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Clinical Implications of High Definition Multileaf Collimator (HDMLC) Dosimetric Leaf Gap (DLG) Variations

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This study is to evaluate the dosimetric impact of dosimetric leaf gap (DLG) and transmission factor (TF) at different measurement depths and field sizes for high definition multileaf collimator (HD MLC). Consequently, its clinical implication on dose calculation of treatment planning system was also investigated for pancreas stereotactic body radiation therapy (SBRT). The TF and DLG were measured at various depths (5, 8, 10, 12, and 15 cm) and field sizes (6×6, 8×8, and 10×10 cm^2) for various energies (6 MV, 6 MV FFF, 10 MV, 10 MV flattening filter free [FFF], and 15 MV). Fifteen pancreatic SBRT cases were enrolled in the study. For each case, the dose distribution was recomputed using a reconfigured beam model of which TF and DLG was the closest to the patient geometry, and then compared to the original plan using the results of dose-volume histograms (DVH). For 10 MV FFF photon beam, its maximum difference between 2 cm and 15 cm was within 0.9% and it is increased by 0.05% from 6×6 cm^2 to 10×10 cm^2 for depth of 15 cm. For 10 MV FFF photon beam, the difference in DLG between the depth of 5 cm and 15 cm is within 0.005 cm for all field sizes and its maximum difference between field size of 6×6 cm^2 and 10×10 cm^2 is 0.0025 cm at depth of 8 cm. TF and DLG values were dependent on the depth and field size. However, the dosimetric difference between the original and recomputed doses were found to be within an acceptable range (<0.5%). In conclusion, current beam modeling using single TF and DLG values is enough for accurate dose calculation.

Key Words: HDMLC, Dosimetric leaf gap (DLG), MLC transmission factor, Stereotactic body radiation therapy (SBRT), Pancreas

Introduction

Advanced radiation therapy techniques such as intensity-modulated radiation therapy (IMRT), volumetric arc therapy (VMAT), image-guided radiation therapy (IGRT), and stereotactic body radiation therapy (SBRT) have been widely used because they minimize the probability of complications to normal tissue while maximizing tumor control.[1-3] The multileaf collimator (MLC) plays a key role in such advanced radiation therapy for delivering the spatially varied complex pattern of radiation fluence with high accuracy.[4,5] Consequently, for accurate computation of the radiation dose delivered by the MLC, accurate dosimetric modeling of the MLC such as that of its leaf transmission factor (TF) and dosimetric leaf gap (DLG) should be included in the treatment planning system (TPS).[6]

Several investigators have studied the impact of plan and dosimetric distribution according to the width and shape of the leaf and the leaf speed.[7-9] They have investigated the impact of the DLG on the dose distribution and calculation by using the Millennium 120 MLC (Varian Medical Systems, Palo, Alto, CA, USA) under only one fixed depth.[10-15] It was shown that the DLG value was different from the value measured at

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the reference condition (where the source-to surface distance was 95 cm and the depth was 5 cm), and that the changed DLG values could be reconfigured in the TPS in order to produce an optimized treatment plan. DLG and TF values measured only at a fixed depth were used for beam configuration in the TPS and therefore, all treatment planning and dose calculations was performed using a single DLG value regardless of the tumor's depth and irradiation field. Subsequently, DLG values depending on the change in the depth and size of the tumor were used in the TPS to obtain an optimized treatment plan and dose distribution. However, the authors were unaware of studies investigating the dosimetric impact of DLG values in clinical patient case studies. Therefore, to compare the dosimetric difference according to the tumor's depth and size, pancreas case is selected because it was relatively located at deep depth to other tumors in this study.

The purpose of this study was to evaluate the dosimetric impact of the measured TF and DLG, under different depths and field sizes of a tumor, on an HDMLC for SBRT in pancreatic cancer treatment.

Table 1. Patient characteristics (n=15).

Characteristics	Value
Age (year)	
Range	39~80
Mean/Median	63/61
Gender	
Male	11
Female	4
Tumor depth (cm)	(Avg±SD)
Anterior	7.90±1.73
Posterior	12.02±0.87
Left	14.42±2.46
Right	14.44±2.59
Tumor size (cm)	(Avg±SD)
Lateral	7.64±1.17
Anteroposterior	7.38±1.15
Dose/Fractionation	
26 Gy/4	1
28 Gy/4	7
30 Gy/4	5
32 Gy/4	2

Avg: average, SD: standard deviation.

Materials and Methods

1. Patient characteristics

This study involved 15 patients (with pancreatic cancer) treated with SBRT from March 2015 to April 2016 at our institution (Table 1). For each patient, the depth and diameter of the pancreas were measured to evaluate the dosimetric impact of the DLG as a function of the depth and field size of the pancreas (Fig. 1). The depths (5, 8, 10, 12, and 15 cm) and field sizes (6×6, 8×8, and 10×10 cm^2) for measuring the TF and DLG were determined after considering the average and variation in these parameters on the SBRT fields as measured in the four directions (anterior, posterior, left and right).

2. Experiment setup and HD 120 MLC

A HD120 MLC installed on a linear accelerator (TrueBeamSTx 1.5, Varian Medical Systems, Palo Alto, CA, USA) was used in the study. The radius of curvature of the HD120 leaf end was 16 cm. The central pairs of tungsten leaves were 2.5 mm wide and the 28 outer pairs of leaves were 5.0 mm wide and projected to the isocenter.[7,15] Its maximum field size was 22×40 cm^2. All measurements were performed in a water phantom (MT100T, CIVCO Medical Solutions, Orange City, Iowa, USA) with a volume of 30.5×38×38 cm^3 using an ionization chamber (FC65-G, IBA, Germany). The gantry and collimator angle was set of 0^o.[14] The collection volume of the ionization chamber was located perpendicular to the central beam

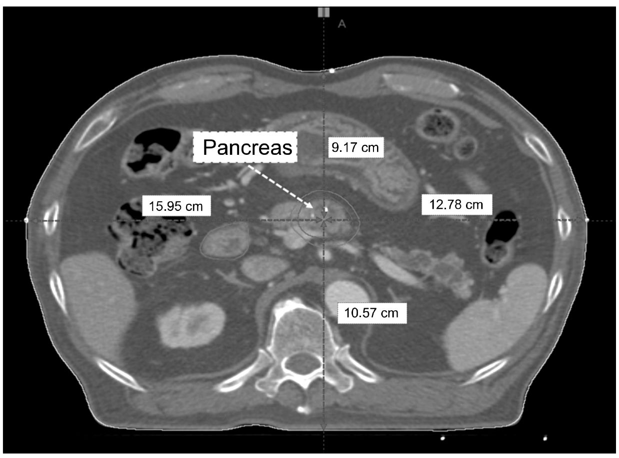

Fig. 1. Measurement of tumor size and depth.

axis and to the MLC leaf motion direction.

3. MLC DICOM files and measuring the DLG

The TF and DLG are required to calculate the dose distribution for the dynamic MLC technique in the TPS (Eclipse, Version 13.0, Varian Medical Systems, Palo Alto, CA, USA). We used a dosimetric leaf separation (DLS) MLC digital imaging and communications in medicine (DICOM) file provided by the manufacturer to determine the two MLC parameters. It consisted of sliding window files with nominal MLC gap widths of 2, 4, 6, 10, 14, and 20 mm in a field size of 10×10 cm^2 to calculate the leaf gap and open and closed fields to calculate the TF. The TF is defined as the ratio of leakage and scatter dose in MLC leaves to the open field dose.[9)] The DLG was measured by extrapolating the size of the static or dynamic fields formed by the MLC leaves to the size under which the measured dose matched the MLC leakage.[12)] It consisted of open and closed fields, DLS of 2, 6, 10, 14, and 20 mm in a field size of 10×10 cm^2. All leaves moved by 100 mm during beam on in despite of the gap width in this leaf configuration.[15)] Consequently, the same MUs with the same leaf speed were delivered for all gaps.[15)] To evaluate the impact of the field size on the DLG, the field size in the original DLS file was modified to 6×6 cm^2 and 8×8 cm^2 as average size of pancreas case selected in this study.

All measurements were conducted by delivering 100 monitor units (MUs) at a rate of 400 MU/min and with photon beam energies of 6 MV, 6 MV flattening filter free (FFF), 10 MV, 10 MV FFF, and 15 MV. For each beam energy, the TF and DLG were measured for a field size of 10×10 cm^2 at five different depths (5, 8, 10, 12, and 15 cm). The same measurements were repeated with the two other field sizes. Finally, the DLG values with various beam energies, depths, and field sizes were calculated following the method by Wasbø et al. with a linear relationship between the leaf gap width and the measured dose.[15)]

4. Treatment planning

To evaluate the dosimetric impact of the DLG value at different tumor depths inside the patient's body, the measured TF and DLG values were applied to the Eclipse TPS. The dose distribution recalculated with the modified parameters was compared with that of the original plan in which the TF and DLG values were measured at the reference depth. We used the 10 MV FFF photon beam for VMAT SBRT in pancreatic cancer treatment, and the anisotropic analytical algorithm (AAA) was used to calculate the photon dose.

Results

1. Transmission factor (TF)

Fig. 2(a) shows the TF values measured for the field size of 10×10 cm^2 at four different depths (2, 5, 10, and 15 cm) and

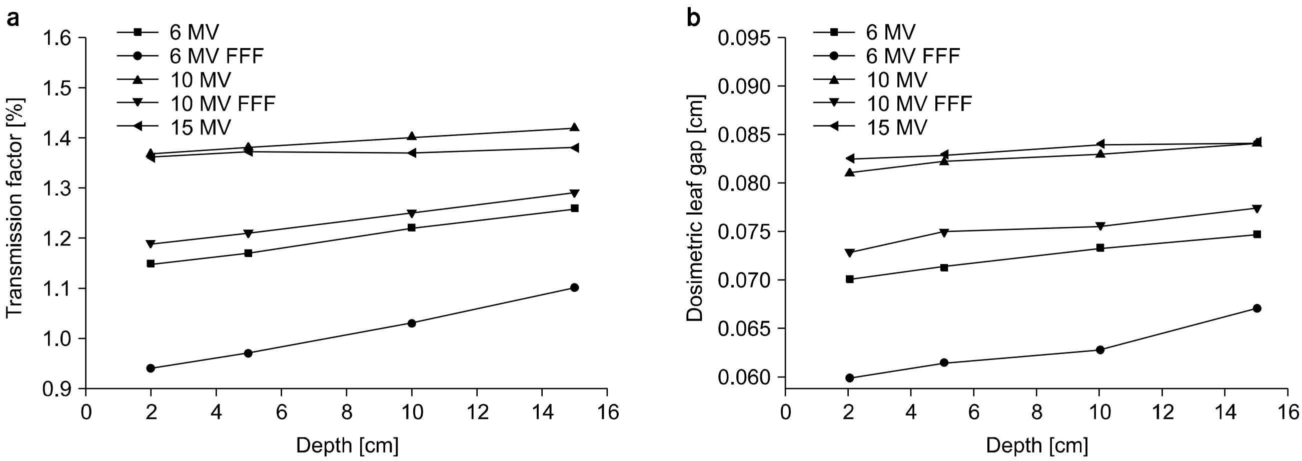

Fig. 2. Measured transmission factor (a) and dosimetric leaf gap (b) at a field size of 10×10 cm^2 at different depths (2, 5, 10, and 15 cm) and with a photon beam energy of 6 MV, 6 MV FFF, 10 MV, 10 MV FFF, and 15 MV.

photon beam energies of 6 MV, 6 MV FFF, 10 MV, 10 MV FFF, and 15 MV. The TF increases as the beam energy and depth increase. The maximum absolute differences in the TF between photon energies of 6 MV FFF and 10 MV were 0.43% and 0.41% at depths of 2 cm and 5 cm, respectively. At a depth of 15 cm, the minimum difference in the TF between the two energies was 0.31%. For a 10 MV FFF photon beam, the difference between a depth of 2 and 15 cm was within 0.9%. Fig. 3(a) shows the TF measured for a photon beam energy of 10 MV FFF at different field sizes (6×6 cm^2, 8×8 cm^2, and 10×10 cm^2) and different depths (5, 10, and 15 cm). The TF increased by 0.05% when the field size was varied from 6×6 cm^2 to 10×10 cm^2 for a depth of 15 cm (Table 2, Fig. 3).

2. Dosimetric leaf gap (DLG)

Fig. 2(b) shows the DLG measured for a field size of 10×10 cm^2 at four different depths and for all photon beam energies. Similar to the tendency of TF, DLG increased as the beam energy and measurement depth increased. At a depth of 2 cm, the maximum difference between the 6 MV FFF and 15 MV photon beams was 0.023 cm and the minimum difference was 0.02 cm at a depth of 15 cm. When using a 10 MV FFF photon beam, the difference in DLG between the depth of 5 cm and 15 cm was approximately within 0.005 cm for the three field sizes (Table 2). In addition, the DLG increased with increasing field size at each measurement depth. At a depth of 8 cm, the maximum difference between a field size of 6×6 cm^2 and 10×10 cm^2 was 0.0025 cm. The minimum difference was approximately 0.0014 cm between a depth of 5 and 10 cm.

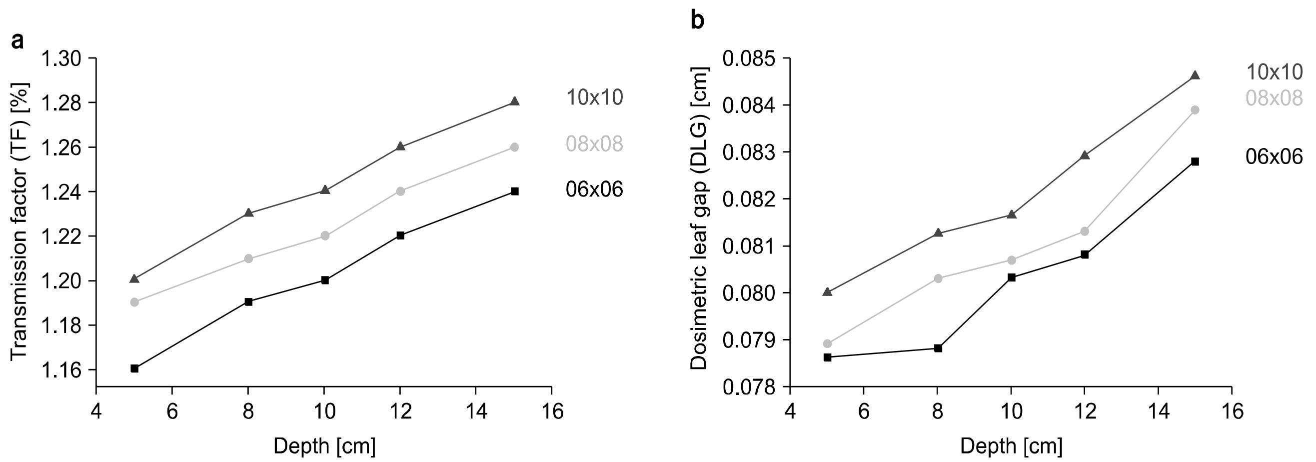

Fig. 3. Measured transmission factor (a) and dosimetric leaf gap (b) with a 10 MV FFF photon beam at different field sizes (6×6, 8×8, and 10×10 cm^2) and different depths (5, 10, and 15 cm).

Table 2. Transmission factor (TF) and dosimetricleaf gap (DLG) at various depths and field sizes with a 10 MV FFF photon beam.

Depth (cm)	Transmission factor (%)			Dosimetric leaf gap (cm)		
	6×6 (cm^2)	8×8 (cm^2)	10×10 (cm^2)	6×6 (cm^2)	8×8 (cm^2)	10×10 (cm^2)
5	1.16	1.19	1.20	0.0786	0.0789	0.0800
8	1.19	1.21	1.23	0.0788	0.0803	0.0813
10	1.20	1.22	1.24	0.0803	0.0807	0.0817
12	1.22	1.24	1.26	0.0808	0.0813	0.0829
15	1.24	1.26	1.28	0.0828	0.0839	0.0846

3. Comparison between the original and modified plans for SBRT in pancreatic cancer

Fig. 4 shows the dose volume histogram (DVH) of the original (▲) and modified plans (■) for depths of 5, 8, and 10 cm. The dose discrepancies between the original and recomputed doses were within 0.5% for all depths.

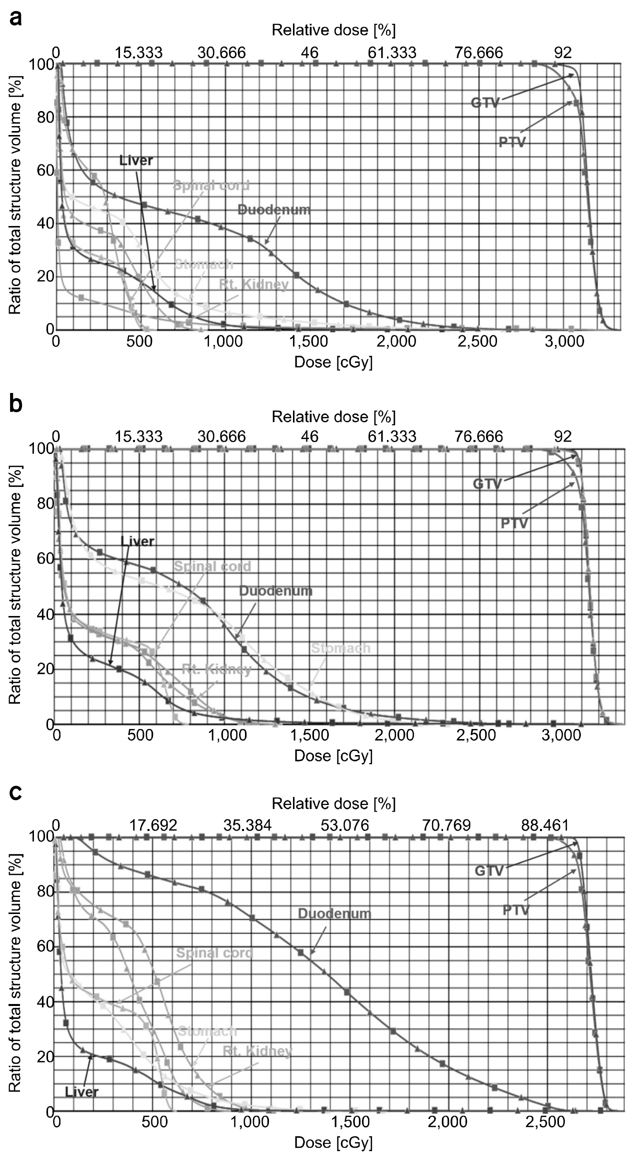

Fig. 4. Dose volume histogram (DVH) of original plan (▲) and modified plans (■) for depths 5 cm (a), 8 cm (b), and 10 cm (c).

Discussion

We evaluated the dosimetric impact of the DLG at different depths and field sizes on an HDMLC. Its clinical implication on the dose calculation of the TPS was also investigated for SBRT in pancreatic cancer treatment.

For all photon beam energies, the TF and DLG values increased with an increase in the depth and field size (Fig. 2). However, we confirmed that the values of the two parameters did not significantly change as the measurement depth increased for photon beam energies of 10 MV and 15 MV. This result is consistent with a previous study on the DLG in the Millennium 120 MLC.[14)] With regard to the 6 MV and 15 MV photon beams, the results are similar to those reported by Wasbø et al.[15)] The increase in the TF and DLG as a function of depth is likely caused by the larger phantom scatter. As shown in Fig. 3, the two parameters increased with an increase in the field size when the 10 MV FFF photon beam was used. This result is consistent with the previous study[15)] and the increase in the TF and DLG according to the field size is likely caused by the increase in collimator scatter.

As a result, we confirmed that TF and DLG values according to changes in the tumor depth and size should be applied to the TPS when SBRT in pancreatic cancer treatment is performed with a 10 MV FFF photon beam. Furthermore, we compared the DVHs between the original and modified plan (Fig. 4). The dosimetric discrepancies between the two plans were found to be within an acceptable range for all depths. Therefore, we confirmed that the change in the TF and DLG as a function of depth does not need to be considered in a TPS even though the TF and DLG values are dependent on the depth and field size.

This study focused on pancreatic cancer. In future work, this dosimetric impact will be studied for head, neck, and skin cancer that is at a relatively shallow depth to verify that the dosimetric discrepancies between the two plans are similar to that in the pancreatic case, even though the TF and DLG vary with depth and field size. Furthermore, the TF and DLG will be measured at other gantry angles to correct for the variation in this angle, which was not done in this study. In the future, dosimetric accuracy will be studied with the corrected TF and

DLG in VMAT plans.

Conclusion

We have evaluated the dosimetric impact of the measured TF and DLG at different depths and field sizes on an HDMLC for SBRT in pancreatic cancer treatment. The TF and DLG were found to vary with the depth and field size. However, the dosimetric difference between the original and recomputed doses was found to be within an acceptable range (<0.5%). Therefore, current beam modeling using single TF and DLG values is sufficient for accurate dose calculation, even though the TF and DLG vary with depth and field size.

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