Introduction

The three-dimensional conformal radiotherapy (3D-CRT), intensity-modulated radiotherapy (IMRT), and image-guided radiotherapy (IGRT) are the most advanced techniques in radiotherapy, which use irregular fields—using multileaf collimators in a linear accelerator. The accuracy of these techniques depends on dosimetric characteristics of the multileaf collimators. There is an option for optimizing the jaws to the irregular MLC field to reduce the scattered radiation and intra- and inter-leaf radiation leakage beyond the field. In this study, 120-leaf MLC system has been taken to compare and differentiate their characteristics with 6-MV and 18-MV photon beams.

Materials and Methods

Varian 2300CD CLINAC linear accelerator with 6-MV and 18-MV photon beams and 120-leaf multileaf collimator. Eclipse treatment planning system, PTW MP3 3D water phantom with 0.125-cc field and reference chambers, 0.6-cc farmer chamber, and PTW solid water (slab) phantom.

A. 120-leaf MLC system

The Varian 120-leaf MLC system consists of an MLC head assembly and control system. The MLC system is attached to the head of the CLINAC 2300CD as a tertiary collimator consisting a pair of 60 opposed leaves. These
leaves are mounted in two leaf banks below ‘X’ jaws. The leaf width at the isocenter for each of the central 80 leaves is 0.5 cm; and for all others, it is 1.0 cm.

**B. Measurement of dosimetric characteristics**

Measurements were made in water using PTW MP3 water phantom using the following methods:

- MLC field with jaws optimized (MLC+Jaw) — optimization method
- MLC field with jaws parked at 35×35 cm (MLC only) — non-optimization method
- Jaw field with X1, X2, Y1, and Y2 jaws (Jaw only)

**C. Dose rate (DR)**

The dose rate was measured in a PTW solid water (slab) phantom using a 0.6-cc PTW (PTW-Freiburg) waterproof ion chamber and a PTW UNIDOS digital electrometer. The solid phantom is tissue equivalent with a density of 1.045 g/cc; its dimensions are 30×30×30 cm (width×length×depth). It has a slot to position the 0.6-cc chamber. All measurements were made in source-to-surface distance (SSD) setup of 100 cm for field sizes 5×5 cm², 10×10 cm², 15×15 cm², 20×20 cm², and 30×30 cm² using IAEA TRS-398 absolute dose calculation protocol, for all the above-mentioned fields for 6-MV and 18-MV photon beams at a reference of depths 5 cm and 10 cm respectively.

**D. Percentage depth dose and beam profile**

The central axis percentage depth dose (PDD) and beam profile were measured using PTW MP3 3D radiation field analyzer system controlled by Mephysto computer software. The RFA consists of a cubic water tank with inner dimensions 60×50×40.75 cm (width×length×depth). The drive mechanism of the scanning system has a positional accuracy of ±0.5 mm and reproducibility of ±0.1 mm. Semi-flex cylindrical chambers, 0.125 cc, were used. The measuring chamber was positioned perpendicular to the radiation beam and parallel to the water surface. A reference detector was placed in one quadrant corner of the radiation field so that it does not interfere with the reading of the field detector. The PDD and beam profile were measured for source-to-surface (SSD) = 100 cm, for the square fields 5×5 cm², 10×10 cm², 20×20 cm² and 30×30 cm², using all the three field-defining methods as described in section B.

**Results and Discussion**

Dose rate (DR) in medium was measured as described in section C, at a reference depth of 5 cm for 6-MV and 10 cm for 18-MV photon beams. The increases in the DR as shown in Figures 1 and 2 were more pronounced for the fields defined by ‘MLC only’ and had higher values compared to those for the fields defined by ‘Jaw only’ and/or ‘MLC+Jaw’. The range of ‘percentage of difference’ between the ‘MLC only’ field and ‘MLC+Jaw’ field was (0.9% to 4.40%) and (1.14% to 7%) for 6-MV and 18-MV photons respectively. It was found that there was no significant difference between the dose rates of ‘MLC+Jaw’ and ‘Jaw only’ fields in both the energies. The increase in dose rate due to MLC+Jaw fields may be due to increase in head scatter with MLC.[1-4] The leaf setting strategy and effect of leaf width on physical dose distributions were discussed by Yu et al. and Fiveash et al. respectively.[5,6]

Tables 1 and 2 show the comparison of PDD parameters for all the fields using the three field-defining methods for 6-MV and 18-MV photon beams. The PDD data was measured at SSD = 100 cm, for the depth ranging from 0 to 30 cm for all the fields. The measurement are performed with the three field-defining methods (i) Jaw only (MLC in park position), (ii) MLC only — (fixed jaws opening at 35×35 cm), and (iii) MLC+Jaw (jaw optimized to MLC irregular ‘MLC+Jaw’ Fields.). From Tables 1 and 2, it
is clear that the surface dose (S-0) for 6 MV and 18 MV was higher for field sizes defined by ‘MLC only’ than that for field sizes defined by ‘Jaw only’ and ‘MLC+Jaw’. The ‘percentage of difference’ of surface dose between ‘MLC only’ and ‘MLC+Jaw’ fields was (2% to 3%) and (3.5% to 5%) for 6-MV and 18-MV photons respectively. It was found that the dose in the build-up region was higher for the ‘MLC only’ field than that for the other two field-defining methods in both energies. It was found that the position of ‘depth of dose maximum’ (dmax) shifted more towards the surface for 18 MV compared to 6 MV, with increase in the field size. No significant difference in the PDD was observed beyond the dmax, that is, depth between dmax to 30 cm, for both the energies.[1] The difference in the ‘depth of 80% dose’ was within 0.5 to 1.5 mm for 6-MV and 1 to 4 mm for 18-MV photon beams for all the field defining methods. There were no significant variations when comparing the quality index (QI) with the three field-defining methods, for both the energies. The 120-leaf MLC system, which has a 5 mm leaf width, improves the dose coverage to the tumor volume and is useful in organ avoidance in head and neck tumors.[6] This will produce an ideal DVH curve for a tumor volume which gives uniform dose distribution; and at the same time, DVH of critical organs will show minimum dose contribution. In studies,[7-13] various dosimetric characteristics of multileaf collimators are measured and analyzed. The increase in the surface dose and dose rate will definitely not have any effect on the dose to the tumor, and there shall be no consequence on the clinical approach and outcome.

### Beam profiles

The beam profiles were measured using 120-leaf MLC system, for the square field sizes 5×5 cm², 10×10 cm², 20×20 cm², and 30×30 cm² at dmax and 10 cm in the cross-plane orientation for the three field-defining methods mentioned in section D. The flatness and symmetry of the beam profiles were determined for the fields defined above; it was found that the flatness and symmetry were within 3% for both energies. The ‘width of 50% dose level’ was measured and analyzed; it was observed that the width of the ‘MLC only’ field was higher by 2 to 4 mm for 6-MV and 1 to 2.8 mm for 18-MV photon when compared with ‘Jaw only’ and/or ‘MLC+Jaw’ fields. Tables 3 and 4 show the comparison of the ‘widths of the 50% dose level’ in the three field-defining methods for 6 MV and 18 MV respectively.

### Tables

#### Table 1: Comparison of percentage depth dose parameters for 6-MV photon beam

| Field size (cm x cm) | Field defining method | Percentage depth dose (%) | Depth of 80% dose (mm) | Quality index (QI) |
|----------------------|-----------------------|---------------------------|------------------------|--------------------|
|                      | Dmax | D-0 | D-100 | D-200 |                      |                      |
| 5x5                  | Jaw only | 16 | 46.97 | 63.29 | 34.81 | 61.22 | 0.6344 |
|                      | MLC only | 16 | 46.98 | 63.39 | 34.66 | 60.12 | 0.6301 |
|                      | Jaw+MLC | 16 | 44.41 | 63.68 | 35.19 | 60.97 | 0.6341 |
|                      | Jaw only | 16 | 50.84 | 67.10 | 38.52 | 65.86 | 0.6664 |
| 10x10                | MLC only | 16 | 51.37 | 67.04 | 38.62 | 65.65 | 0.6693 |
|                      | Jaw+MLC | 18 | 48.94 | 66.94 | 38.5 | 66.19 | 0.668 |
|                      | Jaw only | 16 | 59.02 | 70.3 | 42.76 | 71.67 | 0.7115 |
| 20x20                | MLC only | 16 | 60.41 | 69.65 | 42.82 | 69.37 | 0.7201 |
|                      | Jaw+MLC | 17 | 57.33 | 69.95 | 42.85 | 72.1 | 0.7172 |
|                      | Jaw only | 14 | 65.4 | 71.05 | 44.8 | 73.08 | 0.7402 |
| 30x30                | MLC only | 12 | 66.68 | 71.32 | 44.72 | 74.68 | 0.7357 |
|                      | Jaw+MLC | 16 | 63.8 | 71.26 | 44.78 | 73.7 | 0.7374 |

#### Table 2: Comparison of percentage depth dose parameters for 18-MV photon beam

| Field size (cm x cm) | Field defining method | Percentage depth dose (%) | Depth of 80% dose (mm) | Quality index (QI) |
|----------------------|-----------------------|---------------------------|------------------------|--------------------|
|                      | Dmax | D-0 | D-100 | D-200 |                      |                      |
| 5x5                  | Jaw only | 35 | 24.1 | 79.23 | 51.27 | 97.87 | 0.7611 |
|                      | MLC only | 41 | 27.47 | 79.04 | 50.78 | 97.18 | 0.7553 |
|                      | Jaw+MLC | 37.5 | 22.43 | 79.8 | 51.53 | 99.3 | 0.7595 |
| 10x10                | Jaw only | 33 | 33.43 | 79.27 | 52.73 | 97.92 | 0.7835 |
|                      | MLC only | 30 | 36.9 | 78.25 | 51.37 | 94.7 | 0.7728 |
|                      | Jaw+MLC | 30 | 31.59 | 79.52 | 52.74 | 98.66 | 0.7811 |
| 20x20                | Jaw only | 30 | 45.68 | 78.41 | 53.66 | 95.21 | 0.8068 |
|                      | MLC only | 24 | 50.21 | 77.25 | 52.86 | 90.85 | 0.8066 |
|                      | Jaw+MLC | 25.5 | 45.31 | 78.15 | 53.43 | 94.09 | 0.8059 |
| 30x30                | Jaw only | 27 | 52.64 | 78.7 | 54.46 | 95.73 | 0.8159 |
|                      | MLC only | 21 | 57.1 | 77.84 | 53.43 | 92.81 | 0.8092 |
|                      | Jaw+MLC | 22.5 | 53.55 | 77.8 | 54.01 | 93.66 | 0.8184 |
Table 3: Width of 50% dose level for 6 MV

| Field width at SSD = 100cm (mm) | Width of 50% dose level defined by “MLC+Jaw” field (mm) | Width of 50% dose level defined by “Jaw only” field (mm) | Width of 50% dose level defined by “MLC only” field (mm) |
|--------------------------------|----------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|
| 50                            | 50.3                                                     | 51.1                                                   | 52.7                                                     |
| 100                           | 101.1                                                    | 102.1                                                  | 103.3                                                    |
| 200                           | 202.4                                                    | 203.9                                                  | 204.6                                                    |
| 300                           | 304                                                      | 307.2                                                  | 308.3                                                    |

Table 4: Width of 50% dose level for 18 MV

| Field width at SSD = 100cm (mm) | Width of 50% dose level defined by “MLC+Jaw” field (mm) | Width of 50% dose level defined by “Jaw only” field (mm) | Width of 50% dose level defined by “MLC only” field (mm) |
|--------------------------------|----------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|
| 50                            | 50.9                                                     | 51.5                                                   | 53.7                                                     |
| 100                           | 102.8                                                    | 102.5                                                  | 105.2                                                    |
| 200                           | 206.3                                                    | 207.2                                                  | 208.4                                                    |
| 300                           | 308.3                                                    | 309.2                                                  | 311.1                                                    |

Figure 3: Comparison of penumbra at dmax for 6-MV photon beam, ‘Jaw only’ uses standard collimator jaws for field definition, ‘MLC only’ MLC field with jaws parked at 35×35 cm, non-optimization method, ‘MLC+Jaw’ MLC field with jaws optimized (zero gap), optimization method

Figure 4: Comparison of penumbra at depth 10 cm for 6-MV photon beam, ‘Jaw only’ uses standard collimator jaws for field definition, ‘MLC only’ MLC field with jaws parked at 35×35 cm, non-optimization method, ‘MLC+Jaw’ MLC field with jaws optimized (zero gap), optimization method

Figure 5: Comparison of penumbra at dmax for 18-MV photon beam, ‘Jaw only’ uses standard collimator jaws for field definition, ‘MLC only’ MLC field with jaws parked at 35×35 cm, non-optimization method, ‘MLC+Jaw’ MLC field with jaws optimized (zero gap), optimization method

Figure 6: Comparison of penumbra at depth 10 cm for 18-MV photon beam, ‘Jaw only’ uses standard collimator jaws for field definition, ‘MLC only’ MLC field with jaws parked at 35×35 cm, non-optimization method, ‘MLC+Jaw’ MLC field with jaws optimized (zero gap), optimization method
show the penumbra at depth $d_{\text{max}}$ for 6 MV and 18 MV respectively, and Figures 4 and 6 show the penumbra at depth 10 cm for 6 MV and 18 MV respectively. A study$^{[14]}$ compared the penumbra width (80% to 20%) of 10 mm leaf of three manufacturers and found that the smallest was in the Varian MLC system.

**Conclusion**

The dosimetric characteristics of the Varian 120-leaf MLC system were measured, compared, and analyzed using 6-MV and 18-MV photon beams. It was found that its characteristics were quite similar to those of the standard collimator (jaws) system except for the dose rate, surface dose, dose in the build-up region, width of 50% dose level and penumbra. Dose rate for 6-MV and 18-MV photon beams was higher for ‘MLC only’ field than that for the other two field-defining methods. The PDD comparison shows that the surface dose and dose in the build-up region were more for ‘MLC only’ fields. Beam profile analysis shows that the flatness and symmetry for both the systems were within 3%; the ‘width of 50% dose level’ and penumbra were slightly higher for ‘MLC only’ fields in both energies. The 120-leaf MLC system with 5 mm leaf width showed improved dose coverage to the tumor volume and was found to be useful in organ avoidance in head and neck tumors. The results of this study suggest that standard collimator jaws should be optimized to the irregular MLC field (i.e., MLC+Jaw) to minimize the surface dose, dose rate, penumbra, and dose in the build-up region.

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