Comparison of reference dosimetry protocols for small radiosurgery fields

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Introduction

Small field dosimetry remains a vital component of radiosurgery for several treatment modalities, including Gamma Knife (GK). There are several protocols that may be used to measure absorbed dose to water, including the American Association of Physicist in Medicine (AAPM) Task Group (TG) report 21, TG-51, and the International Atomic Energy Agency (IAEA) report 483. Each approach may yield slightly different results based on the exact execution of the protocols and on the equipment used, making it difficult to compare clinical experiments with literature values. In this study, the reference absorbed dose to water rate for Gamma Knife ICON was determined following recommendations of TG-21, TG-51, and IAEA 483 formalism for small and nonstandard fields.

Materials & Methods

Two 16 cm diameter Leksell spherical phantoms, an acrylonitrile-butadiene-styrene (ABS) and a certified therapy grade solid water Dosimetry Phantom (Elekta, Stockholm, Sweden) were used for dose rate measurements. The measurements were performed utilizing four ionization chambers: 0.125 cm^3 Semiflex 31010 and 0.016 cm^3 PinPoint 31016 (PTW, Freiburg, Germany) and Exradin 0.053 cm^3 A1SL and 0.007 cm^3 A16 (Standard Imaging, Middleton, WI). For each detector the absorbed dose to water calibration coefficients $N_{D,w}^{Co60}$ traceable to a primary standard were obtained through an Accredited Dosimetry Calibration Laboratory (ADCL) service. Detector specific factors accounting for the change in the response of the ionization chambers for the reference and GK-specific fields were applied for the IAEA formalism. In addition, the GK output factor (OF) measurements in Leksell solid water phantom were validated using EBT3 radiochromic films (Ashland ISP, Wayne, NJ), and a PTW microDiamond detector.

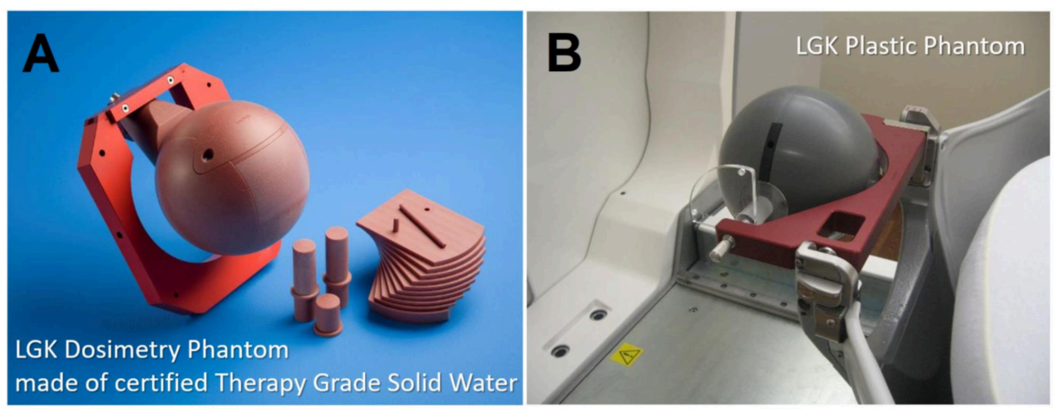

Figure 1. A) shows the Leksell solid water dosimetry phantom and B) shows the Leksell ABS, or plastic, phantom. The phantom inserts were appropriately exchanged based on the type of chamber used for the measurement.

Method	Chambers			
	A16	A1SL	PTW 31010	PTW 31016
TG-21	0.77%	0.27%	2.68%	2.67%
TG-51	-1.71%	-0.72%	-0.36%	0.23%
IAEA 483	-0.04%	-0.26%	0.01%	0.63%

Table 1. The dose to water rates compared to the GK treatment planning system are shown. The IAEA 483 formalism demonstrates the best agreement with the GK treatment planning system dose rates (0.085%± 0.38% averaged over all chamber measurements), whereas the TG-21 protocol agrees least with the treatment planning system dose rates (1.60% ± 1.26% averaged over all chamber measurements).

Results

Collimator	Output Factor	
	Diamond	EBT3 Film
4 mm	0.825	0.826 ± 0.047
8 mm	0.894	0.91 ± 0.056
16 mm	1*	1*

Table 2. The output factor measurements are shown for the diamond detector and the EBT3 film measurements. The asterisk indicates that the 16 mm collimator values were used for normalization. The EBT3 film calibration was performed on the same batch of film used for the measurement, and the data were analyzed using the red channel. The output factor values in the treatment planning system are 0.814 and 0.9 for the 4 mm collimator and 8 mm collimator, respectively.

For all four ionization chambers, on average, the TG-21, TG-51 and IAEA measured variations of GK ICON dose rates were (0.34±1.27)% relative to the treatment planning system value. The output factors measured with EBT3 film and diamond were both within 1% and 1.5% agreement relative to the nominal GK values of 0.900 and 0.814 for the 8 mm and 4 mm collimators, respectively.

Discussion and Conclusions

The IAEA formalism, with detector specific correction factors calculated for GK phantoms, yielded favorable agreement with the treatment planning system results. The uncertainties present in the measurements are largely from the uncertainty of $N_{D,w}^{Co60}$ (approximately 0.75%). Other factors also contribute to measurement uncertainty, including uncertainty in the charge readings and the corrections for polarity, ion recombination, temperature/pressure, among others.

References

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