1.371 for the 6MV beams, TrueBeam and Versa HD, respectively. The same figure for the 10MV beams were 1.484-1.524, and 1.501-1.543. Concerning beam penetration, TPR20,10 for 6 and 10 flattened and FFF TrueBeam beams were: 0.665, 0.629 (6MV) and 0.738, 0.703 (10MV), while for Versa HD beams are: 0.684, 0.678 (6MV) and 0.734, 0.721 (10MV).

Conclusion: Renormalization factor and unflatness parameters proved to be efficient to describe the FFF beam characteristics. Renormalization factors here presented could be used for all TrueBeam and Versa HD beams, without the need of recalculate them for the site specific conditions.

PO-0810

Implementation of Normalised Dose Difference method for evaluation of VMAT Monte Carlo QA

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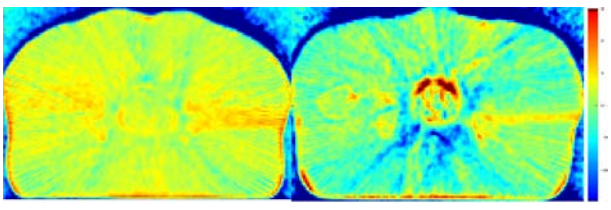
Purpose or Objective: Monte Carlo calculations are increasingly applied as an independent QA tool for pre-treatment verification of patient plans for complex treatment delivery techniques such as VMAT. The dose obtained is usually imported to the treatment planning system for further analysis. The analysis can encompass visual comparison of dose distributions as well as qualitative and/or quantitative comparison of Dose Volume Histograms for specific structures. More sophisticated quantitative comparison in 3D includes gamma analysis combining dose difference and distance-to-agreement evaluation generating pass/fail maps. The normalized dose difference (NDD) method is considered to be an extension of the gamma-index concept including locally defined, spatially varying normalization factors. The NDD is reported to be insensitive to the dose grid size. Also, it shows which dose distribution has a higher value at the comparison point (has a sign).
The objective of the work is to test the applicability of the NDD method in the Monte Carlo pre-treatment QA procedure, as well as to develop a stand-alone module which will include visual and quantitative analysis.

Material and Methods: Monte Carlo simulations were performed using the EGSnrc/BEAMnrc code system with modifications, capable to compute dose distributions due to a continuously moving gantry, dynamic multileaf collimator and variable dose rate (I.A. Popescu and J. Lobo, Radiother. Onc.2007). A Monte Carlo model of a Varian Clinac iX accelerator was used. Patient treatment plans were generated by Eclipse treatment planning system (Varian Medical Systems, USA) and calculated by the AAA algorithm. NDD formalism has been applied in Matlab (Mathworks®) as described in (Jiang SB, et al. Phys Med Biol 2006).

Results: Dose distributions for patients in different anatomical regions have been obtained; pelvic and head and neck. Example of NDD analysis for a prostate cancer is shown in the figure.



A 3%, 3 mm tolerance criteria is used. The colour scale varies from ±3%, i.e. the region of acceptance. Negative values indicate that the Eclipse dose (AAA) is lower than the Monte Carlo calculated dose. The Monte Carlo simulations include the air surrounding the patient. Therefore the NDD values outside the patient are negative. All the NDD values are within tolerance on the left transversal slice, i.e. there is agreement between Monte Carlo and AAA. On the right transversal slice, the AAA shows higher target dose in small ventral regions and lower dose at some points in the risk organ (rectum). In general the pass-rate observed is > 95%. A slight dominance of the Monte Carlo dose has been observed in the NDD statistics expressed as a shift of the maximum in the NDD distribution.

Conclusion: The NDD method can give important information for pre-treatment verification of VMAT plans, which is complementary to the dose analysis in the treatment planning system.

PO-0811

Patients in vivo skin dosimetry using the Exradin W1 plastic scintillator for proton therapy

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Purpose or Objective: To evaluate the usefulness and accuracy of a commercially available plastic scintillator (Exradin W1) for use in *in vivo* proton therapy skin dosimetry.

Material and Methods: Six patients undergoing passive scatter proton therapy for prostate cancer were enrolled in an IRB approved protocol. The Exradin W1 plastic scintillator was used to measure *in vivo* skin dose by attaching the detector to the patient's skin at the central axis of each treatment field (2 laterally opposed treatment fields). Measurements were acquired once per week for the entire treatment course resulting in a total of 93 measurements. The detector was first calibrated on a Cobalt-60 unit, and phantom measurements in the proton beam with the W1 and a calibrated parallel plane ion chamber were used to account for the under-response due to ionization quenching. The average dose difference between the Exradin W1 *in vivo* dose and parallel plane ion chamber in phantom dose over all measurement and per-patient was computed, as well as standard deviations. Furthermore, dose extracted from the treatment planning system was compare to the parallel plane ion chamber. Finally, baseline stability measurements in the cobalt unit were performed weekly for the duration of the study.

Results: The calibrated detector exhibited a 7% under-response for 225 MeV proton beams. The temperature under-response was 4% when used at 37° C (relative to the response at the calibration temperature of 20° C). The detector exhibited a stable response and was within 1% for the duration of the study (144 days). The average dose difference between the Exradin W1 and parallel plane ion chamber over all patient measurements was 0.27 ± 0.67% after applying the temperature and quenching correction factors. The dose difference between the Exradin W1 *in vivo* measurements and parallel plane ion chamber for all six patients treatment fields throughout the study were all within ± 2% with a standard deviation of 0.67% (see figure 1).

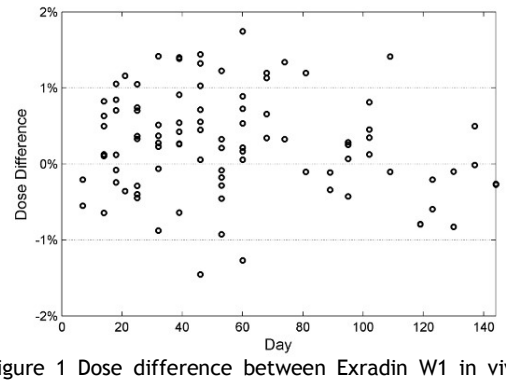

Figure 1 Dose difference between Exradin W1 in vivo dose and parallel plane ion chamber dose for every patient during the study.

Conclusion: The Exradin W1 exhibited a high level of accuracy for *in vivo* skin dosimetry measurements in passively scattered proton beams. The quenching correction and temperature corrections are easy parameters to extract. The detector will be useful as a verification tool for proton therapy patients because plastic scintillators are water equivalent, very small detectors (2mm diameter), accurate, and durable.

PO-0812

Dosimetric accuracy of TPS algorithms for actively scanned proton beams and small target volumes

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Purpose or Objective: To evaluate the accuracy of different lateral proton beam spreading models of two commercially available treatment planning systems (TPS) in optimizing proton pencil beam dose distributions for small targets located at increasing depths in water.

Material and Methods: The TPSs analytical algorithms were benchmarked against experimental data and the FLUKA Monte Carlo (MC) code, previously validated for the selected beam-line. We tested the Siemens Syngo and the RaySearch RayStation TPS plan optimization modules for water cubes, by fixing the configurable parameters at clinical standards, with homogeneous target coverage to a 2 Gy (RBE) (Relative Biological Effectiveness) dose prescription as unique goal. An RBE of 1.1 has been used. For shallower targets requiring a range shifter, two different approaches were adopted with Syngo: A) the passive absorber was numerically accounted for its water equivalent thickness only and a single Gaussian approximation was considered for the lateral evolution of the beam; B) the passive absorber was contoured as a body included in the TPS calculation volume, where a double Gaussian modeling for the beam lateral spread is applied. Case B served to directly compare Syngo with the RayStation strategy of accounting the range shifter as a part of patient geometry during pencil beam tracing. Transversal and longitudinal profiles, acquired across target centers, were compared and a γ-analysis was performed within each volume between TPS and MC. Optimized plans were delivered and the dose at each volume center was measured in water with a calibrated PTW Advanced Markus chambers. An EBT3 film was also positioned at the phantom entrance surface for the acquisition of 2D dose maps.

Results: Discrepancies between TPS calculated and MC simulated values were mainly due to the different lateral spread modeling and resulted to be related to the field-to-spot size ratio. Severe limitations were found for Syngo configuration A (clinical scenario), when planning on very small and shallower cubes. The high level of agreement shown between MC and Syngo configuration B and RayStation, regarding these challenging targets, supported the hypothesis that the use of a single Gaussian beam model is one of the main sources of dose deviations for superficial volumes. No major discrepancies were registered in all cases analyzed, either at the volume center or in the penumbra region.

Conclusion: The accuracy of the TPSs was proved to be clinically acceptable in all cases but very small and shallow volumes, when a poor beam lateral spreading model is used (single Gaussian). Satisfactory dose calculation accuracy could be achieved by using either a double Gaussian parameterization or the RayStation version of this algorithm, separately handling the nuclear halo effect, for range shifter modeling in the TPS. In this contest, the use of MC to validate experimental results proved to be a reliable procedure for pre-treatment plan verifications.

PO-0813

Assessing the quality of proton PBS delivery: log file analysis of every treatment at PSI Gantry 2

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Purpose or Objective: Pencil beam scanning (PBS) proton therapy requires the delivery of many thousand proton beams, each modulated for position, energy and dose, to provide a highly conformal patient treatment. The quality of the treatment is dependent on the delivery accuracy of each beam and at each fraction. In this work we describe the use of treatment log files, which are a record of the machine parameters for a given field delivery on a given fraction, to investigate the integrity of treatment delivery compared to the nominal planned dose, for all clinical patients treated at Paul Scherrer Institute on Gantry 2.

Material and Methods: The dosimetry-relevant log file parameters are used to reconstruct the 3D dose distribution on the patient anatomy, using a TPS-independent dose calculation system developed at our institute and experimentally validated previously. The analysis was performed for all clinical treatments, both for individual fields and per series, and delivery quality was assessed by comparing the log file dose to the TPS dose, in particular by determining the percentage of voxels within +/- 1% of the nominal dose, as well as gamma index using 1% and 2mm criteria.

Results: The mean +/-1% pass rate on the series-level is 96.4%, though individual fields showed larger variations in pass rate. Furthermore, this work establishes a correlation between the delivery quality of a field and the beam position accuracy. This correlation is evident for all delivered fields regardless of individual patient or plan characteristics. We have also detailed further implementation of log file analysis within our clinical workflow, including the clinical evaluation of patient delivered dose from a problematic fraction delivery, the discovery and diagnosis of systematic issues in treatment planning or delivery workflow, extra TPS quality assurance, and the trending of machine performance following repairs or upgrades.

Conclusion: We have demonstrated the usefulness of treatment log files in PBS proton therapy, particularly in regard to assessing the quality of daily treatment delivery by calculating 3D dose distributions on the patient anatomy and comparing it to the nominal TPS dose. We have presented the results of this analysis for every patient field and series delivered thus far on Gantry 2. Additionally, we have shown that the integrity of treatment delivery is highly correlated with the accuracy of spot position and believe this will be useful for driving machine performance improvements in the PBS field.

PO-0814

Beam quality and perturbation factors of Farmer chambers in magnetic fields

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Purpose or Objective: Hybrid MR-Radiotherapy devices combine radiation treatment and excellent soft tissue contrast imaging, which does not deliver any additional radiation dose to the patient. The permanent magnetic field of the MRI is known to deflect the electrons during irradiation, influencing the dose response of ionization chambers [Meijsing 2009]. This work investigates the effect of the magnetic field on the beam quality and the perturbation factors for six customized Farmer chambers with different sensitive volumes.