doubling of risk of hematologic grade ≥3 toxicity based on previously published NTCP parameter estimates. NTCP modeling well predicted toxicity using IMRT in this sample. Predicted toxicity using CRT lay marginally outside 95% CI NTCP modeling in this sample.

EP-1480

Development and validation of a proton decision support system comparing dose, toxicity and cost-effectiveness

Q. Cheng[1], E. Roelofs[1], B. Ramaekers[1], D. Eekers[1], J. Van Soest[1], T. Hendriks[1], F. Hoebers[1], A. Dekker[1], P. Lambin[1]
[1]*MAASTRO Clinic, Radiation Oncology, Maastricht, The Netherlands*

Purpose/Objective: To facilitate a prompt recommendation of photon vs. proton therapy a decision support system (DSS) is essential. This paper presents the development and validation of an online, three-level (dose, normal tissue toxicity reduction and cost-effectiveness level) proton DSS, and its proposed application for patients with Head and Neck cancer.

Materials and Methods: Meaningful benefits were defined for all three levels based on expert opinions and published papers. For the dose comparison layer, benefit was defined as a plan meeting clinical acceptable organs-at-risk thresholds: parotid gland <26Gy, pharyngeal constrictor muscle superior <50Gy, supraglottis area <50Gy. For the toxicity reduction layer, a clinical significant grade 2+ toxicity reduction was set at >10% based on a published toxicity prediction model for xerostomia and dysphagia at 6 and 12 months after therapy. For the cost-effectiveness layer, the acceptable cost for a quality-adjusted life year (QALY) gained was set at 80.000€ and based on a published Markov model. The DSS was developed with a component oriented design and implementation to reuse independent in-house resources in a systematic way and implements both the calculations and comparisons of photons vs. protons at the three levels (see figure). A Head and Neck cancer patient, planned with both IMRT and IMPT, was used to test the DSS.

Results: A web-based DSS was successfully developed to deliver layered computation and comparison services. After providing clinical patient information and the photon and proton plans, the following comparison results were generated (see table): *(1)* On a dosimetric level, proton therapy generated a more desirable dose distributions; *(2)* On the toxicity estimation level, proton therapy appeared more capable of lowering the risk of complications for xerostomia or swallowing dysfunction; *(3)* On the cost-effectiveness level, proton therapy was more effective although photon therapy was more cost-effective.

Conclusions: This DSS is able to quantitatively compare photon and proton treatment options and provide multi-level decision support. From the limited validation, proton therapy demonstrates its capacity to deliver a better dose distribution and lower toxicity to the normal tissue in comparison with photon therapy. However, given the current acceptable payment for a QALY gained, the lower costs of photon therapy appears to outweigh the benefits of proton therapy making photons more cost-effective for this specific case.

EP-1481

A treatment planning study of the clinical optimality of ion beam therapy with different ions in presence of hypoxia

A. Attili[1], F. Torriani[2], C. Mingioni[2], G. Russo[1], F. Dalmasso[3], S. Giordanengo[1], F. Bourhaleb[4], G. Battistoni[5], F. Marchetto[1], R. Cirio[3]
[1]*Istituto Nazionale di Fisica Nucleare (INFN) Section of Torino, Physics, Torino, Italy*
[2]*Politecnico di Torino, Physics, Torino, Italy*
[3]*University of Torino, Physics, Torino, Italy*
[4]*Internet-Simulation Evaluation Envision (I-See), Torino, Italy*
[5]*Istituto Nazionale di Fisica Nucleare (INFN) Section of Milano, Physics, Milano, Italy*

Purpose/Objective: The reduced concentration of oxygen in cells (hypoxia) results in a significantly lower cell death rate after exposure to ionizing radiation that can lead to treatment failure. This oxygen effect can be expressed by the oxygen enhancement ratio (OER) that was found experimentally to be strongly related to the quality of radiation and, in general, to the linear energy transfer (LET). Studies to quantify this effect in treatment simulations have been pursued [Wenzl T & Wilkens, JJ (2011) *Phys Med Biol, 56; Scifoni E, et al. (2013) Phys Med Biol, 58;* Bassler N, et al. (2014) *Acta Oncol 53*]. However, systematic studies to evaluate the impact of hypoxia in treatments with beam of different ion species are still lacking. Furthermore, the radiobiological models used to quantify the OER in these studies are based on the dose averaged LET estimates and do not explicitly distinguish among varying ion species and fractionation schemes. In this work a new model to predict the OER taking into account the specificity of the different ions, tissues and fractionation schemes was implemented to quantify the clinical outcomes of treatments with beams of different ion species via an intercomparison of treatment plans for a set of clinical cases.

Materials and Methods: A novel model, based on the microdosimetric effect model [Hawkins RB (2003) *Rad Res, 160*], to predict the OER was implemented. The model was benchmarked with in-vitro data, V79 and HSG cells in aerobic and hypoxic conditions, irradiated with different ions [Furusawa Y, et al. (2000) *Rad Res, 154*]. The benchmarked model was then included in the simulation of treatment for a set of 12 clinical cases (head and neck and prostate cancer) using p, Li, He, C and O ion beams. The plans were evaluated using a treatment planning system (TPS) that is able to evaluate the LET spectra at a voxel level for primary and secondary particles. The expected treatment optimality as a function of oxygen partial pressure, HTV size, dose per fraction and primary ion type, was quantified in terms of Tumor Control Probability (TCP) and Normal Tissue Complication Probability (NTCP).

Results: The modelled OERs were found to be dependent on both LET and ion charge, showing also a decreasing OER for increasing dose per fraction with a slope that depends on the LET. These behaviours were found to have a good agreement with the experimental OER assays. The treatment simulations shows a substantial OER dependence by dose per fraction and an increase in TCP by increasing the ion charge and dose per fraction (e.g. up to 40% variation from p to O). However, high NTCP in normal tissue for high-LET radiation was also observed.

Conclusions: A novel modeling of the OER that explicitly includes the dependence on ion type and dose per fraction was implemented. The model was successfully included in a TPS to evaluate the impact of hypoxia with different ion species.

Electronic Poster: Physics track: Intrafraction motion management

EP-1482

A 4D LEGO anthropomorphic phantom for intrafraction motion modeling during patient breathing

N. Maffei[1], G. Guidi[1], A. Ciarmatori[1], G. Gottardi[1], M.G. Mistretta[1], C. Vecchi[2], G. Baldazzi[2], F. Bertoni[3], T. Costi, (1)
[1]Az.Ospedaliero-Universitaria di Modena, Medical Physics, Modena, Italy
[2]Alma Mater Studiorum University of Bologna, Physics, Bologna, Italy
[3]Az.Ospedaliero-Universitaria di Modena, Radiation Oncology, Modena, Italy

Purpose/Objective: An anthropomorphic phantom was built using LEGO Mindstorms to simulate breathing and tumors motion in lung district. By 4-Dimensional Computed Tomography (4DCT) and simulation of asynchronous motion of tumor and rib cage we can predict changes, due to patient's breathing phases, to improve accuracy of Stereotactic Body Radiation Therapy and motion spatial estimation.
Materials and Methods: In our robot, human chest is simulated by an 8 ribs apparatus. Mechanical gears allow synchronous/independent motion of each rib with different angular velocity. 2 artificial tumor masses, with a 4 degree of freedom motion, are located inside the thoracic cavity. Robot is driven by intelligent brick LINUX OS CPU, LABView programmable. The phantom has pediatric dimensions (≈30x24x24 cm^3); gears and robotic parts, made ??of plastic material, avoid artifacts during CT acquisition. Through 4DCT a real-time signal is obtained by optical surface tracking system (VisionRT). Patient's breathing phases are acquired instantaneously by InfraRed/UltraSound eyes. Quasar phantom allows correlation between physiological and robotically surrogated signal. To understand internal-external motion correlation, tumor center of mass is individuated by 4DCT images and followed during respiration.
Results: A 4D function obtained and simulated by the anthropomorphic phantom during a new 4DCT study quantifies the degree of divergence due to internal dynamics of organ deformation. Sinusoidal signals (6, 10, 12, 15 and 17 Breaths per Minute-BPM) were used to evaluate and commissioning phantom. Pearson correlation coefficient returned a strong similarity between Quasar and LEGO phantom, showing an R fitting 0.94÷0.90 for all signals. Validated on above theoretical/ad hoc waveform, the phantom was tested in clinical condition. Breaths and CT study of 6 patients were randomly selected from a sample of 107 patients. A jitter low-pass filter was applied, to smooth discontinuous signals, with a threshold of 0.20÷0.30 Hz before observation. Analysis of real signals returned an R value 0.89÷0.92. In patients with a respiratory stasis between inspiration and expiration <1 s some criticalities occur.

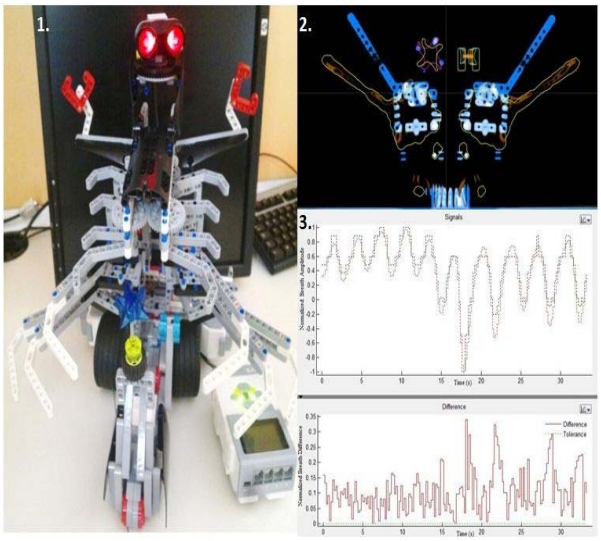

Figure (1.) The LEGO Mindstorms phantom; (2.) 4DCT study with maximum inspirum (orange) and expirium (blue); (3.) Real breath comparison (up) and difference (down).
Conclusions: A biomechanical system shaping a realistic model for external/internal motion correlation was realized and validated for sinusoidal inputs. Due to intrinsic irregularities in patients, mechanical reproducibility becomes more complex for pseudo-periodic human breaths. Anyway, R remains very strong, at least for patients without abnormal respiratory stasis. Future research with TLD and ion chamber installed inside tumors and ribs models will allow evaluating impact of respiratory irregularities in dosimetric measures. Our 4D LEGO phantom can predict tumor position and intrafraction organs motion, with the aim of increasing accuracy in real-time treatments.

EP-1483

A segmentation and point matching enhanced efficient deformable image registration for HDR dose accumulation

X. Zhen[1], H. Chen[1], H. Yan[2], L. Zhou[1], L.K. Mell[3], C.M. Yashar[3], S.B. Jiang[2], X. Jia[2], X. Gu[2], L. Cerviño[3]
[1]Southern Medical University, Department of Biomedical Engineering, Guang Zhou, China
[2]The University of Texas, Southwestern Medical Center, Dallas, USA
[3]University of California San Diego, Department of Radiation Medicine and Applied Sciences, San Diego, USA

Purpose/Objective: To propose and validate a novel *segmentation and point-matching enhanced efficient deformable image registration (DIR)* algorithm (named SPEED) to facilitate dose accumulation between treatment fractions of high-dose-rate (HDR) gynecological brachytherapy.
Materials and Methods: In SPEED, segmentation and point matching steps are performed before DIR to remove the applicator region (AR, including the packing gauze) and to account for the AR deformation between fractional HDR CT images. Specifically, in the segmentation step, the incremented foreground and background point sets are generated by region growing on a density map involving the