**Conclusions:**

Agreement between measured and calculated dose distributions. The dose verification in the heterogeneous phantom revealed good calculation times for a typical treatment plan are about 5 minutes.

**Small field dosimetry in Flattening Filter Free (FFF) beams:**

Small field dosimetry in flattening filter free (FFF) beams: OC-0065

Simpson S, Weston D, Thwaites D, McKenzie D, Suchowerska N

The media as well (an alternative is to express doses in water). The transport was done in the proper media and doses are expressed in the media as well (an alternative is to express doses in water). The calculation times for a typical treatment plan are about 5 minutes. The dose verification in the heterogeneous phantom revealed good agreement between measured and calculated dose distributions.

**Conclusions:**

A novel radiotherapy treatment planning system for small animals was developed and validated. The system may play an important role in pre-clinical translational studies.

**OC-0065**

Small field dosimetry in flattening filter free (FFF) beams: comparison of diode, film and scintillation dosimeters

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**Purpose/Objective:**

Flattening filter free (FFF) beams can improve the delivery of radiotherapy treatments by reducing treatment times. The delivery of stereotactic treatments, in particular, can greatly benefit from FFF beams. The combination of high dose per fraction combined with patient immobilization can result in long periods of patient discomfort. However, the small treatment fields used in stereotactic treatments and the changes in beam spectrum and scattering conditions that occur with a FFF beam provides challenging conditions for accurate dosimetry. This study aims to assess the performance of a range of dosimeters in an FFF beam with particular attention focused on small field dosimetry. The dosimeters used were: an ionisation chamber; diodes; an air core fibre optic dosimeter (FOD) and EBT2 film.

**Materials and Methods:**

The beam output ratios (OR) for fields as small as 0.5 cm, were measured at depths of 5 cm and 10 cm in water with all detectors. Measurements were performed on the Elekta Synergy and the Varian Trubeam at a nominal 6 MV. The response of various detectors at small fields was compared between flattened and FFF beams, as well as to measurements on the Varian Novalis which uses a smaller stereotactic flattening filter.

**Results:**

For all linacs, the FOD agreed with the EBT2 film within measurement uncertainty for all field sizes, in both flattened and FFF beams. In the flattened beam, diode detectors showed an overresponse at small fields, as predicted in the literature (Ralston 2012, McKerracher 1999). For the smallest field, the OR measured with a PTW diode was 4.4% higher than that measured with the FOD. For the same irradiation in an FFF beam, however, the expected overresponse was not observed. The PTW diode instead showed an underresponse of 2.0% relative to the FOD.

**Conclusions:**

These results support the conclusion of Scott (2012), derived from Monte Carlo simulation, that density correction factors for specific beam conditions may not be applicable to other beam conditions. Diode correction factors derived on-axis for flattened beams at a particular depth may not be applicable off-axis, for FFF conditions or at other depths.

**OC-0066**

Detector comparison for small field output factor measurements with flattening filter free photon beams

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**Purpose/Objective:**

Flattening filter free (FFF) photon beams offer various advantages compared to flattened (FF) beams, e.g. a higher dose rate, reduced head scatter and leakage radiation. Forms of applications of FFF-beams are the treatment of tumors with small volumes in a hypofractionated stereotactic setup and the treatment of concave shaped tumors using IMRT or VMAT. For both, an accurate determination of output factors is mandatory. Therefore, influence of filtering on the measurement of output factors was investigated in this study.

**Materials and Methods:**

Several different ionization chambers and solid state detectors were investigated for small field dosimetry. An Elekta Precise Linac (Elekta, Crawley, UK) which is able to produce 6MV and 10MV FF and FFF photon beams was used in this study. The fields were shaped by a BrainLab M3 μMLC (BrainLAB AG, Heimstetten, Germany). The detectors were mounted in a Blue Phantom (IBA dosimetry, Germany) at SSD 95 in 5cm depth. For this study 10 different square fields between 10x10cm² and 0.6x0.6cm² were investigated. All detectors were pre-irradiated with 1000MU. For each field 5 x 100MU were delivered. A Bragg Peak chamber (PTW, Germany) with its entrance window positioned at the water surface was used to verify the Linac output. The measured output factors were corrected for volume averaging effects which were determined in collaboration with the IAEA. Within this collaboration, output factors measured with the CC01 were compared to alanine dosimeters which agreed within 1% for all investigated field sizes. Hence, the measured output factors were normalized to those of the CC01.

**Tab. 1. Summary of detectors used for output factor measurements.**

<table>
<thead>
<tr>
<th>Detector Type</th>
<th>PTW PinPoint 31014</th>
<th>PTW PinPoint 31016</th>
<th>PTW Diamond 60003</th>
<th>PTW MicroLion 31018</th>
</tr>
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<tbody>
<tr>
<td>IBA CC13</td>
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<tr>
<td>IBA IC10</td>
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<tr>
<td>IBA CC04</td>
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<tr>
<td>IBA CC01</td>
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<tr>
<td>IBA PFD</td>
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<tr>
<td>IBA SFD</td>
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<tr>
<td>IBA EFD</td>
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</table>
Results: Independent of filtering all investigated detectors showed qualitatively the same behavior over the investigated range of fields for all energies. SFD, EFD and the air filled ionization chambers agreed within 1% for field sizes equal or larger than 2.4x2.4 cm². Moreover, the readings of SFD and EFD agreed within 1% of all investigated field sizes and deviated by less than 4% compared to the reference detector. PFD and MicroLion showed a systematic over response by more than 1% for field sizes smaller than 4.2x4.2 cm². The smallest field size of 0.6x0.6 cm² the output factors measured with the CC13 and IC10 decrease rapidly by about 20% compared the CC01 due to their comparatively large volume. For the CC04, PinPoint 14 and PinPoint 16 an under response of up to 10% was observed, whereas MicroLion and PFD showed an over response of up to 14% and 5%, respectively.

Conclusions: No substantial influence of filtering on the readings of the investigated detectors was found. With the exception of the CC13 and IC10 chambers all investigated detectors might be used for small field dosimetry. However, appropriate detector correction factors need to be determined.

OC-0067 Performance of the first commercial miniature plastic scintillation detector
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Purpose/Objective: With properties such as water-equivalence, high spatial resolution and energy independence, plastic scintillation detectors (PSDs) have been shown to be excellent dosimeters for radiation therapy applications. In this work, our purpose is to perform a thorough benchmarking of the first commercial PSD, the Exradin W1 radiation therapy applications. In this work, our purpose is to perform a thorough benchmarking of the first commercial PSD, the Exradin W1 radiation therapy applications.

Materials and Methods: The Exradin W1 is a commercial PSD comprising a miniature scintillator probe (~2.3 mm² sensitive volume), a clear optical fiber and a photodiode enclosed in a shielded housing. The electric signal produced by the photodiode is read by a dual-channel electrometer. In a first study, the basic properties of the Exradin W1 were evaluated. Precision and signal-to-noise ratios were determined as a function of delivered doses. Stem effect, which was a well-known problem in PSD was characterized in depth. The effect of the bending radius of the optical fiber was determined as well as the impact of stray radiation on the photodiode housing. Finally, the robustness of the calibration and its stability over time was assessed. In a second study, clinically relevant measurements were performed. Depth dose curves, profiles, out-of-field measurements as well as intensity modulated radiation therapy (IMRT) output measurements were made. Photon irradiations were made with Cobalt-60 and high-energy linear accelerators. Electron irradiations were made with energies between 6 MeV and 18 MeV. Measurements were compared with data acquired with ion chambers.

Results: Detector precision was excellent, and the measured uncertainty was typically below 0.4% for repeated measurements. Day-to-day reproducibility was 0.6% thus showing the high stability of the system. Nevertheless, the current generated by the photodiode is typically an order of magnitude lower than the current produced by an ion chamber. Bending the optical fiber had measurable effects starting at a bending radius of 7 cm (1% loss). Up to 8% losses were measured for a bending radius of 3 cm. After following the calibration procedure given by the manufacturer, no measurable stem effect was observed. Accuracy of the clinically relevant measurements was high with less than 0.6% discrepancy between the PSD and the reference data. Sample data for depth dose curves is shown in Figure 1. Measurements of out-field doses were also in good agreement (better than 2%) with ion chamber data even though the PSD signal intensity was low.

Conclusions: The W1 scintillator has been validated through an extensive set of measurements. Although the signal is small the precision and accuracy are high, thus making this detector ideal for radiation therapy measurements and monitoring. In future work, we will investigate the use of this detector for specific applications such as radiosurgery and in vivo measurements.

OC-0068 A methodological approach to reporting corrected small field relative outputs
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Purpose/Objective: The clinical viability of applying small field central axis relative output correction factors requires standardization in measurement, a mechanism by which dosimetric values can be correlated to the actual delivered field size and assessing the suitability of Monte Carlo (MC) correction factor data for use across a population of linacs. Each is addressed in this work.

Materials and Methods: Measurements were made at a nominal 6 MV on multiple Varian iX linacs at two different institutions using the SFD and T60017 un-shielded diodes. Detector specific output ratios (ORdet) were calculated with respect to a square jaw collimated field of side 3 cm. For square field sizes of side 1.0, 0.9, 0.8, 0.7, 0.6 and 0.5 cm. During each measurement session five central axis output readings and five profile measurements were made for each field before changing the collimation to the next field size. This was repeated during three independent experimental sessions. The standard experimental uncertainty was calculated for both ORdet and field width, defined as the FWHM A(50%) at A and B (x-plane). An effective field size, defined as FEff = (A·B)/2, was calculated using the measured field widths and is presented as a field size metric for reporting measured relative output in small fields. The appropriateness of using FEff and linear interpolation between MC calculated ORdet data at the nominal field sizes, was investigated. FEff was then used to linearly interpolate between the MC calculated correction factors to account for the detector specific over-response in small fields.

Results: In general, one cannot assume jaw collimated small field size constancy across apollopulation of linacs. A clear example would be the actual field widths measured on two of linacs used in this study. For a nominal 0.5 cm x 0.5 cm jaw collimated field the measured sizes were 0.43 cm x 0.53 cm and 0.45 cm x 0.46cm. FEff for each was 0.477 cm and 0.454 cm respectively. For these cases linear interpolation between MC calculated ORdet at 0.45 cm and 0.50 cm validated the electron source FWHM for each linac to be 0.10 cm and 0.11 cm respectively. Correction factors were then found for each detector through linear interpolation between the corresponding correction data.

Conclusions: FEff is a conceptually simple method for reporting measured relative output to the actual field size, yet just such a metric clearly standardizes the methodology of reporting delivered field size across a population of linacs. In addition, using a linear interpolation method between tabulated ORdet and correction factors is...