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Small Field Dosimetry of a 0.35T MR-Linac System

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Abstract
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Abstract

Objectives:

Small field dosimetry is a tricky task to perform during commissioning due to 1) lack of charged particle equilibrium, 2) partial occlusion of source, and 3) detector volume effect. The MRIdian® 0.35T MR-Linac is inherently designed from its roots to heavily utilize small fields for optimal SBRT and SRS delivery using a unique double-focused MLC and a real-time target tracking. To confirm accuracy of small fields modeling in the MRIdian® TPS, we conducted a comprehensive study with a wide-ranging detectors dedicated for small field dosimetry, under the 0.35T magnetic field, including Field Output Factors (FOF), Beam Profiles (BP), and Percentage Depth Doses (PDD), all with a dedicated MR-compatible 3D water scanning system (PTW BeamScan® MR).

Methods:

Five detectors designed for small fields were used for FOF measurements including: Standard Imaging Exradin® W2 Scintillator, PTW microDiamond®, Sun Nuclear EDGE Detector™, PTW Semiflex 3D MR® Ion Chamber, and Standard Imaging Exradin® A28 Ion Chamber, using the water tank at depth of 5 cm for square field sizes of: 0.83, 1.66, 2.49, 3.32, 6.64, 8.30, and 9.96 cm2. The FOF correction factors for these detectors were obtained from the IAEA TRS 483 report. In addition, the FOF measurements were also performed with the GafChromic EBT3 film for the same field sizes with Solid Water™. The BP and PDD were measured with the PTW microDiamond® detector for all square field sizes of: 0.83, 1.66, 2.49, 3.32, 4.15, 4.98, and 9.96 cm2, and subsequently calculated penumbra for at the depths of 1.5 (dmax), 5, 10, and 15 cm. The baseline reference data used in this study to which all our measurements were compared was a Monte Carlo dose calculation engine from the MRIdian® TPS.

Results:

Exradin® W2 Scintillator exhibited the closest agreement with the MRIdian® TPS for all small fields used (4.8% @0.83 cm2 and ⩽0.2% for others). GafChromic EBT3 film measurements also showed close results with slightly larger differences compared to Exradin® W2 Scintillator (5.5% @0.83 cm2 and ⩽0.6% for others). PTW microDiamond® and EDGE Detector™ showed good agreements to the baseline (< 1.6%) for most field sizes except the smallest (6.1% and 7.4%, respectively @0.83 cm2). However, PTW Semiflex 3D MR® and Exradin® A28 detectors showed significantly larger differences (18.6% and 25.8%, respectively @0.83 cm2, and ⩽2.2% and ⩽3.1% for others). For the BP and PDD measurements, PTW microDiamond® exhibited an excellent agreement (< 0.55 mm penumbra and < 1.6% PDD discrepancies).

Conclusion(s):

Commissioning the ViewRay's MRIdian® 0.35T MR-Linac system inevitably requires accurate small field dosimetry due to the unique dual-focused MLC design that allows exquisitely small segments, which are in turn used with real-time target tracking technology to generate and deliver complex IMRT and SBRT treatments. In this study, we have evaluated a wide-ranging array of detectors to assess the accuracy of small field FOF, BP, and PDD generated by the MRIdian® TPS. The Exradin® W2 Scintillator turns out to be the best available detector for small field FOF measurement and the GafChromic EBT3 film can be used in the absence of or as a complement to the Exradin® W2 Scintillator. The PTW microDiamond® is an appropriate detector for beam scanning and measuring the BP/penumbra and PDD. Our plan to extend this study to include most (if not all) commercially available MR-compatible small field detectors and water scanning systems in the market, to provide a reference dataset for the MR-Linac community, is actively under progress.