EP-1499
A method to improve VMAT delivery
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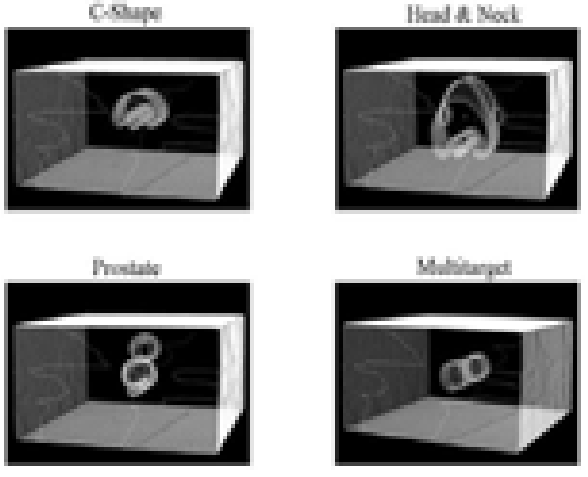
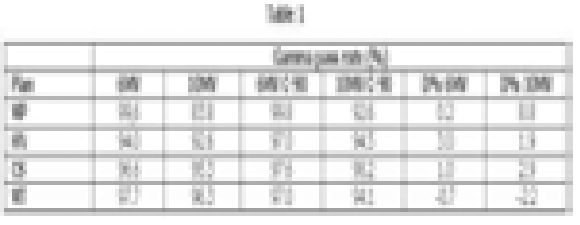
Purpose/Objective: In a standard VMAT treatment the collimator angle is often set to 0° and MLC, dose rate and gantry speed are managed in order to attain the best possible dose distribution in the patient, using goal functions. Such geometry has an intrinsic limit in modulating the dose along the longitudinal direction of the patient related to the resolution of the MLC leaves at the isocentre. MLC with resolution of 1 cm suffers this limit more than MLC with resolution of 5mm or less. More, if the collimator angle is fixed at 0° the inter-leaves leakage is always projected at fixed transversal plans in the patient, and this could generate local unintended extra doses. In this work we investigated the effect of a simple method to improve the modulation capabilities of a commercial low resolution MLC and share the inter-leaves leakage.

Materials and Methods: A LINAC Synergy (Elekta, SW) with a 1 cm MLC resolution (MLCi) was used in this study. VMAT plans, according to AAPM TG119 (Mock Prostate (MP), Head and Neck (HN), C-Shaped target (CS) and Multitarget (MT)), were calculated and optimized on a dedicated cylindrical PMMA phantom surrounding two orthogonal matrixes with 1069 total diodes (Delta4 – ScandiDos, SW), with a Monte Carlo RTPS (Monaco, Elekta, SW) with both 6 and 10 MV photon beams. Sixteen plans were prepared, two for each virtual patient and photon energy: one with 2 contiguous arcs clockwise and counter clockwise (360° each) with the collimator at 0° and a maximum of 150 control points for each rotation and one with the collimator of the arcs alternatively rotated at 0 and 90° (C-90), in order to share the resolution limit of the MLC and the inter-leaf leakage along two orthogonal directions. The two sets of plans were delivered and measured with Delta4 and thus compared with a global 2%-2mm gamma index test, with a 10% of maximum dose threshold.



Results: Table 1 shows results for gamma index for all plans and energies, the percentage difference between gamma results of plans with the rotation of the collimator at 0 and 90 degree (D%) is also reported. D% has a mean value of 0.9 ± 1.6 % for 6MV, and a mean value of 2.9 ± 4.5 % for 10MV.



Conclusions: A gamma index of 2%-2mm easily helps to highlight small differences between planned and delivered dose distributions. Plans with collimator rotation usually have a greater gamma pass rate whenever the modulation begins to be complex. In this contest, MT is an exception being a simple sequence of three cylinders with a homogeneous dose distribution inside and without OARs, forcing high gradients outside the PTVs. This result is related to the better ability in dose reconstruction of the MLC and the inter-leaves leakage shared on the whole volume and not concentrated in single areas. These differences seem to be more evident in more complicated plans and suggest implementing the rotation technique in searching a better agreement between measured and planned dose distribution when possible.

EP-1500
Impact of patient-applicator air-gap in dedicated mobile accelerator for Intra-Operative Radiation Therapy
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Purpose/Objective: During Intra-Operative Radiation Therapy (IORT), the electron beam is collimated by an applicator towards the patient tumor bed. Air-gap distance from the end of the applicator to the target region, defined during the surgery, changes for one patient to another depending on treatment conditions. However its effect and the need of avoiding it using a bolus remain yet to be established. Full Monte Carlo (MC) simulations of a dedicated mobile accelerator, LIAC® (SORDINA, Italy), were performed to study the impact of the air-gap on patient dose distributions.

Materials and Methods: Experimental data from a LIAC® accelerator were acquired for energies of 6, 8, 10 and 12 MeV and for 3, 4, 5, 6, 8 and 10 cm diameter applicators in a water phantom, to validate the full MC simulation. Depth dose curves and transverse dose profiles were acquired with a flat ionization chamber and an electron diode (IBA), respectively, with an air-gap of 3 mm to avoid water from the phantom flowing up the applicator due to capillarity.
The LIAC® accelerator was simulated in detail with penEasy [1] for energies from 6 to 12 MeV and all applicators sizes, without air-gap. Experimental depth dose curves were employed to fit, by means of a genetic algorithm [2], one energy spectrum for every energy, to be employed for all applicators. MC simulations were computed in a cluster whit 200 cores, which allowed us to simulate within 24 hours dose distributions with enough statistics. Once the LIAC® simulations are tuned, dose estimates in water were obtained for several air-gap distances: 1, 2, 3, 4 and 5 mm.

Results: The 12MeV energy spectrum that we generated is similar to the onepresented by Iaccarino et al. [3]. Dose distributions computed withpenEasy are in good agreement with experimental data. The simulationspredict depth dose curves and transverse (at depths larger than 1 cm)dose profiles with deviations from the measurements of less than 1% ofthe maximum dose.
MC dose distributions with various air-gap valueswere compared to measurements with 3 mm air-gap. The dose differencebetween the experimental profile and the profiles simulated withoutair-gap or with 5 mm air-gap are respectively 4%, and 1.5% of themaximum dose. Those transverse dose profiles are represented in Figure1 which shows that the 5 mm air-gap simulation best describes themeasured profile.

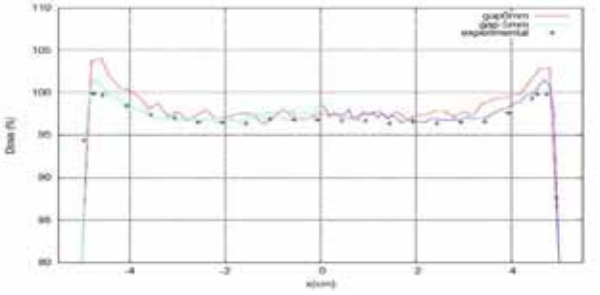

Figure 1: PenEasy simulated transverse dose profiles without gap and with 5 mm air-gap compared to experimental dose profile acquired with 3 mm air-gap.

Conclusions: We developed a tool which allows us to fully simulate with penEasy a dedicated mobile accelerator with good accuracy for several energies and applicator sizes and employed it to study the effect of air-gap size. This air-gap study shows that it may have an impact on dose distributions at the 3-4% level of the maximum dose, especially on the edge of the shallowest transverse dose profiles.

References:
[1] J. Sempau et al. 2011. Med. Phys. 38(11), p. 5887.
[2] C. Fernández-Ramírez et al. 2008. Phys. Rev. C. 77(6), p. 065212.
[3] G. Iaccarino et al. 2011. Phys. Med. Biol. 56(14), 4579-4596.

EP-1501
Evaluation of a prototype in vivo dosimetry device
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Purpose/Objective: Evaluation of the sensitivity in error detection of the Delta^4 AT (ScandiDos, Sweden) prototype in vivo dosimetry device. The device consists of a 2D array of diodes mounted to the head of the linear accelerator. The diodes have a spacing of 5mm in the direction parallel to MLC travel and 2mm perpendicular to MLC travel when projected to the isocentre.

Materials and Methods: 6 clinical VMAT plans (Eclipse, Varian Medical System, USA) for treatment sites including head and neck, anus, brain, pancreas, oesophagus and a superficial temporal lesion were measured. For each case, initial plan normalisation was increased by 1%, 2% and 4% to measure the sensitivity of the Delta^4 AT device to machine output. To verify MLC leaf position, a sag of 2mm was introduced into the MLC leaf bank for each clinical case. The Delta^4 AT measurement device was attached to the head of a Trilogy (Varian) linear accelerator and the Delta^4 PT (ScandiDos, Sweden) was positioned on the treatment couch. The Delta^4 AT was calibrated for each case by irradiating the Delta^4 PT and Delta^4 AT devices concurrently. A second control measurement was made only with the Delta4 AT to test the stability of the device. Subsequent measurements of introduced error plans were made with the Delta^4 AT device only. Results were evaluated using the Delta^4 software and the Gamma Agreement (GI) scores (3%/3mm) were calculated. For MLC and output error analysis, the average GI score, maximum GI and mean dose difference (DD) were then compared to the Delta4 AT control measurement.

Results: There was excellent agreement between the Delta^4 PT and Delta^4 AT (GI =100% ±0.1%). A 1% output increase resulted in a GI=99.9% ±0.1%, 2% GI=99.8% ±0.2%, and 4% GI=65.6% ±14.9%. Average GI score increased by 0.2 ±0.0 for 1%, by 0.3 ±0.1 for 2% and by 0.7 ±0.1 for 4%. The Max GI score increased by 0.8 ±0.7 for 1%, by 1.2 ±0.5 for 2% and 1.6 ±0.2 for 4%. The DD median increased linearly with output variation and was detected with an accuracy of less than 0.2%. Dosimetrically, the MLC leaf sag plan showed no significant difference to the control plan (GI =99.8% ±0.4%). After changing the distance to agreement to 1.5mm the pass rate dropped by at least 5%.

Conclusions: We have found that the Delta4 AT device is sensitive to variations in machine output and MLC positional error.

EP-1502
High resolution portal image prediction for radiotherapy treatment verification & in vivo dosimetry
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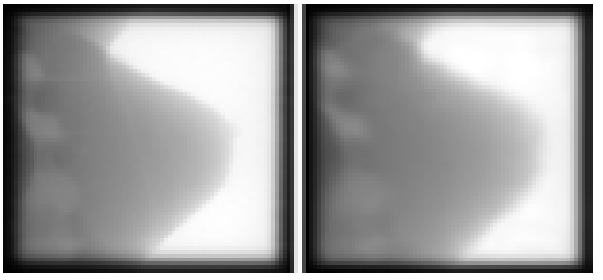
Purpose/Objective: Historically designed as a control system for patient positioning for radiotherapy treatment, Electronic Portal Imaging Devices (EPIDs) are nowadays widely used for quality assurance and dosimetric verifications in new irradiation techniques. One of the main advantages of the EPID is its high resolution which can detect small details. The objective of this study is to compare the EPID image acquired during the treatment with a predicted high resolution portal image computed by Monte Carlo (MC) simulation. A new method for prediction of high-resolution EPID images is tested for *in vivo* treatment verification.

Materials and Methods: Experiments were carried out on a Siemens ARTISTE™, equipped with a 160-MLC™, and its Siemens Optivue™ 1000 EPID. This EPID has an active detection area of 41 x 41 cm^2 and a matrix of 1024 x 1024 pixels. A model of this linac and the EPID was developed with the MC code Penelope, and commissioned. We focus on a breast treatment conformational beam (6 MV) on the CIRS adult female phantom. The CT-scan of the phantom was used as input, and Hounsfield numbers were converted in density and atomic composition, so as to obtain a voxelized geometry used in the Penelope code. Particles exiting the phantom and impinging on the EPID are simulated up to the EPID in order to compute the predicted portal image by scoring the energy deposited in the phosphor layer on a 1024 x 1024 virtual grid. The simulated image was then smoothed using a denoising algorithm in order to keep the high resolution advantage. Several denoising algorithms were tested, among them IRON, LASG and a recently developed one called DPGLM. For now, we use the gamma-index technique to evaluate the accuracy of the simulated image against the experimental one.

Results: Figure 1 shows the acquired image and the simulated one. The gamma-index is satisfied for 94.4 % of the pixels for 3.5 % and 3.5 mm criterion. The DPGLM gives the best result toward accuracy and computed time. Indeed, the denoising of 1024 x 1024 images takes about 1h30 mn, 2h and 5 mn using DPGLM, IRON, and LASG, respectively. The LASG algorithm is really fast but the result is too smoothed for the high resolution purpose.



Conclusions: This work is the first step in the aim of in vivo dosimetry by comparing experimental portal images with high resolution predicted images obtained using MC simulations in a voxelized geometry. First results obtained on a breast treatment are encouraging, and we can expect to detect treatment errors.

EP-1503
The effect of the frequency of absolute dose calibration on the performance of ArcCHECK in helical TomoTherapy DQA
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Purpose/Objective: A cylindrical diode array detector system, ArcCHECK (Sun Nuclear Corp., US), has been widely used for delivery quality assurance (DQA) of patient treatment plans in radiotherapy. The system required two calibration procedures: the array calibration that measures the sensitivity of each detector, and the absolute dose calibration that generates a dose calibration correction factor that is applied to all detectors to convert the relative dose values to absolute dose values on the ArcCHECK. The array calibration is not treatment machine specific and is recommended to perform every one to three years, while the absolute dose calibration is specific to each machine and energy. This study aim to investigate the effect of different absolute dose calibration of ArcCHECK on DQA in two helical TomoTherapy over a period of one year.

Materials and Methods: Patients with variety of malignancies DQA plans were created using TomoTherapy treatment planning station with the target situated at the center of the ArcCHECK. Dose calibration correction factors were measured at different intervals over a period of one calendar year on two TomoTherapy machines (TomoHD). The study can be divided into three phases. Phase I: the absolute dose calibration was performed every week for three months, and each calibration factor was applied to 12 DQA plans for evaluating the gamma passing rate calculated from the comparison of the measured and calculated dose distribution. Phase II with the absolute dose calibration performed every two weeks for another three months, and the gamma passing rate of 18 DQA plans were evaluated by applying the 12 dose calibration correction factors obtained biweekly over the past 6 months. Phase III with the absolute dose calibration performed monthly for another 6 months, and data of 25 DQA plans were evaluated by applying the 12 dose calibration correction factors obtained monthly. The mean, standard deviation and coefficient of variation of the gamma passing rates for each DQA plan were then calculated for each phase for analysis.

Results: The gamma criteria, dose difference/distance to agreement 3%/3 mm, were used to evaluate the DQA plans. The results shown that by applying different dose calibration correction factors on each plan, the mean gamma passing rate is consistent and ranged from 91.8% to 100.0%, with the maximum coefficient of variation of 0.03 for all three phases on both TomoHD machines (see table). It was found that a DQA plan with lower gamma passing rate seems to be more sensitive to the dose calibration correction factor than a DQA plan with high gamma passing rate.