DETERMINATION OF FIELD OUTPUT CORRECTION FACTORS OF RADIOPHOTOLUMINESCENT GLASS DOSIMETER IN 6 MV SMALL PHOTON BEAM

S. Yabsantia

Medical Physics Program, Department of Radiology, Faculty of Medicine, Chulalongkorn University

Abstract— Background: Small field is utilized in advanced radiotherapy techniques for performing the complex fluence to achieve the better dose distribution in radiation treatment. However, the small field problems including the lateral charged particle disequilibrium, source occlusion and size of detectors with respect to the field size limit the response of each type of detector and impact the absorbed dose determination.

These problems lead to the large variation of output factors (ratio of reading) among various detectors types. The IAEA and AAPM group established the proposal for small field dosimetry and proposed the field output correction factors ($k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$) in order to improve the output factor determination. In 2017, the IAEA/AAPM TRS 483 has been released and the $k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$ of several active detectors were reported. The $k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$ is defined using the following equation.

$$k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}} = \frac{D_{\mathrm{w},Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}} \Big/ \bar{D}_{\mathrm{det},Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}}{D_{\mathrm{w},Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}} \Big/ \bar{D}_{\mathrm{det},Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}} \tag{1}$$

Where $D_{\mathrm{w},Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}$ and $D_{\mathrm{w},Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}$ are absorbed dose in water for clinical field size and machine specific reference field size, respectively. $\bar{D}_{\mathrm{det},Q_{\mathrm{clin}}}^{f_{\mathrm{clin}}}$ and $\bar{D}_{\mathrm{det},Q_{\mathrm{msr}}}^{f_{\mathrm{msr}}}$ are average absorbed dose in sensitive volume of detector for clinical field size and for machine specific reference field size, respectively.

Radiophotoluminescent glass dosimeter (RPLGD) is a passive detector and increasingly applied for output factor measurement due to its small size. However, high Z (12.04) and high physical density (2.61 g/cm^3) of RPLGD restrict its response for small field output factor measurement. Moreover, the orientations of RPLGD with respect to the beam central axis may influence the $k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$ as a consequence of altering the detector size with respect to the field size.

Therefore, this study aims to determine the $k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$ of RPLGD in 6 MV small photon beam for perpendicular and parallel orientations using Monte Carlo (MC) simulation.

Methods: The $k_{Q_{\mathrm{clin}},Q_{\mathrm{msr}}}^{f_{\mathrm{clin}},f_{\mathrm{msr}}}$ were determined using EGSnrc Monte Carlo code. The TrueBeam linear accelerator) Varian Medical Systems, Palo Alto, CA, US) with 6 MV WFF was simulated using BEAMnrc code. Each component module of simulated machine is illustrated in Fig 1. For tuning the source parameters, the PDD and beam profile were reproduced by DOSXYZnrc and compared with the measurement data.

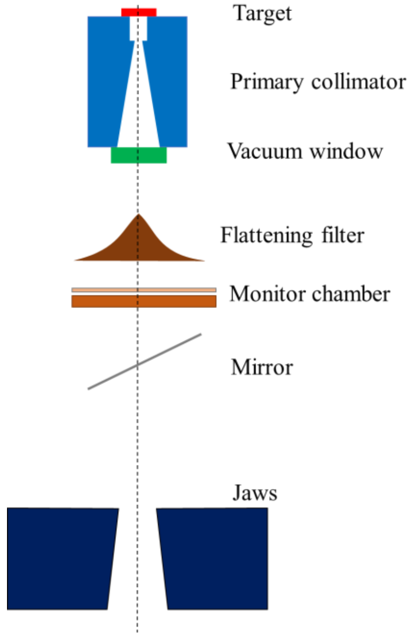

Fig. 1 The treatment head geometry of linear accelerator

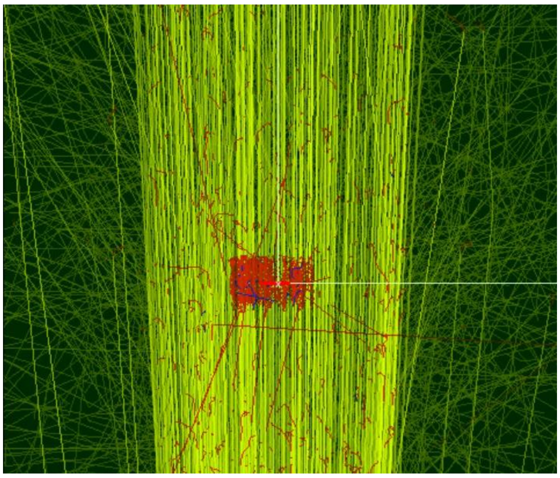

Fig. 2 Example of particle track of perpendicular RPLGD using egs_view

The egs-chamber was utilized to simulate the detector or point of water in water phantom and to calculate dose in scoring volume (Fig. 2). The orientations of RPLGD were studied in both perpendicular and parallel to the beam axis. The absorbed doses in water and average doses in sensitive volume of detector at 90-cm SSD and 10-cm depth for field size ranging from 0.5×0.5 to 10×10 cm^2 were calculated. The number of particles were set to maintain the statistical uncertainty less than 0.08%. The dose in each field size was normalized to 10×10 cm^2 machine specific reference field. Then, the $k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}}$ was determined using equation (1).

The equivalent square small field size (S_{clin}), which was given by the geometric mean of full width of half maximum (FWHM) of in-plane and cross-plane, was determined.

Results: For MC commissioning, the suitable source parameters were 5.9 MeV initial electron energy and 0.11 cm FWHM. The average percentage differences between measured and simulated dose distribution were within 1%.

The ratio of RPLGD reading which was determined using MC is shown in Fig. 3. For field size 2 × 2 to 6 × 6 cm^2, the ratio of RPLGD reading showed underestimation comparing with the water. This is influenced by the over response in 10 × 10 cm^2. RPLGD exhibits an energy dependent response and over response to low energy scattered photon in large field size due to the high Z of this material.

At the smallest field size, the ratio of RPLGD reading for perpendicular orientation presented underestimation while parallel showed overestimation. In small field size, the perturbation effect was typically affected by volume averaging effect and high density of material. The volume averaging effect was pronounced in perpendicular RPLGD. Therefore, the underestimation was detected. On the other hand, the volume averaging effect was small in parallel orientation and the high density of RPLGD affected the over response, so the overestimation was discovered.

The field output correction factors of RPLGD are demonstrated in Table 1. The $k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}}$ of RPLGD were 1.000-1.118 and 0.954-1.017 for perpendicular and parallel, respectively. Their overall statistical uncertainties were less than 0.13%. Moreover, the $k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}}$ of perpendicular and parallel RPLGD deviated from unity within 5% for field size down to 1 × 1 cm^2 and 0.5 × 0.5 cm^2 each.

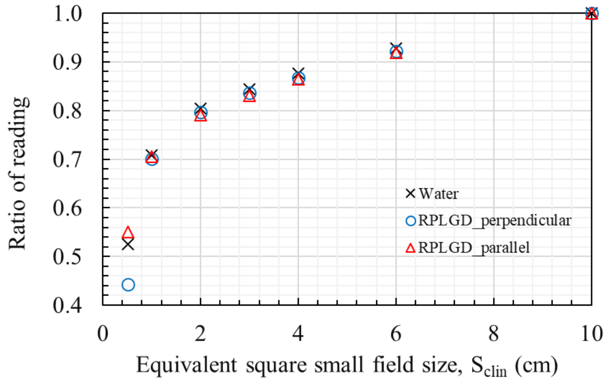

Fig. 3 The reading ratio of RPLGD determined from MC simulation for perpendicular and parallel orientation in comparison to water

Table 1 Field output correction factors

Side of square field (cm)	S_{clin} (cm)	RPLGD perpendicular	RPLGDparallel
10	10.01	1.000	1.000
6	5.98	1.006	1.010
4	4.04	1.010	1.014
3	3.00	1.010	1.016
2	2.00	1.011	1.017
1	1.00	1.011	1.004
0.5	0.52	1.188	0.956

Conclusion: The $k_{Q_{\text{clin}},Q_{\text{msr}}}^{f_{\text{clin}},f_{\text{msr}}}$ of RPLGD for both orientations were reported in this study. The correction factors were practical for field size down to 1 × 1 and 0.5 × 0.5 cm^2 for perpendicular and parallel orientations, respectively. The parallel orientation of RPLGD might be preferred for small field output factor measurement.

Keywords — Field output correction factors, Monte Carlo simulation, Radiophotoluminescent Glass Dosimeter, Small field dosimetry

Contacts of the corresponding author:

Author: Sumalee Yabsantia, M. Sc.
Affiliation: Faculty of Medicine, Chulalongkorn University
Street: Rama IV Rd, Pathum Wan
City: Bangkok
Country: Thailand
Email: sumalee.y@student.chula.ac.th