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Purpose/Objective: Range uncertainties in proton therapy can be reduced using in-vivo range verification based on prompt gamma (PG) imaging. In pencil beam scanning, PG emission can be measured for all pencil beams of the treatment and compared to the treatment planning in order to detect potential range discrepancies. This study proposes a strategy to analyze the large amount of PG profiles acquired during treatment using a priori simulations.
Materials and Methods: Pencil beam scanning treatments were planned on an anthropomorphic phantom. Brain, nasal cavity and lung cases were included in the study. The treatments were delivered to the anthropomorphic phantom at the Proton Therapy Center in Prague, and PG monitoring was performed using a knife-edge slit gamma camera. Both single fraction (2 Gy) and full treatment at once (60 Gy) were delivered and measured. A dedicated analytical PG simulator was used to compute the expected PG profiles for all pencil beams of the treatment in the planning configuration. Several scenarios, corresponding to several possible sources of range discrepancy (i.e. setup errors, CT calibration errors and energy errors), were simulated as well. The corresponding range shifts were computed based on CSDA approximation in order to estimate the range sensitivity. Moreover, the range shifts were estimated from the simulated profiles using a range retrieval method. The difference between CSDA-based shifts and shifts estimated from the simulated PG profiles defined the expected systematic error in range retrieval for each pencil beam. The actual range was then estimated based on the comparison of measured and simulated profiles. The range shifts were also retrieved from the comparison of 2 Gy and 60 Gy acquisitions in order to evaluate an occurrence of the random errors. In order to improve range assessment, a selection of the most reliable pencil beams was done based on weight and expected systematic errors.
Results: Realistic treatments were successfully delivered to an anthropomorphic phantom and monitored using the PG camera. Using all pencil beams, the average systematic range shift extracted from the comparison of the 60 Gy acquisition with the simulation were of 4.1, 5.8 and -4.0 mm for brain, nasal cavity and lung, respectively. The average random error was of 2.4, 4.5 and 2.2 mm. When selecting the pencil beams whose weight was higher than 0.3 MUs and whose systematic error was smaller than 1 mm, the systematic range shift was 4.1, 6.8 and -3.2, and the random errors went down to 1.6, 1.9 and 2.2 mm.

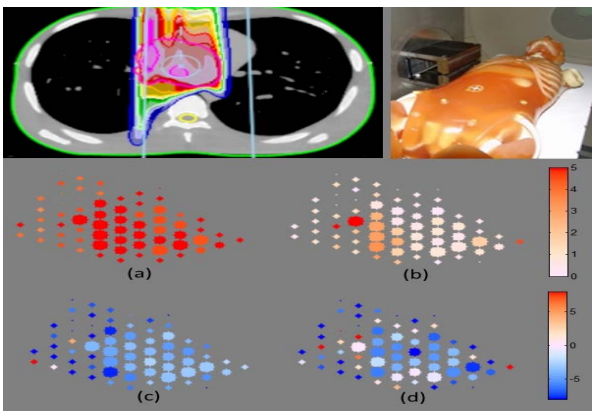

Figure: Treatment plan (top-left), experimental setup (top-right), and range analysis on first energy layer (bottom): (a) range sensitivity to energy variations of +/- 3 MeV on first layer; (b) systematic error on range retrieval for energy variations; (c) range shifts from 60 Gy acquisition; (d) range shifts from 2 Gy acquisition. The size of the spots is proportional to their weight.
Conclusions: The first prompt gamma-based range monitoring of realistic proton pencil beam scanning treatments on an anthropomorphic phantom were successfully conducted and a strategy to extract range discrepancies was proposed.

PD-0379

Reducing the dose-rate dependence of a new radiochromic silicone based 3D dosimeter

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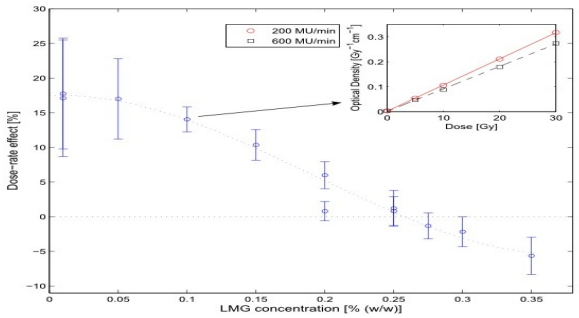
Purpose/Objective: Radiochromic 3D dosimetry has great potential for verification of complex treatment techniques such as adaptive radiotherapy and proton therapy. However, the response to irradiation is often dependent on dose-rate, which can limit their use in clinical environments. Recently, we have developed a radiochromic silicone-based 3D dosimeter, where the first generation of the dosimeter had an issue with dose-rate dependency. However, by changing the chemical composition of the dosimeter, we have in this study reduced the dose-rate dependence to a clinically acceptable level.
Materials and Methods: The silicone-based dosimeters were produced by mixing leuco-malachite green (LMG) dye as the active component, 1 % (w/w) chloroform as the initiator and a silicone elastomer as the host matrix. All dosimeters were left to cure for two days at room temperature. Thereafter they were irradiated with a linac to doses in the range 0-30 Gy, in a 10 cm square field and with a beam quality of 6 MV. During irradiation they were placed at SSD 94.5 cm between two 5 cm slabs of solid water. Experiments were performed at dose-rates of 200 MU/min and 600 MU/min for a series of dosimeters with different LMG concentrations. The dosimeters were then read-out using a spectrophotometer at 627 nm before and after irradiation to obtain the change in optical density (Δ OD) caused by the irradiation. Δ OD was plotted as a function of dose and fitted to a linear expression with the slope giving the dose response. The dose-rate dependence was then expressed as the percentage difference between the dose responses of the two dose-rate measurements, relative to the 200 MU/min measurement.
Results: The dose-rate dependence was greatly reduced with increasing dye concentration (Figure). Below 0.05 % (w/w) LMG it was observed to be around 17 %, while it was eliminated in dosimeters containing 0.25 % (w/w) LMG. For higher dye concentrations the dose-rate dependence was reversed. Similar observations were made for dosimeters with 5 % (w/w) chloroform.
The stability of the dosimeters was found to decrease linearly with increasing LMG concentration, with a 50 % decrease within a day for a concentration of 0.2 % (w/w) LMG. In addition, at the highest concentrations precipitation was observed within days to weeks after production.



The dose-rate effect as a function of LMG concentration for dosimeters containing 1% chloroform. The insert shows the measured dose responses for a dosimeter containing 0.1% LMG and 1% chloroform which were irradiated with 600 MU/min and 200 MU/min. The percentage difference between the slopes of the linear fits is depicted in the primary graph as the dose-rate effect. At low LMG concentrations the dose response is higher for 200 MU/min, but at higher LMG concentrations the 600 MU/min response is slightly higher.

Conclusions: This study shows that the radiochromic silicone based 3D dosimeter is dose-rate independent with 0.25 % (w/w) LMG and 1 % (w/w) chloroform. This greatly enhances its usability in clinical environments, however, the decreased stability of the dosimeter due to the increased LMG concentration must be carefully considered.

PD-0380

FFF pre-treatment QA using TrueBeam Portal Dosimetry with DMI panel and comparison with PTW Octavius 1500

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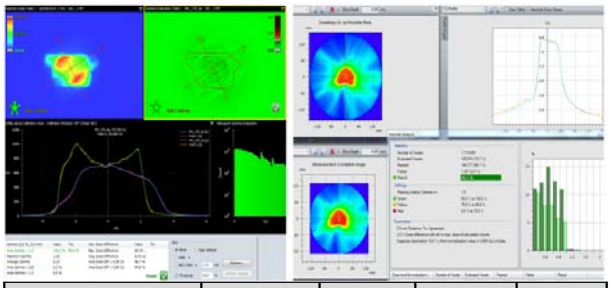
Purpose/Objective: The new DMI MV imaging panel with Eclipse/Aria permits measurements of FFF integrated images and configuration of the Portal Dosimetry algorithm ('PDIP') for QA of IMRT and Rapid Arc ('RA') treatment plans. This study evaluates the commissioning procedure for the Portal Dosimetry ('PD') system for FFF energies and the resulting implementation for IMRT and RA pre-treatment QA. To evaluate the accuracy and performance of the PD system, measurements were also performed using the new Octavius 1500 system.

Materials and Methods: A Varian TrueBeam equipped with HD-MLC and the new DMI imager was used to configure and evaluate the PDIP algorithm. The DMI panel has high resolution imaging capabilities and together with the new version of Eclipse/Aria (V.13) allows for configuration of the PDIP for use with FFF energies. The PDIP was configured for use at 100 cm SDD by measuring the imager output factors and an ideal fluence provided by Varian. The 6 MV was used as the standard for performance evaluation of the imager and PD configuration for the 6 and 10 FFF energies. Measured output factors, open fields, and test complex fluences were compared to those predicted by the PDIP to validate the configuration. Test IMRT and RA plans were measured and analyzed using the PD software. A further evaluation of the PD was performed by repeating fluence and test plan measurements on the new Octavius 1500 array system. The array was commissioned with solid water plates and also inserted in the cylindrical rotational polystyrene phantom (Octavius 4D). The latter setup was used with an inclinometer to assess the agreement between measured and planned doses and for comparison with results obtained on the PD. Volumetric (3D) and planar (2D) gamma analysis are available for the reconstructed dose volume to check the dose in a volume or in a plane, respectively. All fluences and test plans were analyzed using the gamma criteria of 2%-2mm and 10% dose threshold.

Results: The PDIP algorithm showed agreement within <1% between the measured and calculated output factors for 6 MV and 6 FFF and within <1.5% for 10 FFF. The open field and test fluences on the PD system resulted in a gamma passing criteria >99.0% and >97.2%, respectively. The test IMRT plans resulted in gamma analysis >99.2% (<γ>=99.7±0.4%) on the PD, >96.5% (<γ>=98.0±1.6%) on the Octavius with 2D analysis, and >97.1% (<γ>=97.5±0.5%) on the Octavius with 3D analysis. The test RA plans resulted in a gamma analysis >97.0% (<γ>=99.0±1.2%) on the PD and >97.8% (<γ>=99.0±0.7%) on the Octavius with 3D analysis (Figure: 10FFF RA;Table: RA analysis).



RAPID ARC TEST PLAN	Treatment	Energy	QA TOOL	Gamma
06X_RA_AAA	Prostate	6X	PortalDos.	97.4%
			Octavius	98.2%
06F_RA_AAA	Prostate	6 FFF	PortalDos.	99.9%
			Octavius	97.9%
10F_RA_AAA	Prostate	10 FFF	PortalDos.	100.0%
			Octavius	99.1%
06X_RA_AAA	Head&Neck	6 MV	PortalDos.	99.4%
			Octavius	99.5%
06X_RA_Acuros	Head&Neck	6 MV	PortalDos.	99.7%
			Octavius	99.3%
06FFF_RA_AAA	Head&Neck	6 FFF	PortalDos.	99.5%
			Octavius	99.6%
06FFF_RA_Acuros	Head&Neck	6 FFF	PortalDos.	97.1%
			Octavius	99.3%

Conclusions: The Portal Dosimetry system for the TrueBeam with DMI imager can be used for IMRT and RA pretreatment QA verification for FFF energies. The results obtained with the PD were comparable to those obtained with direct measurement equipment such as the PTW Octavius 1500. The PD system has higher resolution and measurement points which could have resulted in a slightly higher gamma analysis passing rate when compared to the Octavius.

PD-0381

Evaluation of a new Electronic Portal Imaging Device (EPID) for pre-treatment and in vivo dosimetry

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Purpose/Objective: This work evaluates the potential of the new aS1200 EPID (Varian Medical Systems) for pre-treatment and *in vivo* dosimetry (IVD) applications.

Materials and Methods: Measurements were performed using one aS1200 and an older aS1000 unit, both mounted on matched TrueBeam linacs. Comparative specifications are in Table 1.