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Wiener Neustadt, 12 July 2013

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Book of Abstracts

ULICE Meeting, Friday 12 June 2013

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Abstract 1

ACCELERATOR HEALTH PHYSICS AND RADIATION RESEARCH AT WEST GERMAN PROTON THERAPY CENTRE ESSEN (WPE)

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Purpose

The West German Proton Therapy Centre Essen (WPE), a daughter institution of the University Hospital Essen currently operates a 230 MeV room temperature proton therapy cyclotron. This presentation highlights several important research activities carried out at our centre in the last two years of operation.

Materials and Methods

Radiological shielding verification of the treatment rooms using neutron and gamma dose measurements and Monte-Carlo simulations. The parameterised neutron attenuation data from our studies could be used to design optimised shielding containment for future proton therapy faculties. An ultra-sensitive OSL-based neutron area monitor has been developed by our group for surveillance of high-energy particle accelerator environment is currently being implemented at WPE. Explicit assessment of organ specific out-of-field neutron and gamma equivalent doses during proton therapy, in particular for paediatric patients using a TLD-based microdosimeter developed at our laboratory, the data can be used to predict the risk of late incidence of secondary cancer. Furthermore, this detector could also be implemented to estimate aircrew dose equivalent during long haul flights.

Results

The estimated out-of-field dose equivalent at the location of critical organs of a paediatric patient during proton therapy estimated using TLD based microdosimeter is shown in Figure 1 below.

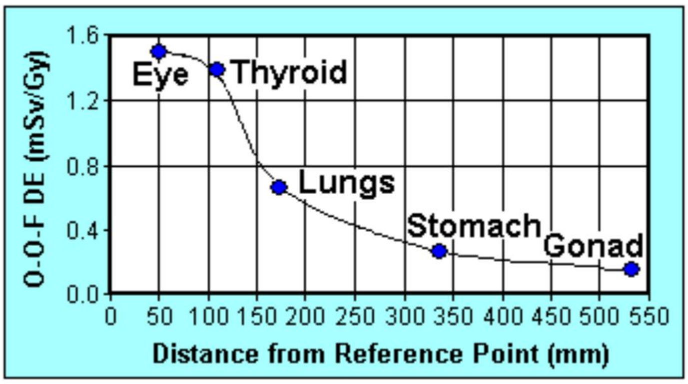

Figure 1: Out-of-field organ dose equivalents per unit delivered proton dose.

Conclusions

Results of some important research activities in radiation physics and dosimetry carried out at WPE are discussed. We welcome research collaborations with other institutions within the framework of ENLIGT-ULICE.

Abstract 2

MEASUREMENTS OF IN-PHANTOM NEUTRON FLUENCE AND DOSE IN AN UNCOLLIMATED PROTON BEAM

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Purpose

During radiation therapy, patients receive undesired dose from neutrons produced in collimators or in the patient. The neutron dose is mainly associated with a potentially increased risk of radiation induced cancer. A part of the rationale for moving towards scanning beams in particle therapy is the elimination of the unwanted secondary neutrons produced in collimators and energy degraders.

Material and Methods

In order to investigate the neutron contribution from proton therapy with scanning beams, measurements of the neutron fluence from a narrow uncollimated 180 MeV proton beam were performed at The Svedberg Laboratory in Uppsala. The proton beam was applied to a water phantom, and the use of a SRAM based neutron counter enabled the experiment to be conducted with a compact fast neutron detector inside the water phantom. Fluka Monte Carlo simulations were conducted for comparison with the results from the measurements.

Results

The measurements and simulations indicated that the neutron fluence at Bragg peak depth drops by about two orders of magnitude from areas close to the beam axis to lateral distances of 15 cm inside the water phantom. Looking at the neutron fluence as a function of depth the measurements implied that the neutron fluence is only to a relatively small degree dependent on the depth in the phantom.

Conclusions

The measurements have given a good overview of the distribution of neutron fluence inside a water phantom irradiated with a narrow proton beam. The results may be relevant for estimation of secondary cancer risk from active proton therapy and for comparison to other treatment modalities.

Abstract 3

REPRODUCIBILITY OF TARGET COVERAGE OF SCANNED PROTON IRRADIATION IN LUNG TUMORS UNDER HIGH FREQUENCY JET VENTILATION

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Purpose
To investigate the reproducibility of the delivered proton dose distribution under high frequency jet ventilation (HFJV).

Materials and Methods
10 patients with 11 peripheral lung lesions treated with single fraction stereotactic radiosurgery under HFJV were selected. Patients received 2 CTs under HFJV: a planning CT and a localization CT on the day of irradiation. For each lesion, rigid coregistration of both CT datasets was performed with focus on the tumor region. Using the original planning CTs, scanned beam proton treatment plans were prepared with the TRiP98 TPS (GSI, Darmstadt, Germany) using two coplanar fields at 0° and 45°, deliverable with the fixed nozzles (horizontal and oblique) available at the Marburg Ion Therapy center (MIT). Delivery of the optimized proton plans was simulated by recomputation on the localization CTs.

Results
Tumor position reproducibility in the localization CTs was in general excellent. From the original coverage (average GTV and PTV V95% >98% for all patients), after recomputation, PTV V95% remained above 97% in 6/12 cases and above 90% in 3/12 cases. Lower PTV coverage was attributed to anatomical variations in the entrance channels due to changes in patient setup e.g. arm mispositioning or slight body rotations.

Conclusion
Through jet ventilation, reproducible tumor fixation for scanned beam proton radiotherapy of lung lesions is achievable. Presented results demonstrate general anatomical and geometrical tumor position reproducibility, sufficient to ensure excellent target coverage at delivery. Small changes in patient setup can lead to dose deterioration, independently of the motion management technique employed, thus confirming the requirement of accurate case-by-case verification prior to irradiation with high-precision particle therapy, to ensure strict anatomical correspondence of the planned beam channels at treatment time.

Abstract 4

DOSIMETRIC CONSEQUENCES OF INTRAFRACTION PROSTATE MOTION IN FRACTIONATED CARBON ION THERAPY WITH RASTER SCANNING

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Purpose
To assess the dosimetric effects of intrafraction prostate motion on fractionated scanned carbon ion beam radiotherapy of the prostate and to investigate applicability of selected countermeasures.

Materials and Methods
For 12 prostate cases, scanned carbon ion treatment plans were prepared with the TRiP98 TPS, using a raster spot size of 7.0-7.5 mm and raster pitch of 2 mm. Plan delivery, in presence of 6 aperiodic prostate motion scenarios derived from published data, was software simulated and piped into TRiP98, resulting in time-resolved dose computation capturing interplay effects in the target.
The CTV coverage with 95% of prescription dose ($V_{95\%}$) was evaluated as function of fraction number by accumulating single-fraction doses. Selected tests were repeated employing varying treatment planning margins and raster settings, on-line motion compensation or in-slice rescanning.

Results
The median (range) CTV $V_{95\%}$ was 88.7 (49.6-100.0)% and 94.6 (68.2-100.0)% with margin 3 mm and 6 mm, respectively. Increase of $V_{95\%}$ through margin expansion was observed for drift-dominated scenarios. No particular raster setting brought a distinct advantage. Under application of intra-beam motion compensation a statistically significant improvement of the CTV $V_{95\%}$ was observed.
An increase of the CTV $V_{95\%}$ was observed up to the 4th fraction with 3 and 6 mm margin, achieving values >95% after respectively 5 and 2 fractions. Median cumulative CTV $V_{95\%}$ was 96.1 (85.3-99.8)% and 98.3 (95.0-100.0)% at 6th fraction with 3 and 6 mm margin.

Conclusion
A systematic assessment of scanning-motion interplay in fractionated prostate ion therapy was carried out. Intrafraction prostate motion may lead to marked target coverage deterioration, which is dependent on the individual motion pattern. Averaging effects of conventional fractionation (n>6) appear sufficient to ensure clinical coverage, while with hypofractionation active countermeasures are recommendable.

Abstract 5

A PATIENTS STUDY FOR DEFORMABLE IMAGE REGISTRATION ALGORITHM VALIDATION

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Purpose
Patients undergoing radiation therapy show anatomic changes during the course of the treatment,e.g. weight loss, tumor shrinkage, organ shape changes and movements, or merely patientmisalignment. In order to assess the overall treatment and dose delivery, respectively, dose accumulation has to be performed that takes the anatomical changes into account. A primary perquisite for dose accumulation is a deformable image registration (DIR). A DIR software basedon the featurelet algorithm was in-house developed. In order to benchmark its performance a pelvic patients study was performed.

Material and Methods
A group of ten gynecological patients having repeated CT and CBCT scans have been collected. Bladder and rectum contours were delineated on the planning CT and on every repeated scan by an expert clinician. DIR using both our in-house developed featurelet-based method and the iPlan® BrainLab TPS softwares was performed with the planning CT as reference and a selection of repeated scans as target data set. The planning CT contours were deformed using the resulting deformation fields and compared to the manual contours. Dice's coefficients (DSC) were calculated for each fractional patient scan structure comparing the volume overlap before and after DIR.

Results
No significant improvement in volume overlap was seen after DIR, independently of imagemodality or DIR method was used. The p-value obtained to discriminate between image modalities were 0.79 and 0.29 for the featurelet and the iPLAN DIR respectively, while its value was of 0.78 when comparing the two DIR modalities.

Conclusions
Since no DIR significant results were obtained in this study, DIR needs to further be investigated in order to be used as a tool for contour propagation in the pelvic region in ART approaches.

Abstract 6

RECOMPARE: WEB-BASED SOFTWARE TOOL FOR INDIVIDUAL PATIENT ALLOCATION TO PARTICLE THERAPY

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Purpose:

To guarantee patients an equal and sufficient access to optimal radiotherapy, it is essential to identify those tumors that have a higher chance to be cured by particle therapy (PT) than by state-of-the art photon therapy. Thus, patients need to be individually allocated to exactly that irradiation type that offers them the best chance for cure. Currently, it seems to be rational to base the decision on patient-specific treatment plan comparison between the available types of radiation. To realize active engagement of non-particle radiotherapy institutions in this decision process—necessary to offer nationwide access to PT—a remote plan comparison tool has to be available.

Materials and Methods:

We developed the web-accessible software tool RECOMPARE (REmote COMparison of PARticlE and photon treatment plans) for individualized patient allocation. It uses a server-client structure and standard formats for the handling of patient data (DICOM) and their protection (EAS, HTTPS). For decision guidance, we implemented radiobiological dose-response modeling based on recommendations from, e.g., QUANTEC and ALLEGRO. An attached database collects the processed patient data and makes them available for research purposes.

Results:

We exchanged treatment plans between European radiation centers and demonstrated compatibility of the software RECOMPARE with common treatment planning systems. Its design meets the essential requirements: data protection; simplicity and standardization; free to use license; particle plan calculation at the PT center and therapy decision at the non-particle radiation institution; dose-response modeling; and availability of processed patient data for research.

Conclusions:

In conclusion, a web-based software system for supporting a cooperative decision of patient allocation to PT is technically feasible. Even small non-particle radiotherapy institutions may find its use admirable due to its simplicity and its free of charge license, encouraging them to actively participate in the patient-specific decision process for the most appropriate treatment modality.

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9	16:46 - 16:53	DOSIMETRIC DIFFERENCES OF ALTERNATIVE TREATMENT TECHNIQUES FOR LOCALIZED PROSTATE CANCER PATIENTS: ADVANCED BRACHYTHERAPY VS. INVERSELY PLANNED PHOTON AND ION BEAM THERAPY.	J. Hopfgartner et.al.	p 13
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Abstract 7

AUTOMATED DETECTION OF SETUP ERRORS IN CARBON ION THERAPY USING PARTICLE THERAPY: FEASIBILITY STUDY

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Purpose:
Previous studies showed the feasibility to detect range uncertainties (>4mm) of ion beams in the head-and-neck region (H&N) with particle therapy (PT) PET, in an automated way. This study explores whether patient setup errors can be detected with PT-PET in an automated manner using in-house developed software based on the Pearson's correlation coefficient (PCC-SW).

Material and Methods:
From TRiP98 carbon-ion plans the reference PT-PET β^+-activity distribution was simulated using an in-house developed MC platform. In the next step the initial beam settings were applied on cranio-caudal (cc) shifted CTs (2-6mm) to simulate patient miss-positioning. Then the expected β^+-activity was calculated for each plan with shifts. Finally, the reference PT-PET images were compared to the “shifted” β^+-activity distribution simulations using the PCC-SW. Tumors in the H&N, prostate, lung and brain were investigated. Further different monitoring scenarios were compared.
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Results:
The automated PCC evaluation of the PT-PET data showed that in inhomogeneous tissue miss-positioning of 4mm and more can be detected. Cc-shifted prostate PT-PET images were too similar to detect shifts in longitudinal direction. Regarding lung lesions the definiteness of detecting patients’ shifts depended strongly on the exact location of the tumor. By evaluating several PT-PET scenarios an in-room scenario with up to 2min delay between irradiation and measurement (measurement time > 300s) was preferable.

Conclusions:
The automated evaluation of PT-PET images depends strongly if the enclosed tissue is homogeneous or not. A large tumor size was found to be an additional challenge. However, the PCC based automated method is a quick and useful technique to support human decisions in the clinical routine. The exploration of different monitoring scenarios indicates a recommendation towards a full-ring PET scanner right next to the treatment site.

Abstract 8

ASSESSMENT OF IMAGING DOSE FOR INTRAFRACTION MOTION MANAGEMENT IN ION BEAM THERAPY

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Purpose
Image guidance is crucial for a safe and accurate particle and advanced photon radiation therapy. However, kV based imaging for treatment planning, position verification and intrafraction motion management leads to additional dose for the patient. Imaging dose for various organs at risk (OARs) caused by different imaging protocols for lung was investigated at the Medical University of Vienna/AKH (MUW) and 2 ion beam centers (CNAO, Pavia, Italy; HIT, Heidelberg, Germany).

Material and Methods Imaging dose was measured with TLD-100 chips (3x3x1mm^3; sensitivity within ±3%) in an Alderson Rando phantom (isocenter in sinister lung). Measurements were performed for 25 points on the skin or within OARs (3 TLDs in each point) for different planar kV setups, CBCT and fluoroscopy. For calibration 5 TLDs were irradiated in a Co-60 beam. 6 TLDs were used to account for background irradiation. The energy dependent sensitivity of the TLDs was accounted for by corrections based on the respective energy spectrum of the beams. Read-out, calibration and annealing of the TLDs were performed at the MUW.

Results OAR doses depended on imaging modality and position of the OARs. Dose for volumetric imaging was on average 2.5-860 times higher than for planar or stereoscopic image pairs. CBCT dose at the MUW was ~20 times higher than at CNAO as more projections with higher mAs setting were used. The skin dose was higher where the skin was closer to the X-ray tube (CBCT) or at the entrance side of the beam (planar kV: anterior, sinister; ExacTrac: posterior). The highest dose per exam (up to 150mGy to the skin) originated from 3min fluoroscopy at the MUW, the fluoroscopy dose at HIT was much lower (~30 times).

Conclusions Imaging modalities like planar kV or stereoscopic imaging result in very low doses (~1mGy) to the patient. When aiming to image a moving target during irradiation lowdose protocols and protocol optimization can reduce the imaging dose to the patient significantly.

Abstract 9

DOSIMETRIC DIFFERENCES OF ALTERNATIVE TREATMENT TECHNIQUES FOR LOCALIZED PROSTATE CANCER PATIENTS: ADVANCED BRACHYTHERAPY VS. INVERSELY PLANNED PHOTON AND ION BEAM THERAPY

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Purpose: To compare four external beam and brachytherapy (BT) treatment modalities for localized prostate cancer with special focus on doses delivered to organs at risk (OAR): rotational IMXT (VMAT), scanned proton beam therapy (IMPT), scanned carbon ion beam therapy (IMCT) and low dose rate (LDR) BT with I-125 seeds.

Material and Methods: 10 patients were considered for this study. OARs included the following structures: rectal wall (RW), bladder wall (BW) and all pelvic tissue (body structure minus individual target volumes). For each patient a VMAT (D/fx=2Gy;39fx), IMPT (D/fx=2Gy(RBE);39fx), IMCT (3.3Gy(RBE);20fx) and LDR BT (145Gy;171d) plan were generated. Physical and RBE weighted (IMPT,IMCT) dose distributions were converted into 3D dose distributions based on a 2Gy(IsoE) fractionation scheme on a voxel basis via in-house developed software tools. Patient population averaged DVHs were analyzed.

Results: In general, VMAT exhibited the largest integral dose (overall dose deposited in tissue) volume. While in the high dose region the differences were less pronounced statistically significant differences were found systematically in the mid- to low-dose range. $V_{30Gy(IsoE)}$ and $V_{50Gy(IsoE)}$ for the RW was on average 11.4Gy(IsoE) and 7.2Gy(IsoE) for VMAT, 8.8Gy(IsoE) and 7Gy(IsoE) for IMPT, 6.3Gy(IsoE) and 4.7Gy(IsoE) for IMCT and 6.8Gy(IsoE) and 4.1Gy(IsoE) for LDR BT, respectively. For respective dosimetric values of the BW 8.7Gy(IsoE) and 5.5Gy(IsoE) for VMAT, 7.3Gy(IsoE) and 5.3Gy(IsoE) for IMPT, 5.5Gy(IsoE) and 3.4Gy(IsoE) for IMCT and 4.4Gy(IsoE) and 2.7Gy(IsoE) for LDR BT were derived.

Conclusions: The potential of reducing exposure and hence toxicities to OARs while providing similar tumor control could be shown for IMPT, IMCT and LDR BT. Treatment modalities and related dosimetric benefits must be chosen on a patient individual basis.

Abstract 10

CAN PARTICLE BEAM THERAPY TREATMENTS BE IMPROVED USING HELIUM ION BEAMS ? – FIRST RESULTS OF A TREATMENT PLANNING STUDY

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Purpose: To explore the potential of scanned helium ion beams compared to scanned proton beam therapy in a treatment planning study.

Material and Methods: Treatment plans for prostate and skull base tumours were created with the treatment planning system Hyperion, utilizing a newly developed pencil beam algorithm for both proton and helium ion beams. Plan optimisation was done with the same constraints for both particle species, employing two lateral beams. Prostate patients received 78Gy to the PTV. Two organs at risk (OAR), rectum and bladder, were delineated. Skull base patients were prescribed 54Gy to the PTV. Five OAR (eyes, optic nerves and brainstem) were delineated. Results were evaluated using dose volume histograms (DVH), target coverage and conformity index (CI).

Results: Two prostate patients have been evaluated so far (PTV volumes ~126ccm). D_{median} for both patients was 78.1Gy. $D_{2\%}$ for prostate patient 1 was 80.3 vs 79.8Gy with a $V_{95\%}$ of 98.6 vs 99.2% for protons and helium ions, respectively. Corresponding values for patient 2 were similar ($D_{2\%}$ of 80.1 vs 79.8Gy with a $V_{95\%}$ of 98.6 vs 99.1%). The HI for both patients was evaluated to be 0.07 for all modalities.
For skull base patient 1 (PTV 81.7ccm) D_{median} was 54.15Gy for both particles. $D_{2\%}$ was 56.2 vs 55.6Gy with a $V_{95\%}$ of 95.2 vs 96.5% for protons and helium ions, respectively. Values for patient 2 (PTV 30.9ccm) and a D_{median} of 54.07Gy, were: $D_{2\%}$ 55.5 vs 55.2Gy with a $V_{95\%}$ of 95.0 vs 95.1%. The HI for skull base patient 1 was 0.11 vs 0.09, for patient 2 0.10 vs 0.09 for protons and helium ions, respectively. All OAR doses were within the tolerances specified in the QUANTEC report.

Conclusions: Systematically steeper PTV DVH curves were obtained for helium ions. The dosimetric improvements of treatment plan parameters motivate a more thorough investigation of helium ions. Current work in progress deals with improvements in RBE modeling of helium ions during optimisation to fine tune the model.

Abstract 11

ULTRA FAST 2D/3D REGISTRATION USING KV-MV IMAGE PAIRS FOR TUMOR MOTION TRACKING IN IMAGE GUIDED RADIOTHERAPY

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Purpose: Intra-fractional respiratory motion during radiotherapy is one of the main sources of uncertainty in dose application creating the need to extend the margins of the planning target volume (PTV). Real-time tumor motion tracking by 2D/3D registration using on-board kilo-voltage (kV) imaging can lead to dose reduction by reducing the PTV. One limitation of this technique is the inability to resolve motion along the imaging beam axis using only one projection image. We present a retrospective patient study to investigate the impact of paired portal mega-voltage (MV) and kV images, on registration accuracy.

Materials and methods: We used data from ten patients suffering from NSCLC undergoing regular SBRT lung treatment at our center. For each patient we have a planning CT and sequences of kV and MV images acquired during treatment. Our evaluation consisted of comparing the accuracy of motion tracking in 6 degrees offreedom (DOF) using only the kV sequence or the sequence of kV-MV image pairs. Our registration approach uses GPU based DRR rendering for optimal performance.

Results: Motion along cranial-caudal (CC) and lateral (LR) directions could accurately be extracted when using only the kV sequence but in AP direction we obtained large random errors. When using kV-MV pairs, we obtained an average error reduction from 2.9 mm to 1.5 mm. The motion along AP, when present, was successfully extracted by registration and clearly correlates with the motion which was previously annotated in the 2D images. Mean registration time is of 188 ms.

Conclusions: Our evaluation shows that using kV-MV image pairs leads to improved motion extraction in 6 DOF. Though lung tumor motion is mainly in CC direction we observed significant motion in AP direction and successfully extracted this motion. Since the images were acquired during actual treatment sessions this approach can be used to improve 6 DOF registration for tumor motion tracking.

Abstract 12

ASSESSMENT OF IMPROVED ORGAN AT RISK SPARING FOR MENINGIOMA FOR MIXED OR SINGLE PHOTON AND PARTICLE BEAM TREATMENTS

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Aim: To investigate the combination of photons, protons and carbons (^{12}C) for an optimal study design for meningioma treatment. Particle treatment could lead to a potential benefit in increased local tumor control as a boost or sole treatment modality.

Method: 2 different planning tumor volumes (PTV) were constructed for 4 meningioma patients: PTV_{init} treated with 25x2 Gy(RBE) and PTV_{Boost} with 6x3 Gy(RBE). For the initial clinical target volume (CTV_{init}) a margin of 1cm was added to the gross tumor volume (GTV). CTV_{init} plus 3mm formed PTV_{init} and GTV plus 3mm PTV_{Boost}. Organs at risk (OAR) were delineated using MRI information adapted to the planning CT.
Intensity modulated photon (IMXT), proton (IMPT) and ^{12}C plans were created using the TPS Monaco (v3.0,Elekta), XiO (v4.41,Elekta) and TRiP98, respectively. For IMXT 6 beams were used for PTV_{init} and 4 for PTV_{boost}. IMPT and ^{12}C plans were created assuming fixed beams, 2 beams from ipsilateral side for PTV_{init} and 2 beams from cranio-caudal direction for PTV_{boost}. Dose matrices for the following combinations were generated: IMXT+IMXT/IMPT/^{12}C; IMPT+IMPT/^{12}C; ^{12}C+^{12}C. Conformity and homogeneity index (CI, HI)(ICRU83), $V_{95\%}$, $D_{2\%}$ and $D_{50\%}$ were investigated for both PTVs and $D_{2\%}$, $D_{50\%}$ and DVHs for OARs.

Results: CI was worst for $IMXT_{init}$ with 0.57±0.03 and higher than 0.72 for IMPT and ^{12}C. HI for ^{12}C was 0.04±0.01, thus 3 times better than for IMXT. No remarkable difference in dose was observed for ipsilateral optical nerve and chiasm. $D_{50\%}$ to the contralateral eye was reduced from 4.2±2.1Gy(RBE) for IMXT+IMXT to 0Gy(RBE) for IMPT and ^{12}C. D50% to the brainstem could be reduced by more than 30 Gy(RBE) for the brainstem and by more than 50% for the ispsilateral eye for ^{12}C as single treatment technique.

Conclusion: Highly conformal IMPT and ^{12}C plans could be generated with a nongantry scenario. Improved OAR sparing favors sole ^{12}C and proton plans, which should be included in future trial design for meningioma patients.

		Session 3 **Chairs: M. Dosanjh, R. Mayer**		
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Abstract 13

HYPOXIA DRIVEN ADAPTIVE TREATMENT PLANNING FOR ION BEAMS: MODEL IMPLEMENTATION AND EXPERIMENTAL VERIFICATION

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Purpose: Hypoxia induced radioresistance of tumors can be contrasted with ion beams through introducing in the optimization task of a treatment planning system (TPS) the possibility to account for oxygen enhancement ratio (OER). Doses and LET components are then rearranged accordingly to restore a prescribed survival level. This can allow an optimal use of spatial oxygenation informations arising, e.g., from PET functional imaging, improving the treatment outcome. This was one of the aim of ULICE WP5.

Materials and Methods: The TRiP98 (TPS for particles) code (1) was extended by allowing to import and process OER tables, either those generated with an original semiempirical model for full pO2 and LET dependence, or given by alternative models. The biological effect calculation and optimization was modified accordingly. Biological dosimetry experiments on extended target irradiation were performed with carbon ions at GSI, using a newly developed chamber for hypoxia irradiation.

Results: The TRiP-OER extension was able to perform forward and inverse planning on differently oxygenated targets, predicting expected survival profiles as well as compensating the dose to restore uniform biological effect, using multiple fields. Experiments return agreement with the predicted profiles. Calculations performed with different ions (oxygen), provide indications for the combined use of different beam modalities (2,3).

Conclusions: The first TPS for particles explicitly including OER is presented. Through biological dosimetry it is it possible to verify the model. The efficiency with only carbon beams as well as the possible advantages of mixed beam treatments are quantitatively discussed.

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Abstract 14

BIOMEDICAL EXPERIMENTS AT CERN BASED ON LEIR

Daniel Abler[1,2], Christian Carli[1], Paul Collier[1], Manjit Dosanjh[1], Adriano Garonna[1], Detlef Kuchler[1], Steve Myers[1], Ken Peach[2], Joshua Stafford-Hayworth[1]

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Purpose

A feasibility study is in progress at CERN to investigate the technical challenges involved in the possible use of the Low Energy Ion Ring (LEIR) to produce ion beams for biomedical research.

In the near future, LEIR will be maintained as a lead (Pb) ion accumulator for LHC and for fixed-target experiments with the SPS. This project proposes an additional secondary use of LEIR as biomedical research facility, in parallel to the on-going LHC operation. Minor changes to the current LEIR infrastructure are envisaged, as well as the creation of a dedicated experimental area in the adjacent South Hall.
The aim of this facility will be to complement the limited research beam-time available at clinical ion beam therapy centres. Partly relying on CERN's competences and existing infrastructure, this facility could provide the research community with relevant beams and dedicated infrastructure in a collaborative and cost-effective way.

This idea was put forward in the ‘Physics for Health in Europe’ conferences in 2010 and 2012 and members of the international biomedical research community had the opportunity to provide their needs for experiments in the fields of radiobiology, dosimetry, medical imaging and medical physics through a brainstorming meeting in June 2012.

The feasibility study foresees several modifications and extensions to the existing LEIR infrastructure. A new ion source and front-end for the production of light ions (hydrogen to neon) are being studied. In order to extract these ions towards the adjacent experimental area, a slow extraction scheme must be implemented in LEIR. This requires the insertion of new extraction elements in the synchrotron without compromising its LHC-related operation. Beam transport lines are being designed for guiding the extracted beam to a horizontal and vertical end station in the experimental area.

An overview of the project and the progress of the design studies will be presented.

Abstract 15

ENTERVISION WP4. DOSIMETRIC PHANTOM DESIGN. PRELIMINARY MONTE CARLO AND EXPERIMENTAL RESULTS

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Purpose:
Development of clinical treatment protocols for radiation therapy is dependent on the availability of information on the biological efficacy of radiation doses. In order to gain robust data, multiple cell irradiation experiments must be performed at different dose points, using a range of cell lines. Therefore, it is important to be able to verify the biological effects of complex dose distributions in homeomorphic phantoms, alongside measurements of physical dose. One of the ENTERVISION projects focuses on the development of a biological dosimetric phantom. At this stage of the project the phantom and desired set-ups are being evaluated.

Status: The phantom was irradiated at CNAO mimicking the patients′ pathway starting with the CT scan, followed by treatment planning and being irradiated. For the irradiation, an uniform dose distribution was delivered with a proton beam and the process was repeated using a carbon ion beam. The dose was measured from pinpoint ionisation chambers readings and the uniformity was assessed with radiochromic films. The experimental results were compared with the TPS and Monte Carlo calculations. Using MC simulations it was also investigated how the simulation of a more detailed geometry would affect the obtained results.

Results: The calculated mean deviation was below 2% for both beams used. This brings the result within the acceptance threshold as desired by CNAO QA procedures.

Conclusion: The experimental results obtained showed good agreement with both TPS and Monte Carlo simulations. The next step will involve the verification of a less uniform beam profile, such as those used in actualpatient′ treatment plans.

Abstract 16

CARBONTHERAPY IN FRANCE: CURRENT AND FUTURE ORGANIZATION OF RESEARCH

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Introduction: Particle Therapy with carbon Ions (PTIC) in France

PTCI projects have been existing in France since the early 2000's with the **ETOILE** medical project and the **ARCHADE** technological project. They have attracted attention and gathered around them research teams at the national scale.

Objectives

These applied research activities were encouraged for the application of public support through a specific program: the Investments for the Future (PIA). Two entangled organizations thus appeared, that embrace all the laboratories, projects and teams involved in hadrontherapy in France. Both are supported by the PIA for 15 and 8 M€, respectively. These organizations are:

- the ***France HADRON*** (FrHA) national infrastructure unifying teams and sites: ETOILE (Lyon) and ARCHADE (Caen) as carbon sites; Centre Antoine Lacassagne (Nice), Institut Curie / ICPO (Orsay) and Institut Claudius Regaud (Toulouse), as proton sites, but also the CNRS/IN2P3 and the IRSN (Radiation protection and nuclear safety institute). FrHA's scientific program is multidisciplinary, including clinical research, modeling and computer simulation, radiation biology and instrumentation.
- the ***PRIMES*** Laboratory of excellence that encompasses all the teams involved in PTCI research in Rhône-Alpes-Auvergne associated with other researchers in experimental radiotherapy and medical imaging.

A third success of the PIA in 2011 has been the support of some specific pieces of equipment in Caen, namely the ***Equipex REC HADRON***. This equipment, open to national and international teams, is shared by ARCHADE (Caen) and different laboratories in Caen and will be devoted to the study of ion beam biological efficiency and fragmentation in the living tissues.

Conclusion

In this way, the former research teams initially gathered in Lyon, then identified in different towns of France, are now included in a larger environment mostly supported by the PIA which most visible piece should be France HADRON. This organization should continue to participate to future European projects that ENLIGHT++ could organize and manage.

Abstract 17

PROOF OF CONCEPT: PAIR – PATIENT ALIGNMENT IMAGING RING

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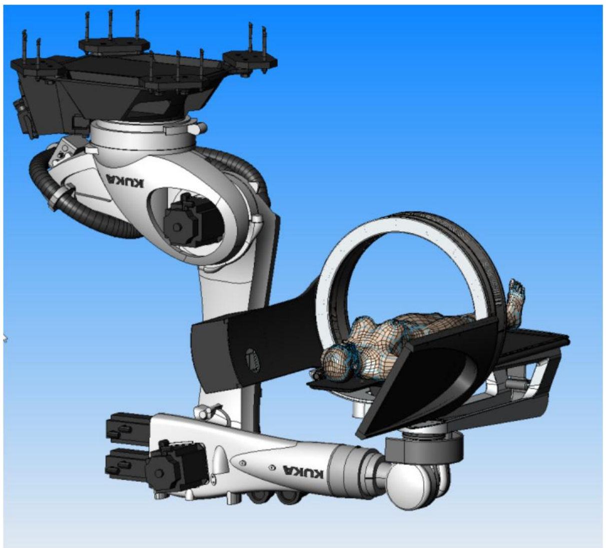
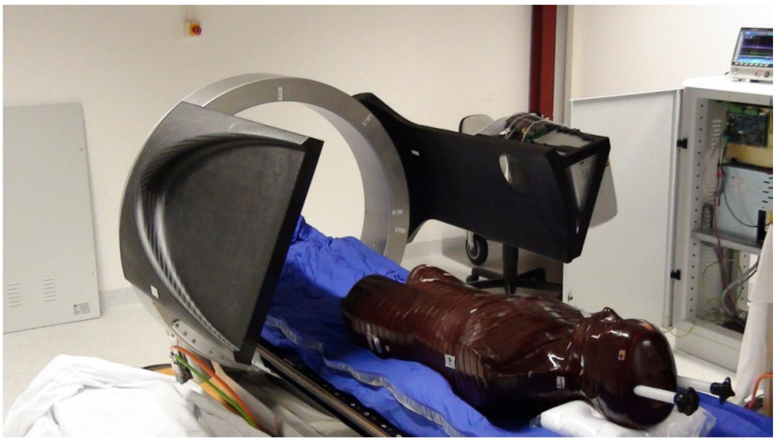
Purpose
To develop and demonstrate the feasibility of a lightweight combined patient alignment (PA) and sliding imaging ring (IR) system for use in cutting-edge in-isocenter patient position verification in particle therapy.

Material and Methods
The system comprises a standard industrial six axis robot carrying a patient table top of variable length. The robot can be optionally combined with a seventh axis to cover extended working space requirements. Mounted on the table top a high-strength aluminum sliding imaging system carries a two-dimensionally collimated x-ray monoblock system and a high-resolution solid state amorphous silicon detector on lightweight and stiff carbon fiber arms. The independently rotatable x-ray source and detector along with the longitudinal degree of freedom enable to track the clinically relevant anatomical sites with sufficient field of view (FOV). A video tracking system integrated within the control system's real-time feedback loop compensates automatically for mass-induced flex of the PAIR system.



Results
The PAIR proof of concept device is able to lift and align patients of up to 200 kg weight. The imaging components offer a maximum acquisition frame rate of up to 30 Hz and a maximum pixel resolution of 0.04 cm/px. The design geometry along with the independently movable source and detector enable fast cone-beam computed tomography (CBCT) reconstruction with a maximum FOV of more than 60 cm in diameter.

Moreover, the x-ray system is able to deliver subsequent pulses with varying energy (40 to 120 kV) and alternating filter insets to form the basis for multi-energy imaging.



Conclusions

The consortium of medPhoton, radART and BEC has successfully proven that an innovative robotic imaging and positioning solution, particularly suited for particle therapy, is feasible. The next big step is to translate the current system into the clinical theater at MedAustron to enrich particle therapy with fast and dose-efficient CBCT, large FOV planar imaging, fast 2D/3D tracking protocols, dual-energy-based soft/dense tissue contrast accentuation and tissue characterization improvements.

Abstract 18

EVALUATION OF RADIATION QUALITY IN ION BEAM THERAPY

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Purpose

Today several facilities perform advanced particle therapy by actively scanned irradiation, using either exclusively protons and or protons or carbon ions. With this procedure it is possible to deliver a radiation which effectiveness is adapted to the characteristics of tumor sub-volumes, and at the same time more effective in sparing healthy tissue and organs at risk surrounding the tumor and in following the moving targets.

Material and Method

The increased accuracy in delivering the irradiation must be complemented with tools that are able to document the radiation characteristic and its effect to the smallest possible size. The strategy is to divide the irradiated volume into sub-volumes and to combine radiation quality (RQ) (through simulations, analytical models, or direct measures) and molecular images capable of assessing, indirectly, acute and late biological effectiveness[a].

Results

MedAustron is participating in the effort to study the possibility of performing microdosimetric measurements of the radiation quality of ion beams before and during the treatment. Different stages of the therapy are potentially affected:

- Pre-clinical studies, where microdosimetric spectra are collected at the same irradiation conditions at which the cell lines are exposed;
- Treatment setup, where co-registration of dosimetric and microdosimetric parameters can be performed in dedicated phantoms;
- During patient irradiation, for those cases where in-beam microdosimetry is feasible;
- Post-irradiation and retrospective studies, using microdosimetric measurements as benchmarks, independent from the treatment facility, to report radiation quality in significant tumor sub-volumes.

In different applications, gaseous or solid-state microdosimeters are options, as for instance the Single Crystal Diamond microdosimeter[b], a result of a research and development study performed by the Austrian Institute of Technology (AIT), ENEA - Centro Ricerche Frascati, EBG MedAustron, and Tor Vergata University.

Conclusions

The main topic of this study is the feasibility of direct radiation quality measurements in these clinical irradiation concerning limitation of use and defining conditions.

References

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