PHANTOM POSITIONING VARIATION IN THE GAMMA KNIFE® PERFEXION DOSIMETRY

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Abstract. The use of small volume ionization chamber has become required for the dosimetry of equipments that use small radiation fields such as the Gamma Knife® Perfexion (GKP) unit. In this work, a pinpoint ionization chamber was inserted into the dosimetry phantom and measurements were performed with the phantom in different positions, in order to verify if the change in the phantom positioning affects the dosimetry of the GKP. Four different phantom positions were performed. The variation in the result is within the range allowed for the dosimetry of a GKP equipment.

1. Introduction

The Gamma Knife® Perfexion (GKP) unit, introduced in 2006, is a fully automated unit for the stereotactic radiosurgery and stereotactic radiotherapy of brain lesions including also certain extra-cranial lesions [1].

It has 192 sealed sources of ^{60}Co arranged on eight movable sectors, each sector containing 24 sources. The collimator system consists of a single large tungsten ring with collimator holes of three different sizes of 4, 8 and 16 mm [2].

When a patient treatment is initiated, all eight sectors with their 24 sources quickly move out from their shielded home position at the extreme rear of the radiation cavity and slide over the tungsten ring and past the 8 mm collimators to park in the "off position" in shielded space between the 8 and 4 mm collimators. During this time, no beam is turned on and the treatment does not start to count. Depending on the size of the beam desired from a particular sector, the sources on that sector are aligned with the desired collimator size. The beams from a sector may also remain "blocked" if the sources in that sector remain parked in the off-position [1].

The presence of many critical structures and eloquent areas in the human brain requires careful stereotactic radiosurgery treatment planning as well as dosimetric verification of the plan. The verification between the plan and the delivery is achieved by comparing the planning dose distribution exported from the treatment planning system (TPS) with the measurement data obtained using radiation detectors [4].

In this work, a pinpoint ionization chamber was inserted into the phantom and measurements were performed with the phantom in different positions, in order to verify if the change in the phantom positioning affects the dosimetry of the GKP. Considering that the GKP dosimetry is performed using the largest size collimator (16 mm), the detector volume used in this study is 0.016 cm^3, which justifies the influence analysis of the size detector effect in the dosimetry of the GKP.

2. Materials and methods

The dosimetry of a GKP is performed using a spherical polystyrene phantom having a diameter of 160 mm, which is provided by Elekta (GKP manufacturer). It consists of two hemispheres each one having 130 mm wide and 5 mm deep slot in the central area across the diameter of the hemisphere. The two hemispheres are held together with the help of two small lucite pegs and corresponding holes for the pegs in the peripheral area of the hemispheres. There is a lucite gamma angle plate on the side of the hemisphere that helps the phantom to stay in its ideal position. The slot in the central area of the phantom is used to accommodate a 130 x 160 x 10 mm^3 insert, made of ABS plastic. The insert is rounded off on two ends so that the surface of the insert is flush with the spherical surface of the phantom [3].

This phantom is held in irradiation position by a C-shaped aluminum adaptor, which has stainless steel side-fixation screws. This side-fixation screws have been proved to attenuate the beam in up to 4.6% [2]. Figure 1 shows the setup of the phantom mounted with the ionization chamber inserted in it.

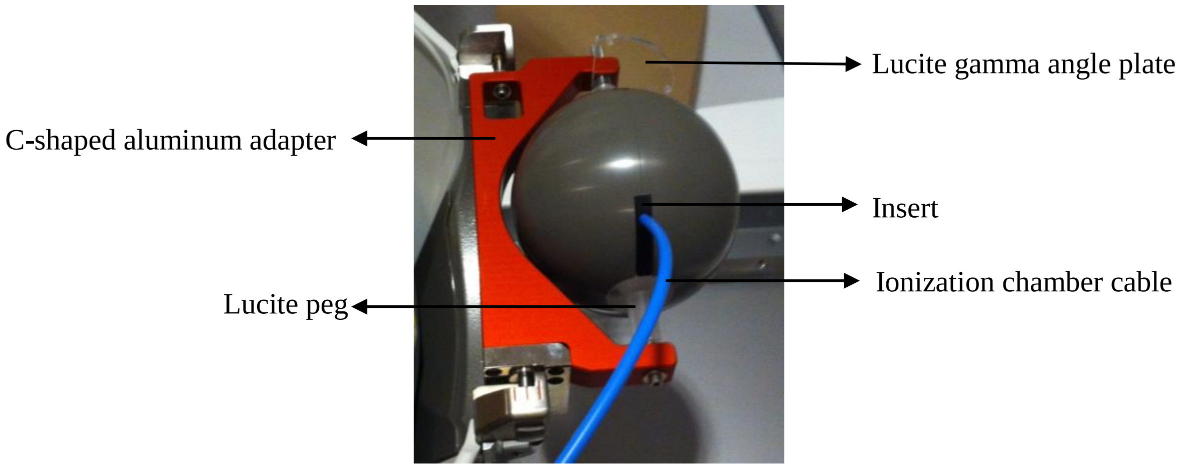

Figure 1. Dosimetry phantom set up

In this study, a pinpoint ionization chamber from PTW-Freiburg with a volume of 0.016 cm^3 was used (Figure 2). The pinpoint ionization chamber was inserted into the phantom having its sensitive volume center in the center of the phantom. A dose-rate calibration of a GKP unit is performed using the largest size collimator (16 mm, shown in Figure 3).

Figure 2. Pinpoint ionization chamber

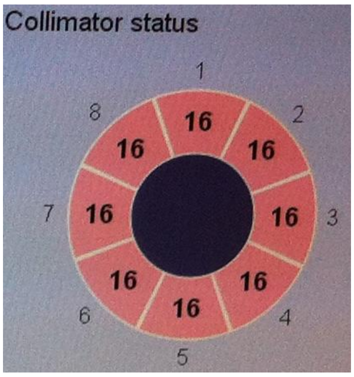

Figure 3. Size collimator used for dosimetry. All sectors opened

Ten readings of one minute each were performed for each position. It must be said that Elekta does not give any requirement related to the position that the phantom must acquire during the GKP dosimetry. The ionization chamber was connected to a PTW Unidos E electrometer.

With the aim of verifying if there is any attenuation that might be considered during the GKP dosimetry, four different phantom positions were performed. All of them are related to the stereotactic XZ plan (PPS plan). Position A: 90° from the PPS plan. Position B: -120° from the PPS plan. Position C: 30° from the PPS plan. Position D: 0° from the PPS plan. For position C, measurements were performed using all collimators opened and also with only sector 4 opened and the other closed. This evaluation was made in order to estimate the scattering contribution on the rod of the ionization chamber. Figure 4 presents the diagram of the possible scattering contribution of beam sector 4 and the Figure 5 shows each position used for the measurements.

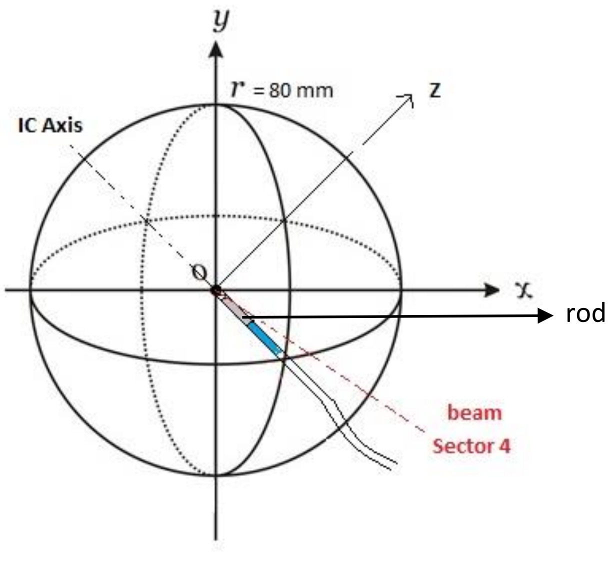

Figure 4. Scattering contribution from beam sector 4

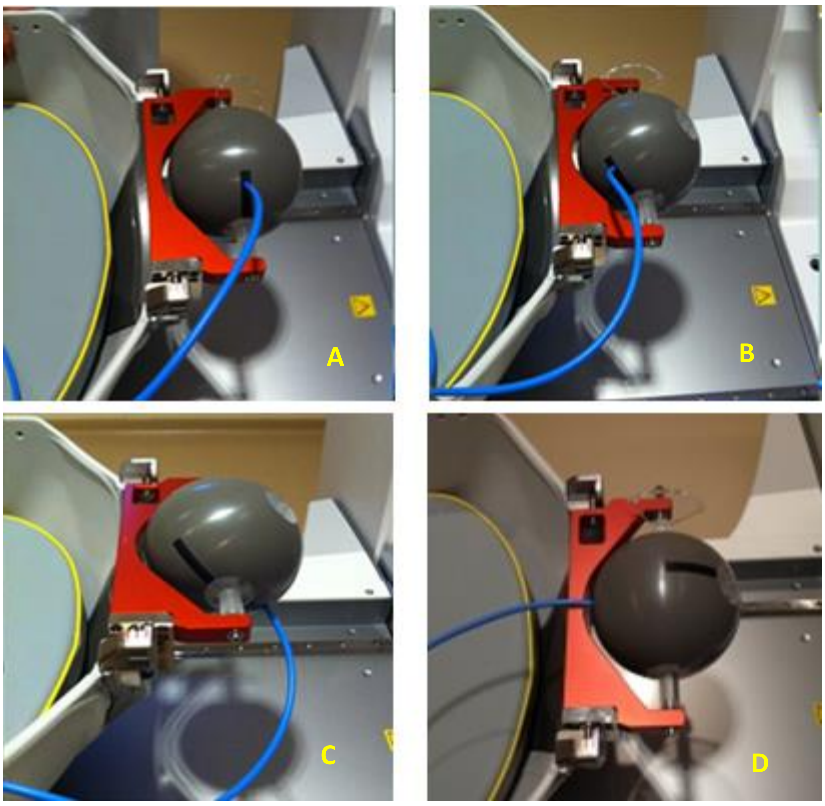

Figure 5. Phantom positions used for the measurements. In A: 90° from the PPS plan; in B: -120° from the PPS plan; in C: 30° from the PPS plan and in D: 0° from the PPS plan.

3. Results

Table 1 shows the results of the readings for the four different phantom positions. To calculate the average charge reading the following equation was used:

$$\bar{L} = \frac{\sum_{i=1}^{10} l_i}{10}$$

Table 1. Results of the collected charge for the four different phantom positions

Positions	Charge (nC)
A	0.9906 ± 0.0038
B	0.9955 ± 0.0029
C	0.9869 ± 0.00013
D	1.000

Table 2 shows the results of the readings for positions A, B and C with only sector 4 of the 16 mm collimator opened.

Table 2. Results of the collected charge for three different phantom positions with only sector 4 opened

Position	Charge (nC)
A	0.1234
B	0.1229
C	0.1154

Considering the average charge values for all positions evaluated, position D showed the highest value, so it is considered the best position to perform the GKP dosimetry.

Position C presented the smallest charge value, which suggests attenuation of the beam at sector 4. The reduction comparing to the other positions was 6.3%.

4. Conclusion

In table 1, the highest charge reading was position D, which means that position D presents the smallest influence of the ionization chamber rod when performing the dosimetry. However, uncertainties of other positions are acceptable for Gamma Knife Perfexion dosimetry. After analyzing the data on the table 2, the impact induced by the rod of the ionization chamber showed a reduction of 6.3% in the reading when compared with positions A and B.

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