Small Field Output Factor Measurement: A Comparison of microdiamond, Scintillation Detectors, and Radiochromic Film

Han Liu, Keith Pearman, Lane Hayes, Robert Moller

Cone Health Cancer Center, Greensboro, North Carolina

CONE HEALTH
Cancer Center

Purpose

Small field sizes used in stereotactic radiosurgery (SRS) present substantial dosimetric challenges because of the loss of lateral charged particle equilibrium, steep dose gradients, and increased sensitivity of detectors to volume averaging and energy dependence effects. In this conditions, detector size, geometry, and response characteristics can significantly influence the accuracy of measured dose data. Aa a result, accurate determination of small field output factors (SFOFs) is therefore critical for accurate beam modeling, treatment planning system (TPS) commissioning, and the safe clinical implementation of SRS treatment.

This study evaluates the performance of three commonly used dosimetric systems for SFOF measurements in SRS-relevant small fields: the PTW microDiamond detector (model 60019), the Medscint Hyperscint plastic scintillation detector, and EBT4 radiochromic film. The microDiamond detector offers high spatial resolution and near tissue equivalence, the Hyperscint detector minimizes perturbation effects through water-equivalent scintillation technology, and EBT4 film provides high-resolution two-dimensional dose measurements with minimal energy dependence. Measured SFOFs obtained with these detectors were compared against TPS-calculated values to assess detector agreement, measurement consistency, and overall reliability for small-field dosimetry in SRS applications. The results of this study aim to provide insight into the suitability and limitations of each detector system for accurate commissioning and quality assurance of stereotactic treatment beams.

Materials and Methods

All detectors and film were positioned at a source-to-surface distance of 95 cm and a depth of 5 cm in water or solid water. Field sizes were defined using high-definition multileaf collimator (HDMLC) apertures of 3×3, 2.5×2.5, 2×2, 1.5×1.5, 1×1, 0.7×1, 0.5×1, and 0.5×0.5 cm², with jaws fixed at 3×3 cm². SFOFs were normalized to a 10×10 cm² jaw -defined reference field. Measurements were performed using 6X-FFF and 10X-FFF beams on a Varian Edge TrueBeam linear accelerator. Field size–dependent output correction factors were applied to the microDiamond detector measurements.

Results and Discussions

Measured SFOFs showed close agreement with TPS calculations for all three measurement techniques. Agreement improved with increasing field size for both photon energies. The largest discrepancies were observed for the smallest field (0.5×0.5 cm²), particularly for the microDiamond detector at 10X-FFF and for film measurements at both energies. For field sizes ≥1×1 cm², all measurements agreed with TPS within 2%.

FS	Equi. FS	TPS	Diamond	%Diff	Scintillation	%Diff	Film	%Diff
0.5x0.5	0.5	0.62	0.64	2.74	0.62	-0.60	0.54	-12.76
0.5x1	0.67	0.72	0.72	0.17	0.70	-2.61	0.71	-1.67
0.7x1	0.82	0.76	0.76	0.29	0.75	-1.29	0.77	2.31
1x1	1	0.78	0.79	0.48	0.78	-0.49	0.78	-0.79
1.5x1.5	1.5	0.84	0.84	0.38	0.85	1.12	0.86	2.38
2x2	2	0.86	0.87	0.42	0.88	1.89	0.88	1.16
2.5x2.5	2.5	0.88	0.89	0.38	0.89	1.37	0.87	-1.11
3x3	3	0.89	0.90	0.33	0.91	1.34	0.89	-0.51

Table 1: Comparison of SFOFs obtained using three measurement methods with TPS calculations for the 6xFFF beam.

FS	Equi. FS	TPS	Diamond	%Diff	Scintillation	%Diff	Film	%Diff
0.5x0.5	0.5	0.54	0.57	5.61	0.55	0.99	0.50	-8.27
0.5x1	0.67	0.67	0.67	1.21	0.65	-2.93	0.65	-2.67
0.7x1	0.82	0.71	0.72	2.30	0.70	-1.47	0.69	-1.71
1x1	1	0.75	0.76	2.32	0.74	-0.65	0.74	-0.68
1.5x1.5	1.5	0.83	0.85	2.01	0.84	1.23	0.84	1.42
2x2	2	0.88	0.89	1.65	0.89	1.64	0.89	1.13
2.5x2.5	2.5	0.90	0.92	1.56	0.92	1.57	0.90	-0.84
3x3	3	0.92	0.93	1.25	0.93	1.45	0.92	-0.06

Table 2: Comparison of SFOFs obtained using three measurement methods with TPS calculations for the 10xFFF beam.

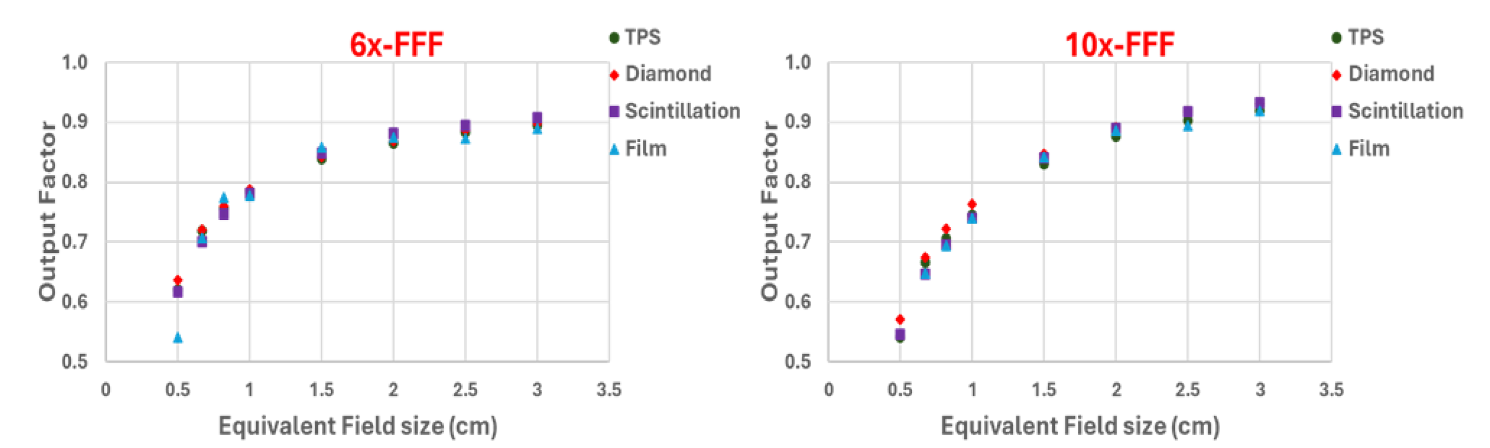

Figure 1: Comparison of SFOFs obtained using three measurement methods with TPS calculations for the 6xFFF and 10xFFF beams

Conclusions

All evaluated detectors are suitable for SRS small field dosimetry, though increased uncertainty exists for sub-centimeter fields. Careful detector selection, appropriate correction factors, and cross-validation using complementary techniques are recommended to ensure accurate SFOF commissioning for clinical SRS applications.

CONTACT

Han Liu, PhD, DABR
Radiation Oncology
Cone Health Cancer Center
2400 W Friendly Ave, Greensboro, NC
Han.liu@conehealth.com