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Diode Array Measurement and Evaluation of 2D Dosimetric Leaf Gap of a MLC System

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INTRODUCTION

Dosimetric Leaf Gap (DLG) is a strongly contributing factor to failed PSQA for intensity modulated plans such as IMRT and VMAT. The array based DLG measurements helped us to determine the impacting factor and amplitude of variations in the 2D map of DLG. By using array detectors such the diode array (MapCheck2, SunNuclear [1]) and film (GafChromic3, Ashland), we generated and verified the accuracy of high resolution 2D DLG distribution. Potentially the 2D DLG distribution can be integrated as part of the beam configuration in the treatment planning system [2].

Previously used DLG measurement techniques used ion chamber (IC) to measure the DLG at the Central Axis (CAX). The proposed study focused on the quantification and analysis of variation of DLG as a function of 2D spatial distribution, and different width of the leaf.

AIM

- To analyze and quantify physics factors that impact the local DLG, which is a strongly contributing factor to failed PSQA for intensity modulated plans, of the STD120 MLC installed on a Varian TrueBeam unit.
- Reconstruct 2D DLG maps for the MLC system at multiple photon energies.
- Analyze the clinical impact of variation of DLG to treatment planning and PSQA results.

RESULTS

The DLG derived from the array measurements showed variations between leaf widths, leaf gap, and distance from central axis, as shown in Figure 2. 5mm leaf DLGs were 26.8%, 21.6%, 26.5%, and 18.2% larger than 1cm leaf DLGs under 6X, 6FFF, 10FFF, and 15X beams, respectively. MapCheck2 measured DLGs under the leaf gap (no shift) were 16.8%, 17.7%, 20.3%, and 19.3% higher than DLG under the leaf (measured with 2.5mm shift) for 6X, 6FFF, 10FFF, and 15X beams, respectively. The result is supported by plotting of DLG profile along inline and crossline at different part of the field as shown in Figure 3. Average leaf gap and leaf DLGs were within 1% of planning system values, which were measured using IC during the initial beam configuration of the treatment machine, for all energies. DLGs under the same leaf showed a slight decrease with increasing central axis distance (0.005mm/cm).

Film measurements were made using the conventional sweeping pattern with 10 by 10 fields [Figure 4]. The DLG result at the CAX was in agreement with the MapCheck2 measured values.

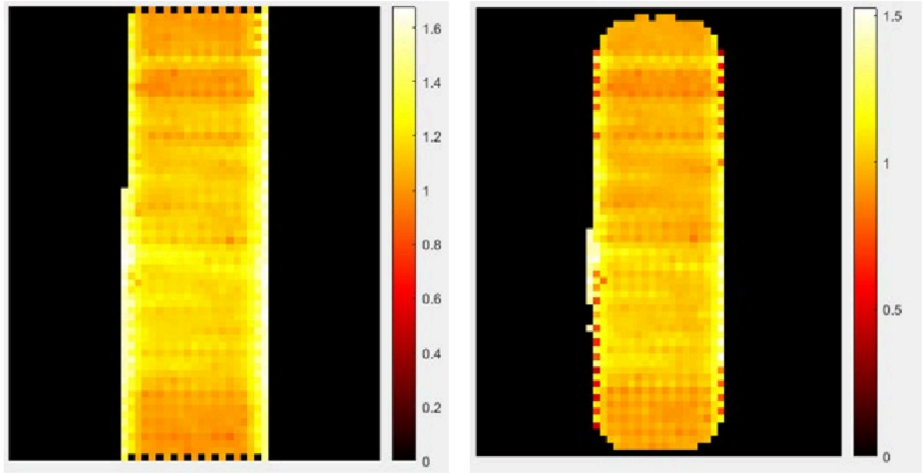


Figure 2: MapCheck 2 measured 2D DLG in the central 10cm in crossline by 32cm in inline region for flattened beam (15X, left) and flattening filter free beam (10FFF, right).

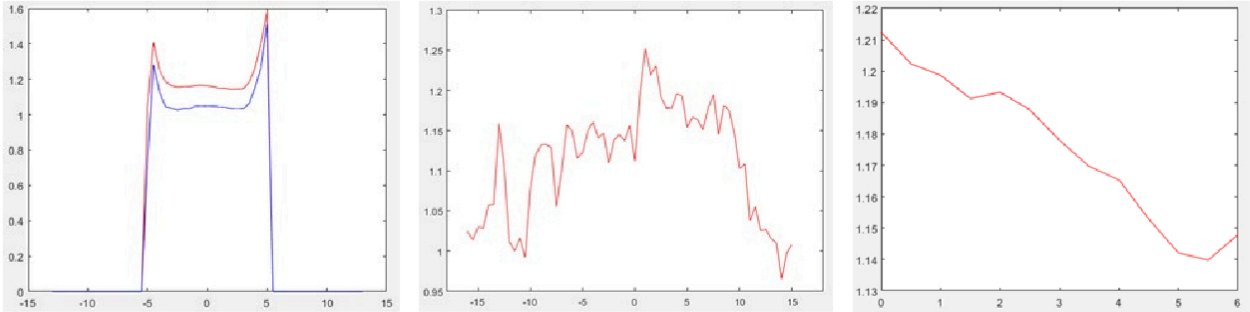


Figure 3: The average DLG value along crossline (left, red profile was the average DLG of all the central 5mm MLC leafs, blue profile was the average DLG of all the 1cm MLC leaf), inline (center), and off center (along x-axis) based on MapCheck2 measurements. The shoulders in the crossline profile are due to the close of x-jaws (5cm symmetrically). It has been decided only the center 6cm crossline profile will be used in the DLG analysis.

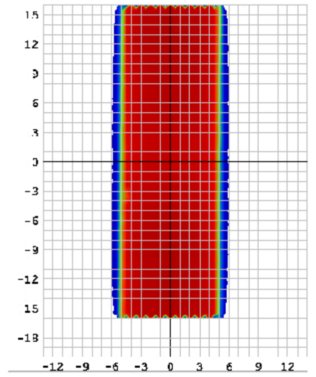
Figure 4: Film based DLG measurement verification: measured using 6X beam with sweeping MLC pattern, the static gap between leaf ends are 14mm (top).; and 10 by 10 open beam (bottom).

METHOD

Multiple xml Varian Developer Mode files for DLG measurement were developed based on the Varian standard sweeping gap technique, including: expanded Y-jaw to 36cm, increased MUs (improved SNR), and MLC and x-jaws shift 3cm laterally (off axis DLG measurement). SunNuclear MapCheck2 (diodes, primary detector) and Ashland GafChromic3 (film, secondary detector) were used to measure MLC transmission and dosimetric response of each sweep gap separately. Measurements were made at 100cm source to detector distance with 5cm buildup. For MapCheck2, all measurements were repeated with a 2.5mm IEC+Y shift to account for MLC tongue and groove effects. DLGs were calculated using the extrapolation method and compared against clinical baseline.

The MapCHECK 2 is a two-dimensional detector array intended to measure radiation dose distribution. The 1527 diode detectors are embedded in polymethyl methacrylate (PMMA) phantom in an array size of 32 cm x 26 cm, with a detector spacing of 7.07 mm. The spatial resolution of the diode detector is 0.8 mm x 0.8 mm, resulting in very little dose volume averaging over the high dose gradient regions in the plan. The MapCHIECK 2 serves as a 20 phantom with the array of detectors located on a 2D surface embedded at a radiological depth of 2 g/cm2 [1].

MapCheck2 measured dose at different leaf gap during the sweeping were analysis using the conventional DLG calculation method. The DLg value at the CAX were compared with the DLG value measured using IC during the initial configuration of the treatment unit. Comparison between the DLG value at the CAX to DLG values at off axis inline and off axis crossline was performed to evaluate the impact of leaf width (peripheral wider leaf vs central thinner leaf) and off axis energy degrading.



CONCLUSIONS

The proposed work showed that the DLG values can vary more than 15% depending on the position of measurement. 2D DLG map maybe necessary for a more accurate estimation on the dosimetry impact of DLG.

The two major physics factor that impacts local DLG values are the leaf width, and energy degrading, besides leaf to leaf DLG variations.

The leaf to leaf variation among leaf of the same width can be as high as 10% for individual leaf.

The leaf of larger width has lower DLG compared to thinner leafs. The variation is independent to energy degrading.

There is minor impact of energy degrading from the CAX to further off axis locations.

Most of these DLG variations do not have critical impact on clinical practices including treatment optimization and PSQA passing rate. However, as single isocenter multiple lesion SRS treatment became more popular as clinically practice, the clinical impact of low DLG at wider peripheral leafs may need further investigation.

REFERENCES

[1] SunNuclear User's Manual for MapCheck 2.

[2] Glide-Hurst C, Bellon M, Foster R, Altunbas C, Speiser M, Altman M, Westerly D, Wen N, Zhao B, Miften M, Chetty IJ, Solberg T. Commissioning of the Varian TrueBeam linear accelerator: a multi-institutional study. Med Phys. 2013 Mar;40(3):031719. doi: 10.1118/1.4790563.

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