Filmless quality assurance tests for the Leksell Gamma Knife® Icon™

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INTRODUCTION

The Leksell Gamma Knife® (LGK) Icon™ (Elekta A.B., Stockholm, Sweden) is a specialized intracranial stereotactic radiosurgery system that can be used to treat brain tumors, arteriovenous malformations and several neurological conditions. The annual quality assurance (QA) of LGK systems are typically performed using film. Film is a good candidate for small field dosimetry due to its high spatial resolution and availability [1]. However, there are multiple challenges with using film. First, film does not allow for real-time measurements and requires a batch specific calibration, both of which make film measurements time-consuming. Additionally, there are several uncertainties associated with film measurements such as handling uncertainties, batch dependency and uncertainty in calibration procedure [2,3]. To address these limitations inherent in film dosimetry, the aim of this work is to describe a filmless approach for performing the annual QA of LGK Icon™.

MATERIALS AND METHODS

Annual QA tests for a LGK Icon™ system were performed using both film-based and filmless techniques. Output calibration, relative output factors (ROF), radiation profiles, sector uniformity/source counting, and verification of the unit center point (UCP) and radiation focal point (RFP) coincidence tests were performed. Radiochromic films, two ionization chambers, and a synthetic diamond detector were used for the measurements.

Relative output factors

Film: The measurements were performed using Gafchromic EBT3 films in axial and coronal planes placed in the central insert inside the spherical Solid Water phantom (Figure 1). The films were calibrated to convert the intensity levels to absolute dose.

Active detector: A PTW MicroDiamond detector was placed in the Solid Water Phantom and irradiated for sixty seconds with all three collimator settings (Figure 1).

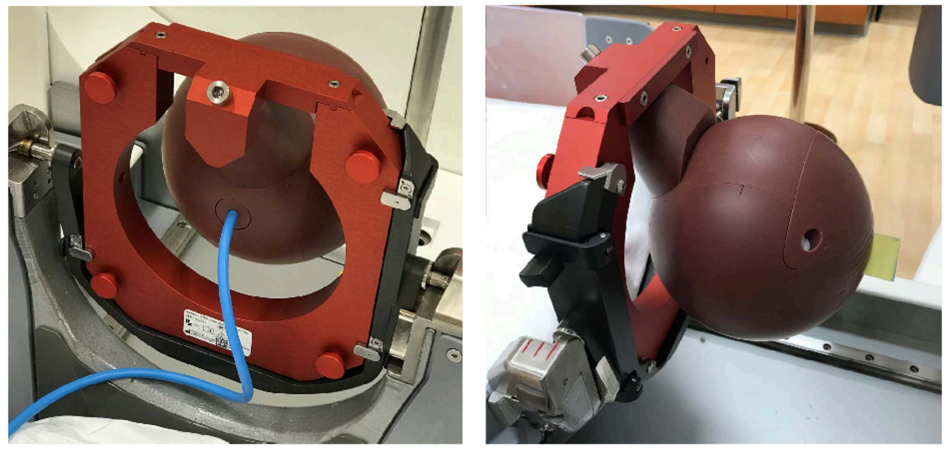

Figure 1. (left) Ionization chamber placed in the 16 cm diameter Solid Water phantom. (right) ROF measurement setup using film inside the Solid Water phantom.

Sector uniformity/Source counting

Film: A CATPHAN phantom was wrapped in a radiographic film (Figure 2) and placed at the UCP and all sectors were opened to the 4 mm collimator. After 10 minutes of exposure, the film was removed and the number of spots was manually counted.

Active detector: Sector uniformity was measured by placing the PTW 310310 ionization chamber at the UCP and recording the total charge collected when the chamber was exposed to each sector individually. In the event of missing a source, a reading difference of about 4% can be expected, since each sector consists of 24 sources with 4.16% contribution from each source if uniformly distributed.

Figure 2. (left) The CATPHAN phantom wrapped in a radiographic film for the source counting measurement. (right) The pinprick film test tool.

Radiation profiles

Film: Six films were irradiated using 4, 8 and 16 mm collimation sizes. Irradiated film were scanned and intensity levels were converted to absolute dose using the calibration curve.

Active detector: Profiles were also measured by translating a PTW MicroDiamond detector in the spherical phantom across the radiation center with programmed couch motions along the three orthogonal directions.

Coincidence of UCP and RFP

Film: The coincidence of UCP and RFP is typically verified using the manufacturer provided pinprick film tool and radiochromic film as shown in Figure 2.

Active detector: The coincidence of UCP and RFP was also compared to the CBCT imaging isocenter alignment. In this test a CBCT of the pinprick film tool was taken and the coordinate of the mechanical pointer's tip was located in the image and compared to the expected coordinates above. The MicroDiamond detector was placed in the Solid Water phantom and centered at the UCP using a cone beam CT. The coincidence of UCP and RFP was verified by finding the central point of the profile in each direction obtained by the detector.

Output Calibration

Measurements were performed using two ADCL calibrated ionization chambers, which included the Capintec model PR-05P and PTW model TN31010 with PTW Unidos 10005 electrometer. The dose rate (in Gy/min) was measured for the 16 mm collimation at the RFP which is at the center of the Solid Water phantom. The measured dose rate was then compared to the output of the TPS.

RESULTS

The measured dose rate of the LGK Icon was within 0.3% of the TPS value set at the time of commissioning using an ionization chamber. ROF for the 8 mm and 4 mm collimators were found to be 0.3% and 1.8% different from TPS values using the MicroDiamond detector and 2.6% and 1.9% different for film, respectively. Excellent agreement was found between TPS and measured dose profiles using the MicroDiamond detector which was within 1%/1mm vs 2%/1mm for film (Figure 3). Sector uniformity was found to be within 1% for all eight sectors measured using an ion chamber. Verification of UCP and RFP coincidence using the MicroDiamond detector and pinprick film test was within 0.3 mm at isocenter for both.

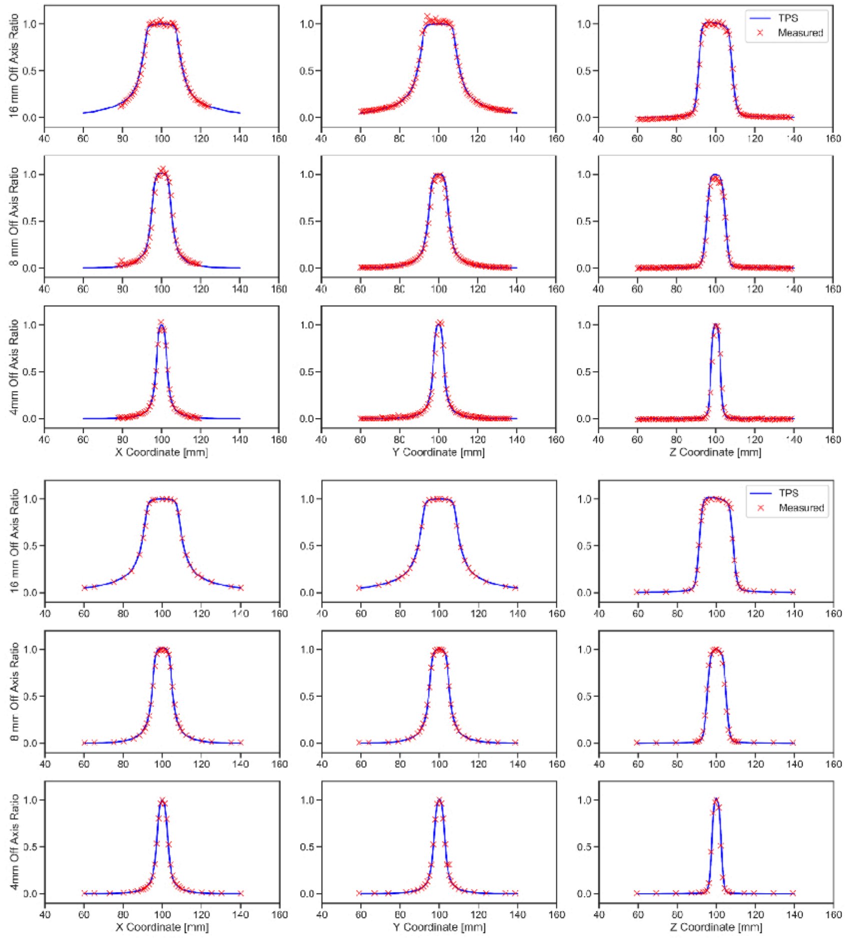

Figure 3. Measured radiation profile along (first column) X, (second column) Y, and (third column) Z for (top row) 16 mm, (middle row) 8 mm, and (bottom row) 4 mm collimators using (top) radiochromic films and (bottom) the MicroDiamond detector.

CONCLUSIONS

The annual QA of a LGK Icon was successfully performed by employing filmless techniques. Comparable results were obtained using radiochromic films. Utilizing active detectors instead of films simplifies the QA process and saves time without loss of accuracy.

REFERENCES

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