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MLC Transmission and Dosimetric Leaf Gap (DLG) Measurement

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Abstract

The Dosimetric Leaf Gap (DLG) is a critical parameter in radiation therapy, particularly for treatment delivery systems utilizing multileaf collimators (MLCs). DLG represents the offset between the projected light field and the actual radiation field, influencing the accuracy of dose calculations in advanced radiotherapy techniques such as Intensity-Modulated Radiation Therapy (IMRT) and Volumetric-Modulated Arc Therapy (VMAT). Accurate modeling of the DLG, along with MLC transmission, is essential for achieving precise dose distribution during treatment planning and delivery. Both parameters play a significant role in characterizing the impact of the rounded leaf ends of MLCs within the Eclipse treatment planning system (TPS)[9]. This study presents a systematic and reliable method for determining the DLG using the cross-field dose width and ionization chamber measurements. By implementing this approach, we aim to enhance the accuracy of dose modeling[6] in the TPS, ultimately improving treatment precision and patient safety in radiotherapy applications.

Keywords: Dosimetric leaf gap(DLG), MLC, Treatment planning systems, GAFCHROMIC film, Multileaf collimator, MRT, VMAT, Radiation therapy, Dose calculation, Eclipse TPS, Ionization chamber, Beam quality, MLC transmission, Radiotherapy commissioning

Introduction

The dynamic multileaf collimator (dMLC) has become an integral component of modern radiotherapy, enabling precise modulation of beam intensity to achieve highly conformal dose distributions. Most MLC systems feature rounded leaf tips with rectilinear motion, which inherently introduces additional x-ray transmission through the leaf ends. This transmission discrepancy leads to a difference between the dosimetric and geometric field widths, necessitating an adjustment to the geometric leaf position. While the radiation field offset (RFO) accounts for the positional offset of a single leaf, the dosimetric leaf gap (DLG) compensates for the combined effect of opposing leaf offsets and MLC transmission.

In treatment planning systems (TPS), two key systematic parameters—DLG and MLC transmission[1]—play a crucial role in accurately modeling dose distributions in dynamic MLC-based plans. The DLG represents a systematic correction applied to MLC leaf positioning, and variations in this parameter can lead to significant dosimetric discrepancies, particularly in complex MLC movements. To ensure high dose accuracy in clinical applications such as Intensity-Modulated Radiation Therapy (IMRT) and Volumetric-Modulated Arc Therapy (VMAT), minimizing systematic errors in the DLG is essential.

The value of the DLG is influenced by x-ray transmission through the rounded MLC leaf ends, making it dependent on factors such as beam quality and MLC design. Typically, DLG values are determined for each beam energy during the commissioning process to ensure precise dose calculations. Two

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commonly employed methods for DLG measurement include the integrating cross-field dose technique and the sweeping gap technique. For Varian treatment systems, the sweeping gap technique, as outlined in Varian Medical Systems' guidelines, provides a practical and effective method for deriving the DLG.
This study aims to present a comprehensive analysis of MLC transmission and DLG measurement, emphasizing their critical role in optimizing dose accuracy in radiation therapy. By refining the determination of these parameters, we seek to enhance the precision of dose modeling in the Eclipse TPS, ultimately improving treatment quality and patient safety.

Methods and Materials[1]

Measurement System and Equipment

All measurements were conducted using a Varian TrueBeam linear accelerator (Varian Medical Systems, Palo Alto, CA) equipped with a Millennium 120-leaf multileaf collimator (MLC). Photon beams of 6 MV, 10 MV, 18 MV, and 6 MV flattening filter-free (FFF) were utilized for this study. The Eclipse™ Treatment Planning System (TPS) (Varian Medical Systems Inc., Palo Alto, CA) was employed for dose calculations and analysis.

Measurement Setup

A PTW BeamScan Radiation Field Analyzer and a PTW PinPoint 0.125cc ionization chamber were used for data collection. The water surface was positioned at a source-to-surface distance (SSD) of 95 cm for beam energies up to 10 MV and 90 cm SSD for energies greater than 16 MV. The dosimetric leaf gap (DLG) was measured in a phantom setup, with the ionization chamber positioned at a depth of 5 cm for lower energies and 10 cm for energies exceeding 16 MV.

DICOM Data and Measurement Procedure

DICOM files provided by Varian contained pre-configured sliding field and static slit MLC field dose distributions with varying gap widths. These fields were used to conduct ionization chamber measurements under different beam energy conditions at specified depths of 5 cm and 10 cm.
The DLG values were determined through linear extrapolation of the measured dose, identifying the point at which the gap width axis intercepts at zero dose.

Field Types and Measurement Parameters

Open Field: This field was used for detector alignment and system warm-up.
Transm X Fields: These fields were used to measure transmission through MLC banks A and B. The fields were blocked by the MLC leaves, with the abutting rounded leaf edges positioned under the collimator jaws. The same collimator jaw settings were applied as in the open field and in the fields with sliding MLC gaps.
XXmm Fields: These fields, with sliding MLC gaps, were measured at 2, 4, 6, 10, 14, 16, and 20 mm gap sizes. The gap varied from -60 mm to +60 mm, moving at a constant speed relative to monitor units (MU). The leaf positions were defined every 10 mm by control points, ensuring uniform fluence within a 10x10 cm² field size.
To begin the measurement process, the DICOM plan file for the specific beam energy, primary fluence mode, and MLC model is opened. The measurement starts with the delivery of the open field, and the recorded value is noted as $\mathbf{R_{open}}$. Next, the MLC transmission for **MLC Bank A** is measured using the

Transm A field, with the recorded value denoted as $\mathbf{R_{T,A}}$. Similarly, the MLC transmission for **MLC Bank B** is measured using the **Transm B field**, and the corresponding value is recorded as $\mathbf{R_{T,B}}$.

Calculate the Average Transmission Reading:

The average transmission reading (R_T,) is calculated using the formula: $R_T = \left(\frac{R_{T,A} + R_{T,B}}{2}\right)$

Measure the Reading for Moving Gap (*Rg*):
Measure the reading (*Rg*) using the moving gap fields with gap sizes ranging from 1 mm to 20 mm.

Calculate the Dosimetric Leaf Gap (DLG):

1. Calculate the Contribution of the Average MLC Leaf Transmission to the Gap Reading (R_{gT}) for Each Gap g*g*: The contribution of transmission to the gap reading is defined as:
$$R_{gT}' = R_T \cdot \left(1 - \frac{g[mm]}{120[mm]}\right)$$

2. Calculate the Corrected Gap Reading for Each Gap gg: The corrected gap reading (Rg′) is defined as: $Rg' = Rg - RgT$

Ion Chamber Measurements Method:[2,8,10]
In the ion chamber measurements method, the average MLC leaf transmission to the gap reading for each gap (Rg_T) was calculated using the sweeping gap technique. The DLG values derived from the cross-field dose width method provide a reliable reference for TPS commissioning. This method ensures accurate modeling of the dosimetric distribution, which is crucial for precise dose delivery in radiation therapy.

Results
DLG values and MLC transmission factors: Table1 shows the measured DLG values and MLC transmission factors for different beam energies. the DLG values measured with the ion chamber for the depths of 5 and 10 cm.

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Table: 1 MLC Transmission and DLG For 6MV Energy

MLC Transmission	
Field	Reading (nC)
Open Field Reading, R_o	38.440
MLC Transmission Reading Bank A, R_{TA}	0.515
MLC Transmission Reading Bank B, R_{TB}	0.509
Average MLC Transmission Reading, R_T	0.5120
Average MLC Transmission Factor	0.0133

Moving Gap (mm)	Reading (nC) R_g	MLC contribution R_{gT}	Corrected Rdg $R_{g'}$
2	1.065	0.503	0.562
4	1.401	0.495	0.906
6	1.705	0.486	1.219
10	2.342	0.469	1.873
14	2.983	0.452	2.531
16	3.304	0.444	2.860
20	3.948	0.427	3.521
Dosimetric Leaf Gap (mm)		1.452	mm
Eclipse Dosimetric Leaf Gap (cm)		0.145	

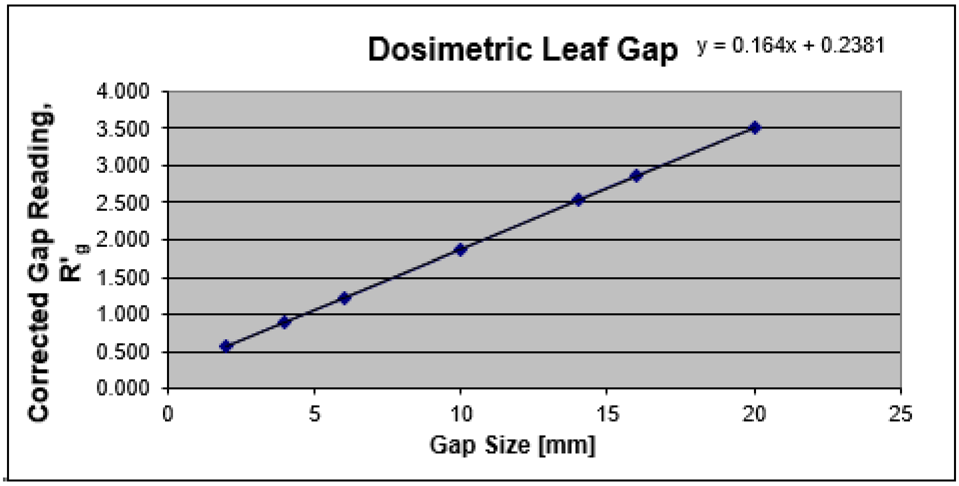

Fig.1-6MV Energy-Plot

Discussion[5, 7, 10]:

The Dosimetric Leaf Gap (DLG) and MLC transmission are two fundamental parameters in the dose calculation algorithms of a Treatment Planning System (TPS). These parameters are particularly critical in the modeling of complex multileaf collimator (MLC) motions, as they directly impact the accuracy of dose distribution in advanced radiotherapy techniques such as Intensity-Modulated Radiation Therapy (IMRT)[4] and Volumetric-Modulated Arc Therapy (VMAT). Since the DLG accounts for additional x-ray transmission through the rounded MLC leaf tips, its value is influenced by multiple factors, including beam quality, MLC type, and specific leaf positioning. Variations in the DLG parameter can introduce significant discrepancies in dose calculations, making its precise determination essential for accurate treatment planning.

As the TPS employs a single DLG value to model the offset of opposing MLC leaves[3], determining an optimal DLG value for each beam energy is a crucial step in the TPS commissioning process. This ensures accurate dose calculations across a wide range of dynamic MLC-based treatment plans. Without an accurate DLG setting, discrepancies in planned and delivered doses can arise, potentially affecting treatment efficacy. To achieve precise dosimetric characterization, the DLG value should be measured independently for different photon energies, rather than relying on generic system defaults.

One of the most widely adopted clinical methods for determining the DLG is the vendor-provided sweeping gap MLC pattern technique. This study followed the calculation methodology outlined in the vendor's documentation and validated that the results align closely with reference data. Baseline DLG values were measured in accordance with vendor guidelines for photon beam energies of 6 MV, 6 MV FFF, 10 MV, and 18 MV. The use of a highly sensitive ionization chamber in this study ensured minimal measurement uncertainty, reinforcing the reliability of the obtained DLG values.
The characterization of the DLG has been observed to be largely insensitive to variations in parameters such as source-to-surface distance (SSD), depth of measurement, dose rate, and ion chamber type. However, the DLG[3]values tend to increase with beam energy, as demonstrated in the results summarized in Table 2. Ion chamber measurements confirmed that while depth variations had negligible effects on DLG determination, there was a clear linear relationship between MLC transmission and DLG values. This suggests that for higher-energy beams, increased x-ray transmission through the MLC leaves contributes to a greater dosimetric offset, which must be accurately accounted for during treatment planning.

Furthermore, an MLC system designed with reduced scattering and minimized radiation transmission should theoretically exhibit a lower DLG value. The findings of this study underscore the importance of precise DLG determination to ensure accurate dose delivery in clinical radiation therapy. By optimizing DLG values based on measured data rather than default system settings, treatment accuracy can be significantly enhanced, reducing uncertainties and improving patient outcomes. This study reinforces the necessity of periodic DLG validation during TPS commissioning and quality assurance processes to maintain optimal dosimetric accuracy in radiotherapy treatments.

Table 2: DLG values and MLC transmissions for different energies

Energy	**MLC Transmission Factor**	**Dosimetric Leaf Gap (mm)**
(MV		
6	0.0133	1.452
10	0.016	1.682
18	0.014	1.655
6FFF	0.011	1.340

Conclusions:
The Dosimetric Leaf Gap (DLG) values derived from the sweeping field technique were found to be consistent with the representative values provided by the vendor. This consistency underscores the reliability and accuracy of the sweeping field technique in determining DLG values.
During the commissioning of a Treatment Planning System (TPS), the assessment of DLG values is a critical step to ensure precise dose calculations and effective treatment delivery. The sweeping field

technique offers a more efficient and accurate approach to this assessment, as it simplifies the measurement process and reduces potential sources of error.

By adopting this method, clinics can achieve a higher level of confidence in their TPS commissioning, leading to improved treatment planning and better patient outcomes. The findings of this study highlight the importance of using standardized and validated techniques for DLG measurement, ensuring that the dosimetric parameters are accurately modelled and that the radiation therapy delivered is both safe and effective.

In conclusion, the sweeping field technique not only aligns with vendor-provided reference data but also enhances the overall efficiency and accuracy of DLG value assessment during TPS commissioning. This method represents a valuable tool for radiation therapy clinics aiming to optimize their treatment planning processes and deliver high-quality care to their patients.

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