LET distribution, it is crucial in deciding the plan's quality and complexity.

[1] ur Rehman, M., Zeidan, O. A., Willoughby, T., Meeks, S. L., Kelly, P., & Erhart, K. International Journal of Particle Therapy, 9(1), 54-63.

P06

The Evolution of Medical Accelerators for Hadron Therapy: From Lawrence to CNAO

Abstract:

This poster explores the historical trajectory of medical accelerators for Hadron therapy, tracing their development from the pioneering work of Ernest O. Lawrence to state-of-the-art facilities like CNAO (National Centre of Oncological Hadron Therapy). The study delves into the technological advancements, scientific breakthroughs and the transformative impact of Hadron therapy on cancer treatment.

Introduction:

The introductory section provides a historical context, outlining the early days of particle accelerators and their relevance to medical applications. It highlights the motivation behind exploring Hadron therapy as an innovative approach to cancer treatment.

Lawrence's Contribution:

This section examines the groundbreaking contributions of Ernest O. Lawrence, the inventor of the cyclotron, in laying the foundation for medical accelerators. It explores the initial applications of accelerators in healthcare and their evolution over the years.

Development of Hadron therapy:

The Evolution of Medical Accelerators for Hadron therapy: From Lawrence to CNAO

> The poster chronicles the development of Hadron therapy, emphasizing key milestones, technological innovations, and the integration of accelerators into clinical practice.

It discusses the advantages of hadron beams in cancer treatment, such as increased precision and reduced damage to surrounding healthy tissues.

Case Study: CNAO (National Centre of Oncological Hadron Therapy):

> A significant portion of the poster is dedicated to a case study of CNAO, elucidating its role as a leading facility in Hadron therapy.

This section details the facility's design, capabilities, and impact on advancing the field of cancer treatment.

Conclusion:

The conclusion summarizes the key findings of the research, emphasizing the historical significance of medical accelerators in Hadron therapy. It also discusses potential future developments and the ongoing impact of this technology on improving cancer care.

Keywords:

Medical Accelerators, Hadron Therapy, Lawrence, Cyclotron, CNAO, Cancer Treatment, Technological Advancements.

Reference:

1. https://books.google.it/books?hl=en&lr=&id=rIuADwAAQBAJ&oi=fnd&pg=PP1&dq=Paganetti+Proton+Therapy.&ots=ItHYvtKkYu&sig=kOpCn_zlhk_As4grgZY2RN4ZwYA#v=onepage&q=Paganetti%20Proton%20Therapy.&f=false
2. https://d1wqtxts1xzle7.cloudfront.net/42130947/Journal_of_the_Korean_Physical_Society__Vol._50__No._5__May_2007__pp._1385-1389-libre.pdf?1454668602=&response-content-disposition=inline%3B+filename%3DAccelerators_and_Medicine.pdf&Expires=1704326202&Signature=VEBfaH4FCJL9FAUv-LppTIXVwQjHbxjfvQlXlddKxAeSg~3DVNYRr7pHaimg7JsJq6KnzcY9LIROBEkg3BX9WZ~KsBt5yxJiWFI4Rk67M-qUvWYtGbKqDI5LgGkKnJnSp~DT-lLAfsPRtm41okK-0BLFjWX383YhjcbCXdF2J~tyMjC4JHC55fV0TA3vcCwWWWsr9poPhELoQ801byzj1al3pmAGa6pPdm9igbDiPnv5eeragVHFvRRSjpwkUs7o13uwTyu7P~lkt6dWea0oGY3I27F2QSeiNtSiPNC7B6Q17aRV4hqLTt-aI8erkGCjNVDRG2ej4ovyk3tI3OScSA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

P07 BEAM CURRENT MEASUREMENTS AT THE NANO-AMPERE LEVEL USING A CURRENT TRANSFORMER

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In conventional proton therapy (PT) typical beam currents are of the order of 0.1 nA. At these currents dose monitoring is reliably achieved with an ionization chamber. However, at the very high dose rates used in FLASH irradiations (employing beam currents >100 nA) ionization chambers will exhibit large intensity dependent recombination effects and cannot be used. A possible solution is a current transformer. Here we report on the performance of the LC-CWCT (Bergoz Instrumentation, France) which has been developed to push noise floor of such non-destructive current measurement systems into the nano-ampere range. We present first beam current measurements at the PARTREC cyclotron (Netherlands). Beam currents measured by the LC-CWCT and a Faraday Cup were shown to linearly correlate up to the maximum intensity of 400 nA used in the measurements. For pulsed beams, charge measured by the LC-CWCT linearly correlated with pulse length over the measurement range from 50 to 1000 µs. Measurement noise as low as 2.8 nA was achieved. The results confirm that the LC-CWCT has the potential to be applied in FLASH PT for accurate determination of beam current and macro pulse charge.

P08

Abstract template for … Poster entitled "Impact of an External Magnetic Field on Biomaterial Usage in Carbon Ion Therapy for Meningioma"…

Yjjou Mohammed [1] , **Dekhissi Hassane**[1] , **and Derkaoui Jamal Eddine** [1]

1

Carbon ion therapy is a promising approach in the field of cancer treatment, offering superior dose distribution and biological effectiveness compared to conventional radiotherapy and proton therapy. In this study, we investigate the potential benefits of incorporating an axial magnetic field into the carbon ion therapy process, specifically focusing on using three biomaterials (PTFE, Alumina and Ti Alloy) as substitutes for the cranium [1]. The objective is to benchmark the impact of the magnetic field on the treatment outcome, considering factors such as equivalent dose deposition, secondary neutron production (SNP), and overall treatment efficacy [2].

To achieve this, comprehensive computational simulations were performed using FLUKA MC code. The simulations encompassed case of a primary tumor (Meningioma) involving both conventional carbon ion therapy without a magnetic field and carbon ion therapy in the presence of an axial magnetic field (MRI-GCIRT) with the two practical values 0.35 T and 1.5 T. The three selected biomaterials were carefully characterized in terms of their magnetic and dosimetric properties, aiming to identify the most suitable substitute for the cranium.

In the use of cranium (without Meningioma) and the practical values of B, the maximium longitudinal retraction is 0.088 cm under 220 MeV/n and 1.5 T.

In the use of cranium (with Meningioma) and the practical values of B, the maximium longitudinal retraction is 0.135 cm under 220 MeV/n and 1.5 T.

In the use of the studied biomaterials instead of cranium, it was observed that the most compatible biomaterial compared to cranium for all studied cases is polytetrafluoroethylene (PTFE).

[1] Dharadhar, S., & Majumdar, A. (2019). Biomaterials and Its Medical Applications. Application of Biomedical Engineering in Neuroscience, 355-380.

[2] Akbari, M., & Karimian, A. (2020). Impact of transverse magnetic fields on water equivalent ratios in carbon-ion radiotherapy. Journal of Instrumentation, 15(05), T05006.

P09

Nanoparticle-aided Radiotherapy with Immunotherapy using smart biomaterials in cancer treatment

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Cancer today is the main cause of death worldwide and metastasis accounts for over 90% of all cancer associated suffering and death, and arguably presents the most formidable challenge in cancer management. The main techniques involved in the cancer treatment are the Radiotherapy (RT), chemotherapy and Immunotherapy. Although these methods and especially RT have made significant advances in the last decades, there is still a significant amount of cancer patients experiencing toxicities on normal cells, cancer reappearance and deadly metastasis. A new method using nanoparticle-aided radiotherapy (RT) where gold nanoparticles can amplify damage to cancer cells during radiotherapy, generating neoantigens that can serve as a cancer vaccine powering cytotoxic immune system T-cells to kill both local and metastatic cancer is presented. The combination of RT with the Immunotherapy (anti-CD40) can further boost local and metastatic tumor cell kill, with minimal damage to healthy tissue. Biodegradable polymers are used as payload for targeted, concentrated and controlled delivery of nanoparticles and immunotherapeutics into the tumor volume, over time. The multifunctional properties of metallic nanoparticles (MNP) related to their physic-chemical properties and biocompatibility make them very suitable for applications both in diagnosis an therapeutic treatment.