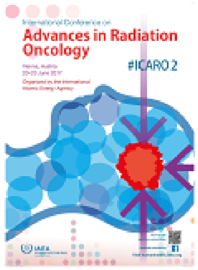

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Monte Carlo calculated correction factors for nine detectors in Leksell Gamma Knife Perfexion unit

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Introduction: The Leksell Gamma Knife (LGK) Perfexion unit is a radiosurgical device delivering a single high dose of radiation and small radiation fields. The dosimetry of LGK should be based on the formalism for the reference dosimetry of small and nonstandard fields since the reference conditions of TG-51 or TRS-398 cannot be established on this unit. There are few published studies on reference dosimetry of the LGK Perfexion. The goal of the present study is to calculate the $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ factors, introduced in the small field formalism, for nine detectors used in the reference dosimetry of the LGK Perfexion using Monte Carlo simulation. This study provides a comparison of EGSnrc and PENELOPE for the calculation of $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ factors for two possible orientations of the detector.

Methodology: Nine chamber types including Exradin-A1SL, A14SL, A14, A16, IBA-CC04, CC01, PTW-31010, 31014 and 31016 were simulated in EGSnrc using the specifications provided by the manufacturers. Five of them including: Exradin-A1SL, A14, A14SL, A16 and IBA-CC04 were also modeled in PENELOPE. For the machine specific reference field (*msr*) set-up, the water phantom, the Solid Water phantom and the Elekta Acrylonitrile Butadiene Styrene (ABS) phantom were modeled as 16-cm diameter sphere made of water, Solid Water and ABS respectively. The reference point of the chamber was positioned at the center of each spherical phantom. In the ABS phantom, calculations were performed for two orientations of chambers with the chamber stem positioned parallel and perpendicular to the symmetry axis of the collimator block. The mean absorbed dose to the air cavity of chamber was calculated for both the reference set-up ($D^{f_{\mathrm{ref}}}_{\mathrm{det},Q_0}$) and the *msr* set-up ($D^{f_{\mathrm{msr}}}_{\mathrm{det},Q_{\mathrm{msr}}}$). The dose to a 3 mm diameter spherical water volume was also calculated in both set-ups independently ($D^{f_{\mathrm{ref}}}_{\mathrm{w},Q_0}$ and $D^{f_{\mathrm{msr}}}_{\mathrm{w},Q_{\mathrm{msr}}}$). Using the following equation and the mentioned quantities, $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ was determined.

$$k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0} \approx \frac{D^{f_{\mathrm{msr}}}_{\mathrm{w},Q_{\mathrm{msr}}}/D^{f_{\mathrm{msr}}}_{\mathrm{det},Q_{\mathrm{msr}}}}{D^{f_{\mathrm{ref}}}_{\mathrm{w},Q_0}/D^{f_{\mathrm{ref}}}_{\mathrm{det},Q_0}}$$

Results: Figure 1 shows the calculated $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ values for all chambers in the water phantom. The uncertainties on $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ factors shown in figure 1 are type A and less than 0.1% (one standard deviation). Depending on the chamber type, the difference between EGSnrc and PENELOPE data of this study varies between 0.02-0.49% in the water phantom. Given that both codes are algorithmically self-consistent with respect to their own cross sections (i.e., they pass the Fano test at the 0.2% level) and the geometries modeled were identical, this difference may be due to slight cross section differences or differences in cross section implementation details in both codes. The EGSnrc and PENELOPE calculated $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ values for all chambers in Solid Water and ABS phantoms are given in table 1. The difference between $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ values in parallel and perpendicular orientations is largest for PTW-31010 (3.5%) and 31014 (2.3%). It is smallest for Exradin-A1SL (0.4%) and A14SL (0.5%). This is due to the cavity lengths to radius ratio, which is the largest for the PTW-31010 and 31014 chambers as well as the fact that these chambers have electrodes made of Aluminum.

Conclusion:
$k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ factors introduced in the small field formalism were calculated for nine detectors and three phantoms using Monte Carlo simulation. Good agreement is observed between $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ values determined with EGSnrc and PENELOPE. The %RMS deviation between EGSnrc and PENELOPE calculated $k^{f_{\mathrm{msr}},f_{\mathrm{ref}}}_{Q_{\mathrm{msr}},Q_0}$ values for Exradin-A1SL, A14, A14SL, A16 and IBA-CC04 chambers studies in this work was found to be 0.4%.

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