Evaluation of a dual-level four-bank micro multileaf collimator in reducing dose undulation, leakage, and transmission

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Abstract

This study was to evaluate the reduction of dose undulation at the field edge, gap leakage and interleaf transmission by utilizing a dual-level four-bank micro multileaf collimator (mMLC) and compare with standard MLC. Method and Materials: A 6MV Varian 600C linear accelerator has been collimated with a dual-level four-bank mMLC. The dual mMLC consists of four banks of leaves with upper and lower levels. The two levels of leaves are perpendicular to the central axis and travel orthogonally to each other. It provides the capability of precise aperture shaping and high edge resolution by using micro leaves with widths of 2.1 mm and operating with two levels of leaves. The maximum field size of the dual mMLC is 97 mm x 108 mm formed by 96 leaves. To evaluate the reduction of dose undulation, dose leakage and transmission, radiographic films of a right triangle aperture generated by the two levels dual mMLC were compared with the aperture using only one level of leaves and the other level of leaves remained open. The parameters for comparison include 2D and 3D dose difference, isodose lines, gamma analysis, and dose profiles. Results: The dual mMLC smoothes the dose undulation at the field edge and reduces gap leakage and interleaf transmission. The maximum dose reduction at the field edge is 39%. The gap leakage was reduced from 12% to less than 3.5%. The mean interleaf transmission was reduced from 6% to 3%. Conclusion: This innovative dual mMLC has shown the advantage of reducing dose undulation, gap leakage and interleaf transmission. It offers the ability of better field-edge shaping, reduced gap leakage and interleaf transmission which are considered important characteristics in IMRT and SRT for target conformity and high dose delivery.

Keywords: micro multileaf collimator; dual level mMLC;

I. Introduction

High-precision techniques are essential for accurate aperture shaping and high dose delivery in intensity-modulated radiation therapy (IMRT), stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT). The field of radiotherapy is evolving rapidly as recent advanced technology and devices have promised improved outcomes. Multileaf collimator (MLC) offers efficient way for field shaping. Micro multileaf collimator (mMLC) provides advantage of accuracy shaping by thinner width leaves (1-5). The evaluations of mMLC have been carried with various leaf width, such as 5 mm (Varian Millennium MLC) (2), 3.75 mm (Radionics MMLC) (3, 4), 5 mm, 3 mm and 2 mm leaves resolution by Siemens HD270 (5). However, the current MLC/mMLC designs are based on two-bank leaves at the same level and move parallel in opposite direction. Since the limitation of finite leaf width, there are three issues remained in two-bank MLC design, which are the undulation of field edge, the leaf gap leakage and the leaf internal transmission as shown in Figure 1(a).

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II. Method and Materials

A right triangle aperture was selected to demonstrate the accurate shaping by dual-level bi-direction mMLC. Theoretically, to reduce the effect of undulation at the field edge, an inserted leaf from orthogonal direction, as Figure 1(b), provides a reasonable solution by reducing the area of each small stepped triangle by 50%. Meanwhile, the overlapped leaves give the benefit to reduce the leaves dose leakage and transmission.

Such a new treatment device has been developed to improve the accuracy and reduce the leakage and transmission. The high-resolution dual level bi-directional 4-bank micro multileaf collimator (mMLC) has been commissioned and evaluated with a 6 MV Varian 600C linear accelerator.

The mMLC, as shown in Figure 2, is called AccuLeaf micro multileaf collimator (6). The mMLC has 96 tungsten leaves divided by four banks, each group consisting 24 leaves. The 4-bank MLC is composed by two parallel levels perpendicular to the central axis, and the leaves travel direction for one level is perpendicular to the other level. Each level has two opposite MLC group. Each leaf has a height of 37.5 mm and a physical length of 60 mm. It provides the capability of precision aperture shaping and high resolution by offering micro leaves with width as 2.1mm and operating in two orthogonal directions. The maximum field size of the DmMLC is 97mm x 108mm formed by total 96 leaves. In Figure 3(a) and Figure 3(b), only 2 banks leaves out of 4 banks in the dual mMLC are used to form a triangle shape. From the beam eye view (BEV), there is visible gap (0.6~1.0 mm) between the head of closed leaves. In Figure 3(c), all 4-bank leaves are used to foam the same aperture, in which the field edge was optimized and the gap was blocked by the orthogonal leaves.

To evaluate the radiographic films generated from these apertures, a film from the lower 2-bank formed aperture, as shown in Figure 4(a), was compared with the film, as Figure 4(b), from the 4-bank leaves. The dose was delivered to EDR2 film (Eastman Kodak Company, Rochester, NY) and dose image was analyzed by using the radiation image tool, RIT113 Version 4.4 (Radiological Imaging Technology, Colorado Springs, CO). The dose image from 2-bank leaves was considered as target image while the film from 4-bank leaves as reference image

III. Results

Figure 5 shows that 80% and 20% isodose lines from the reference dose image overlap in the target image. The approximately straight isodose lines indicated that the accuracy shaping and the reduction of undulation effect at the field edge. Figure 6 shows the dose difference of the target dose image (by 2-bank) subtracting reference dose image (by 4-bank). The maximum dose difference was around 39% at the hypotenuse of the right triangle. Outside the triangle in Figure 7, a couple of points with dose difference between 10% and 15% come as the results of dose leakage of leave gap in standard mMLC. The average dose leakage was reduced from 12% to 3.5 % by using the dual mMLC and the average dose interval transmission was reduced from 6% to 3% as shown Figure 7.

IV. Conclusions

A right triangle shape has been shaped using two-bank MLC and four-bank MLC to show the dosimetry undulation, leakage and transmission. This innovative dual mMLC has shown the advantage of reducing dose undulation, reducing of dose leakage and transmission. It offers the features of accuracy shaping and low dose leakage and transmission which considered as important characteristics in IMRT and SRT for precision shaping and high dose delivery.

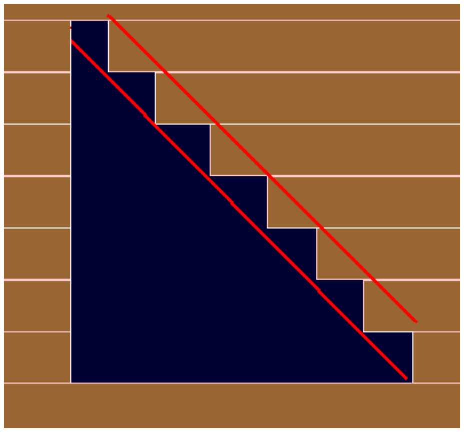

Figure 1(a): Triangle aperture approached by standard 2-bank mMLC leaves

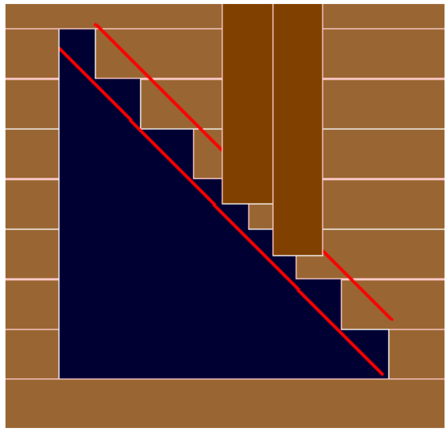

Figure 1(b): Method to reducing dose undulation, dose leakage by dual levels leaves

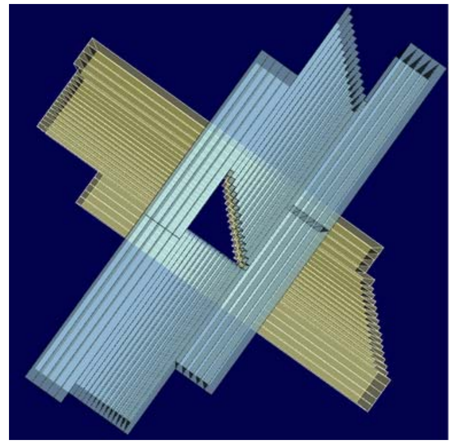

Figure 2: Dual levels four-bank micro multileaf collimator (Dual mMLC)

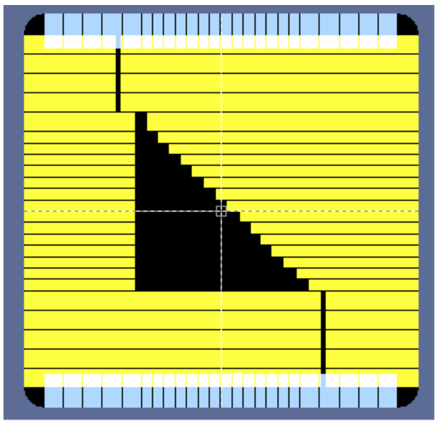

Figure 3(a): BEV aperture generated by 2-bank upper mMLC, with the other 2-bank leaves open

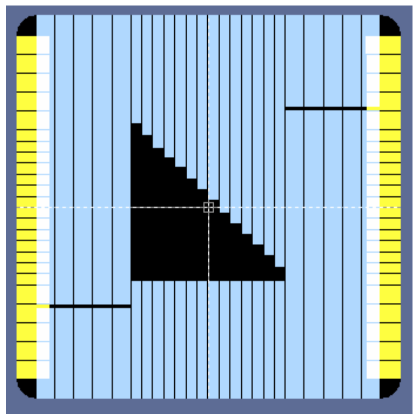

Figure 3(b): BEV aperture generated by 2-bank lower mMLC, with the other 2-bank leaves open

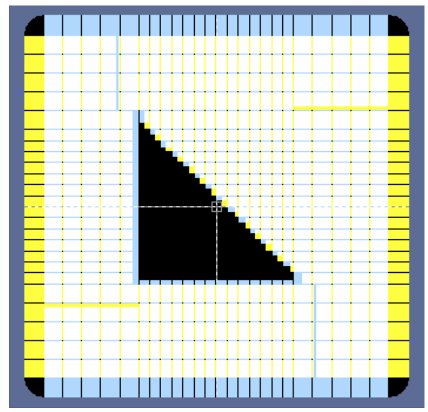

Figure 3(c):BEV aperture generated by dual level 4-bank of mMLC

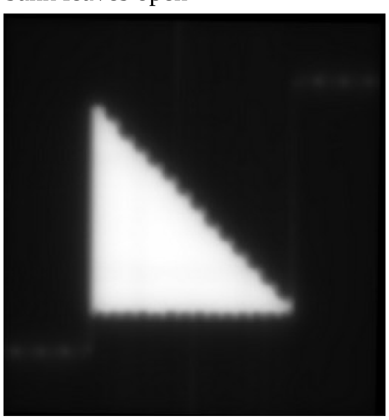

Figure 4 (a): Target dose image by 2-bank mMLC (Kodak EDR2 Film)

Figure 4(b): Reference dose image by DmMLC (Kodak EDR2 Film)

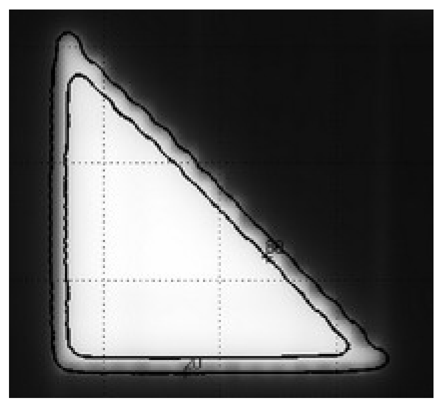

Figure 5: Reference image 80% and 20% of isodose overlay target image

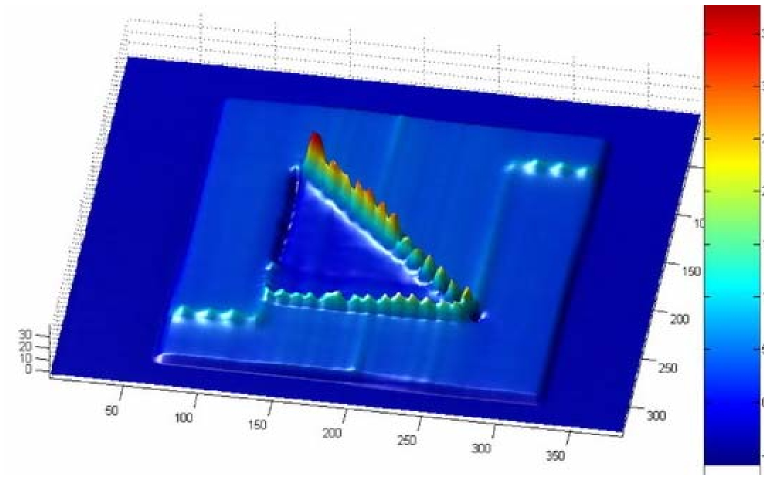

Figure 6: 3D Dose difference (Target subtracting Reference)

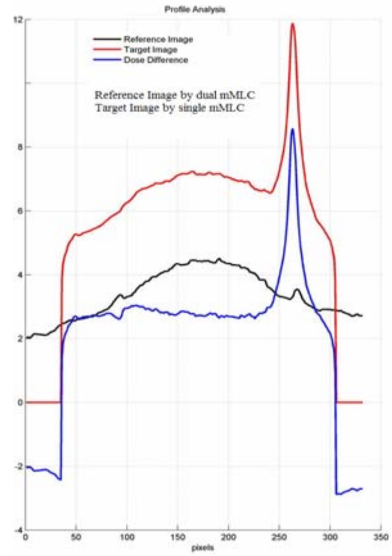

Figure 7: Dose profiles analysis

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