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Original research article

Validation of Dosimetric Leaf Gap (DLG) prior to its implementation in Treatment Planning System (TPS): TrueBeam^{TM} millennium 120 leaf MLC

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ABSTRACT

Aim: Objective of present study is to determine optimum value of DLG and its validation prior to being incorporated in TPS for Varian TrueBeam^{TM} millennium 120 leaves MLC.
Background: Partial transmission through the rounded leaf ends of the Multi Leaf Collimator (MLC) causes a conflict between the edges of the light field and radiation field. Parameter account for this partial transmission is called Dosimetric Leaf Gap (DLG). The complex high precession technique, such as Intensity Modulated Radiation Therapy (IMRT), entails the modeling of optimum value of DLG inside Eclipse Treatment Planning System (TPS) for precise dose calculation.
Materials and methods: Distinct synchronized uniformed extension of sweeping dynamic MLC leaf gap fields created by Varian MLC shaper software were use to determine DLG. DLG measurements performed with both 0.13 cc semi-flex ionization chamber and 2D-Array I-Matrix were used to validate the DLG; similarly, values of DLG from TPS were estimated from predicted dose. Similar mathematical approaches were employed to determine DLG from delivered and TPS predicted dose. DLG determined from delivered dose measured with both ionization chamber (DLG_{Ion}) and I-Matrix ($DLG_{I\text{-}Matrix}$) compared with DLG estimate from TPS predicted dose (DLG_{TPS}). Measurements were carried out for all available 6MV, 10MV, 15MV, 6MVFFF and 10MVFFF beam energies.
Results: Maximum and minimum DLG deviation between measured and TPS calculated DLG was found to be 0.2 mm and 0.1 mm, respectively. Both of the measured DLGs (DLG_{Ion} and $DLG_{I\text{-}Matrix}$) were found to be in a very good agreement with estimated DLG from TPS (DLG_{TPS}).
Conclusions: Proposed method proved to be helpful in verifying and validating the DLG value prior to its clinical implementation in TPS.

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1. Background

Varian TrueBeam^{TM} (Varian Medical Systems, Inc., USA) Medical Linear Accelerator highly equipped with self-calibrated and self-controlled dynamic millennium 120 leaf Multi Leaf Collimator (MLC) Chang et al.[1] It has Flattening Filter (FF) and Flattening Filter Free (FFF) beam delivery capabilities along with KV/MV and CBCT imaging technique Chan et al. and Kielar et al.[1,2] TrueBeam^{TM} has a rounded end Millennium 120 leaf MLC. MLCs are designed with the inner 5 mm of leaf thickness projected at isocenter covered over the central 20 cm of the field size and the outer 1 cm of leaf thickness covered over the 10 cm on each side of the field size. Since MLC allows the maximum field dimension of 40 cm along the direction of gun to target. MLC types play a major significant role in delivering highly precise conformal external beam radiotherapy. Resolutions of MLC define the quality of the treatment plan Park et al.[3] Smaller width of MLC yields target conformity and rapid dose fall outside the target. Dosimetric impact of the rounded end design of MLC on high precession radiation technique such as static, dynamic Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) need to be taken into account. For that dosimetric parameter of MLC such as Leaf Transmission, Leaf Position Offset (LPO), Radiation Field Offset (RFO) and its properties must be considered and fed into the TPS. Such kind of high precision radiation therapy technique relies on the ability of MLC. Increase in the use of these high precession techniques enhanced delivery of high dose per fraction. This leads to concerns in leakage evaluation, which may be due either to interleaf, intraleaf leakage or partial transmission through the round end of the leaf. Parameter account for partial transmission through the end of rounded leaf MLC called Dosimetric Leaf Gap (DLG) Kielar et al. and Szpala et al.[2,4] DLG is also referred to as radiation field offset (RFO) Vial et al.[5] It is designed for patients treated with rounded end MLC to improve the accuracy of dose calculation in advanced high precision technique of radiotherapy. Evaluation and verification of various MLC parameters need to be performed while incorporating the high-end technique as IMRT/VMAT in Treatment Planning System (TPS); DLG is one of those parameters. Increase in radiation field size due to transmission through the rounded end of leaf. Fig. 1 provides the pictorial illustration of DLG. That describes how the radiation field cut off at the edge of MLC leaf; however, the partial transmission through the end of MLC leaves remain there. Also, Fig. 1 shows intensity spectra descend rapidly at the edge of MLC leaf and partial intensity liable for DLG decreasing exponentially. Effective radiation field size can be defined mathematically as follows:

$$\text{Radiation field size (mm)} = \text{MLC optical field size (mm)} + \text{DLG field size (mm)}.$$

IMRT is a complex treatment delivery technique involving numerous objective function & optimization parameters. IMRT first optimizes the objective fluence, and then with the help of leaf motion calculator (LMC) it creates the multiple sequential beamlets and generates segments to convert the objective fluence to the deliverable fluence. The dose delivered through the segment is under the influence of DLG Lee et al.[6] In order to commission the techniques like IMRT and VMAT values of DLG inevitable to measure, verify and its optimum values should be incorporate in TPS. Literature shows several theoretical and experimental methods to investigate DLG. It has been proved that, theoretically, the DLG based on a physical leaf position and DLG based on the integral dose method produce different results. DLG value was adjusted in the TPS until agreement was achieved between the measured and predicted dose for IMRT. However, this method was found to be very cumbersome and involved trial and error. Another way to achieve exact value of optimum DLG is from TPS calculated dose and verified by determining DLG based on integral dose measurement. Several studies have been published to determine the DLG, but none of them provides the validation of DLG inside the TPS. We performed this study in the context to determine optimum DLG and validate them with TPS. In order to minimize the dose variation between measured dose and predicted dose in the IMRT/VMAT technique, optimum values of DLG for all available energies were studied and incorporated in TPS.

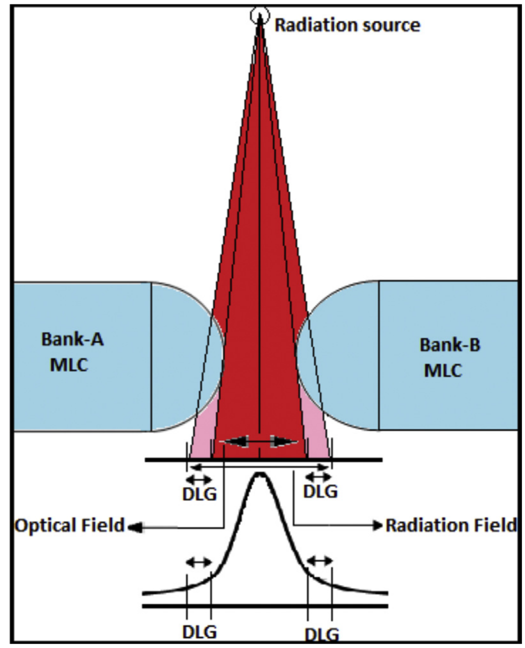

Fig. 1 – Pictorial representation of transmission through the rounded end of MLC leaf illustrating that both the optical field size and DLG constitute a radiation field.

2. Materials and methods

We divided this study into two sections. First, measurement of DLG with Ionization Chamber as well as Two-Dimensional (2D) Array I-Matrix (IBA Dosimetry, Germany) and second, validation of DLG in Eclipse Treatment Planning System (TPS). Measurement and validation of DLG was performed for Varian TrueBeam^{TM} millennium 120 leaves MLC. Primarily, DLG measurements were independently performed with 0.13cc