# Position accuracy evaluation of multileaf collimator (MLC) static in linear accelerator

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**Abstract.** This study was aimed to evaluate the accuracy of static MLC positions using gafchromic BT3 film. EBT3 gafchromic film was scanned using Vidar dosimetry Pro Advantage and was analyzed using Matlab algorithm. Matlab algorithm which determined leaf edge of MLC was using Edge Detection Function with Laplacian of Gaussian Method. The precision of MLC leafs on Linac 1 and Linac 2 was measured using the Matlab application code and being compared to early data in TPS setting. The measurement showed that average value of the best precision was obtained at line 6 and the lowest at line 2 both in Linac 1 and 2. MLC leaf measurement error using Matlab was still within tolerance limit AAPM TG 142 which is ± 1 mm. An Error value of the MLC was increased if the leaf movement over the normal position. This effect was caused by an influence of vertical line scattering (VL) and inaccuracy positioning of gafchromic film EBT3 when scanned. The result of this study showed that MLC position accuracy in LINAC 1 and 2 was still within tolerance limit based on AAPM PG 142. It could be an alternative measurement of MLC position accuracy more easily.

## 1. Introduction

Radiotherapy is one of the main choices for people in the world and in Indonesia for the treatment of cancer. Approximately,50 percent of all cancer patients around the world use radiotherapy as the one of the method for their cancer treatment [1]. Radiotherapy techniques use ionizing radiation that causes damage to cancer cells and healthy tissue.

Therefore, there are several types of radiation techniques used to achieve the optimum dose for cancer cells and a minimum dose for the surrounding target or the normal tissue. Radiotherapy techniques have developed starting from 2D (conventional) techniques to 3-dimensional techniques such as Three Dimensional Conformal Radiotherapy Technique (3D-CRT), Intensity Modulated Radiotherapy (IMRT), and Volumetric Arc Radiotherapy (VMAT). Furthermore, IMRT techniques are able to achieve the conformal doses better than the 3D-CRT technique, especially for irregular shapes target volumes which employed the multileaf collimator. The variation in radiation intensity or fluence is shaped by the shift of MLC leaf which attenuated and collimated the radiation beam according to the required dose distribution.

In 3D-CRT and IMRT, MLC of linear accelerator was used to modulate the fluence in the same field to increase the conformity distribution of doses in the area tumor [2]. There are two kinds of MLC, they are static MLC (SMLC) and dynamic MLC (DMLC) which have been implemented in a clinical

setting. Technically, the static MLC is not moving during beam on (discrete radiation) whereas the dynamic MLC allow the MLC moving continuously during radiation, taking place in each direction on the gantry angle [3]. From several segments, the radiation beam was formed into a fluence map consisting of a set of segments from all radiation fields of different intensities so that the dose distributions given to the target will be conformal.

The accuracy of the MLC position is one of the most important factors determining a patient's dose [4]. It was proposed by Mu *et al.*, that a small systematic error in the inaccuracy of the MLC position could have a major effect on the doses which are given to the target as well as on the normal tissue [5]. The American Association of Physicist in Medicine (AAPM) Task Group (TG) number 142 recommended positioning accuracy for the position of MLC with tolerance $\pm$ 1 mm [6]. A standard measurement is carried out by using the LINAC apparatus with Electronic Portal Imaging Devices (EPID). In the contrary, there are many LINAC apparatus which have no EPID yet. This study was designed in order to obtain another way of measuring MLC position precision accurately without using EPID.

Similar studies had ever been held before. El-Maraghy *et al.* (2014) used 1 Linac Varian with MLC 80 leaves. Each leaf had a thickness of 1 cm and the study field size was 1 cm. Measurement the file used film Kodak EDR2 and being analyzed by using Matlab. Average of the result was 9.95 $\pm$ 0.09. Julia Gotstedt (2015) used 1 Linac with MLC 120 leaves and the thickness was 0.5 cm. Field shape was irregular and accuracy was measured by using EPID [8]. Matlab was also used to analyze the accuracy as the first study did.

## 2. Materials and methods

### 2.1 Scanning slab water fantom
This study employed the solid water phantom with density 1.19 gr/cc. Slab water phantom was scanned by using CT simulator Philip Brilliance 16 slices with 120 kV energy, 50 mAs and a slice thickness of 2 mm. Scanning of slab water fantom by using CT simulator was to obtain the image of the slab water phantom which was sent to TPS for MLC patterns simulation. The gafchromic EBT3 film was positioned at a depth of 1.5 cm in the build-up area and the base thickness 10 cm to avoid backscattering. At the time of scanning was done by a marker on slab water phantom to determine the reference point. After acquiring the image of slab water phantom then the data could be sent to TPS for planning.

### 2.2 Planning MLC pattern
This study was performed by using two Linacs namely Varian Clinac iX at Siloam MRCCC Hospital Semanggi with 120 MLCs millennium consisting of 80 leafs with a thickness of 0.5 cm and 40 leaf MLC with a 1 cm thickness. This study only used 80 leaf MLC with a thickness of 0.5 cm contained in Bank A and Bank B. Besides MLC, Linac has equipped jaws with length 36.7 cm and height 7.8 cm. MLC pattern was created in Treatment Planning System (TPS) Eclipse version 11 with Anisotropic Analytical Algorithm (AAA) algorithm. The inverse planning method was used to determine the radiation parameters for initial treatment such as collimator and gantry angle, MU value and number of the field. This MLC pattern was created based on the previous study which provided 10 MLC patterns [7]. This study was performed by using 3D-CRT with static MLC. An overlapping gap was made between the first and second pattern with 1 cm distances and $0^{o}$ collimator angle. The gap was aimed to get a flat profile in order to see the pattern accuracy. The third to sixth as well as first and second pattern but being different in MLC position depending to film size. The seventh and eighth patterns were also set to be overlapping and collimator angle was $0^{o}$. However, the MLC opening was 10 cm wide both in Bank A and Bank B. They formed a horizontal pattern called horizontal line (HL). The ninth and tenth patterns were made similar to the seventh and eighth one, but with the collimator angle was $90°$. These last patterns were vertical called vertical line (VL). Horizontal line and vertical line were perpendicular to each other, the intersection of these two lines was used as a reference point to measure the position accuracy of each MLC leaf on every line [7]. The MU value assigned to the first to the sixth pattern were 200 MU while seventh to the tenth pattern were 250 MU. The next step of planning is the

simulation of MLC patterns using TPS and sent to Linac machine for irradiation of the gafchromic EBT3 film. Figure 1 showed 10 MLC patterns created in TPS.
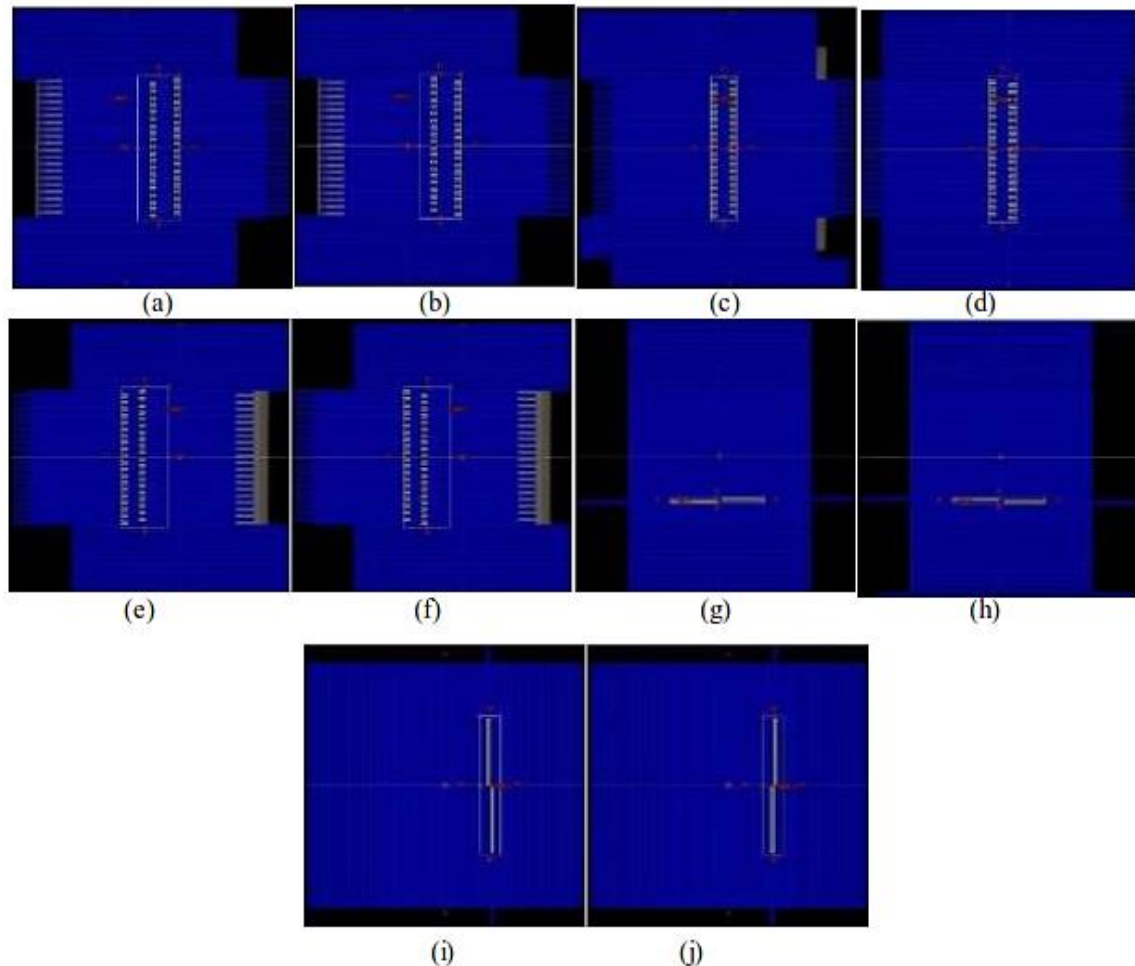


**Figure 1.** The MLC pattern design created on TPS Exclipse (a) the first pattern, (b) the second pattern, (c) the third pattern, (d) the fourth pattern, (e) the fifth pattern, (f) the sixth pattern, (g) seventh pattern, (h) eighth pattern, (i) the ninth pattern, and (j) the tenth pattern.
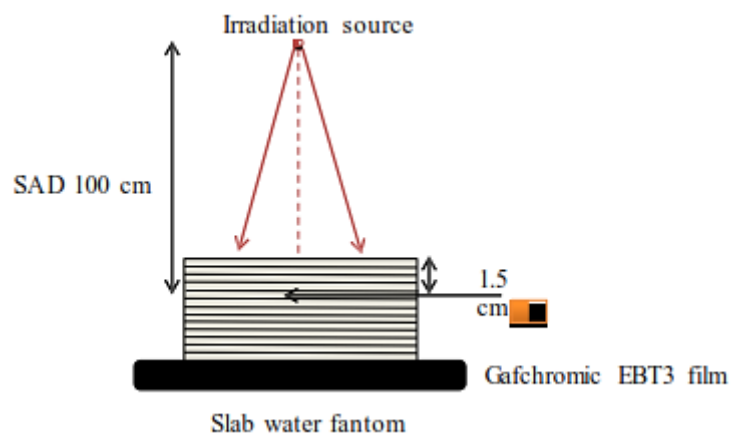


**Figure 2**. Setting of gafchromic EBT3 film irradation position on slab water phantom.

### 2.3 Irradiating of gafchromic EBT3 film

The MLC pattern created at the TPS was sent to Linac for irradiation with 6 MV photon energy. Gafchromic EBT3 film was inserted in the slab of water phantom Adapter Plate RW3-FC65 with size 30cm x 30cm size at maximum depth of 1.5 cm, source to axis distance (SAD) of 100 cm and backscatter materials with 10 cm thickness. The size of EBT3 gafchromic film used in the experiment was 25.4cm x 20.32cm. The position of gafchromic EBT3 film when irradiating 10 MLC patterns was not changed, but the MLC pattern did change. Furthermore, each irradiation on the EBT3 gafchromic film was repeated three times to evaluate precision and accuracy of the MLC leaf position. After irradiation on gafchromic EBT3 film with as long as 2 x 24 hours, then it was scanned using Vidar dosimetry Pro scanner. The scanned image of gafchromic EBT-3 film was converted into Tagged Image File Format (TIFF) and being analyzed by using Matlab. Figure 2 shows the setting of irradiation of gafchromic EBT3 film on slab water phantom.

### 2.4 Matlab code

Matlab algorithm was employed to evaluate the images. The evaluation of the images was performed using the Matlab function Edge Detection with Laplacian of Gaussian Method. This method was found to be the most suitable one for this experiment with a zero threshes value and a standard deviation of sigma 6 After the edge of leaf position was detected, the mark "+" was created. The MLC aperture was determined with a vertical line as the reference. From the reference position, we can automatically calculate how far the distance is between Bank A and Bank B. Matlab reading results are named from right to left with line 1 to line 6 and giving leaf numbers from bottom to top starting from leaf 11 to leaf 50.
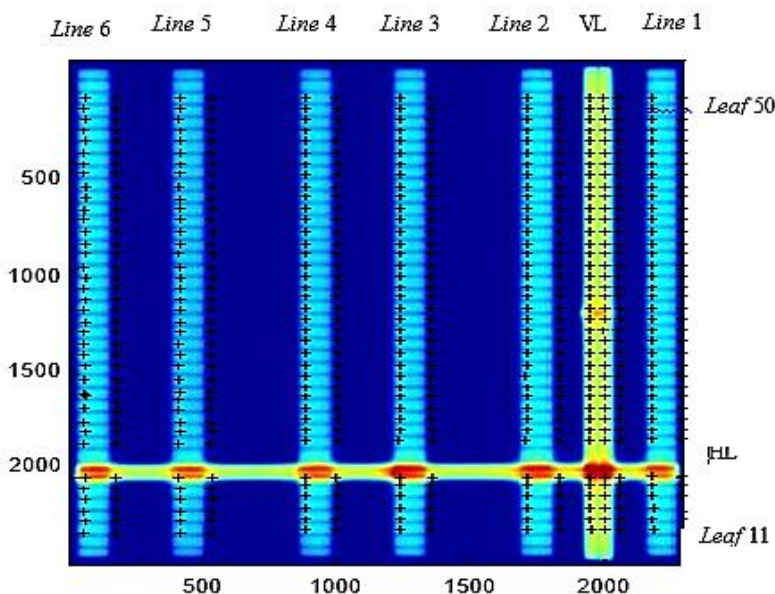


**Figure 3**. The reading results of MLC pattern in gafchromic EBT 3 film used Matlab algorithm.

## 3. Results and discussion

### 3.1 Accuracy test of MLC aperture

*3.1.1 Linac 1.* MLC aperture accuracy test was aimed to determine the error value of each MLC leaf. It used gafchromic EBT3 film three times. After the test, the film was analyzed using Matlab algorithm. The result showed average error value of MLC aperture on line 1 to line 6 respectively were (0.34 ±

0.12) mm, (0.29 ± 0.17) mm, (0.13 ± 0.07) mm, (0.14 ± 0.07) mm, (0.18 ± 0.11) mm, and (0.12 ± 0.07) mm. These results showed that line 1 had the highest MLC aperture value and line 6 had the lowest. The high error value was resulted by scattering effect of the vertical and horizontal line that affected the test result. However, aperture error values for each MLC leaf were still within the tolerance limits recommended by AAPM TG 42 namely ± 1 mm. They showed that the performance of MLC Linac 1 was still in good condition but a periodic check is necessary to ensure that the MLC works optimally. Figure 4 shows the average error value of TPS data MLC aperture on Linac 1 using Matlab algorithm.

*3.1.2 Linac 2.* The average error value of the MLC aperture using Matlab on Linac 2 was still below the tolerance limit value. They were respectively (0.14 ± 0.08) mm, (0.53 ± 0.13) mm, (0.11 ± 0.07) mm, (0.10 ± 0.07) mm, (0.47 ± 0.16) mm, and (0.21 ± 0.09) mm. It could be seen that line 2 had the highest aperture error value and the lowest was in line 4. These result described linac 2 had good MLC aperture accuracy. Figure 5 shows the TPS data MLC aperture average error value using Matlab algorithm on Linac 2.
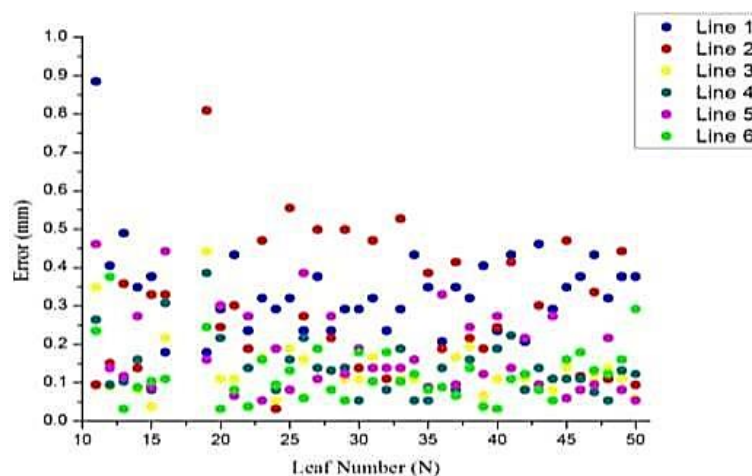


**Figure 4**. The average graph of the MLC aperture error of the six lines between the Matlab measurement results and the TPS data on Linac 1.
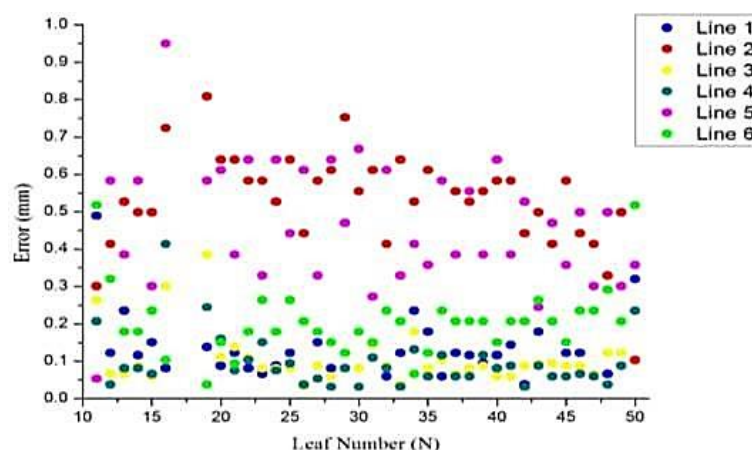


**Figure 5**. The average graph of the MLC aperture error of the six lines between the Matlab measurement results and the TPS data on Linac 2.

### 3.2  Leaf position accuracy evaluation

*3.2.1 Linac 1 at bank A.* MLC position accuracy test was aimed to ensure the accuracy of each MLC leaf forming irradiation field according to TPS data. The test reference point was at the vertical line (VL) and the horizontal line (HL) intersection. When the reference point was obtained, test position measurements could be done to end of each leaf at Bank A and Bank B horizontally. The values on line 1, line to line 6 respectively were $(0.32 \pm 0.14)$ mm, $(0.59 \pm 0.15)$ mm, $(0.31 \pm 0.14)$ mm, $(0.61 \pm 0.14)$ mm, $(0.42 \pm 0.17)$ mm, and $(0.50 \pm 0.15)$ mm. The results showed that line 4 has the highest error value, this was due to leaf movement effect from Bank A passing the normal position. These values showed that Linac 2 was still within the tolerable range recommended by AAPM TG 42 namely $\pm 1$ mm. Although it is not significant, the average value of MLC position accuracy shows that the further movement of leaf MLC passing the normal position the higher the error value becomes. It could be seen by the condition being closer to line 6, the higher error value. It was due to the position of the leaf at Bank A was moving away from the normal position.

*3.2.2 Linac 1 at Bank B.* In Bank B, the MLC error position average value of each line was relatively smaller than Bank A. The values on line 1 to line 6 respectively were $(0.15 \pm 0.07)$ mm, $(0.34 \pm 0.19)$ mm, $(0.26 \pm 0.14)$ mm, $(0.53 \pm 0.10)$ mm, $(0.32 \pm 0.14)$ mm and $(0.50 \pm 0.16)$ mm. They show that the highest error value was at line 4 and the lowest was at line 1. The cause was the movement of the leaf at Bank B not far away passing the normal position. Overall, error value indicates the error position occurring in bank B was still within the tolerance limits recommended by AAPM TG 142 namely $\pm 1$ mm.

*3.2.3 Linac 2 at Bank A.* MLC leaf error position evaluation average value on line 1 to line 6 respectively were $(0.15 \pm 0.08)$ mm, $(0.88 \pm 0.18)$ mm, $(0.30 \pm 0.14)$ mm, $(0.96 \pm 0.17)$ mm, $(0.77 \pm 0.19)$ mm, and $(0.82 \pm 0.16)$ mm. The values showed that line 4 has the highest error average value and line 1 was the lowest. As many as 14.91% of the total leaf had error value exceed the tolerable limit of AAPM TG 142 namely $\pm 1$ mm overlimit values were at line 2, line 4, line 5 and line 6. In general, the values showed position error in Bank B still being tolerable according to AAPM TG 142 namely $\pm 1$ mm average error position of six line in Bank B Linac 1.

*3.2.4 Linac 2 at Bank B.* The average value of MLC error position on line 1 to line 6 were $(0.21 \pm 0.11)$ mm, $(0.33 \pm 0.15)$ mm, $(0.31 \pm 0.12)$ mm, $(0.94 \pm 0.13)$ mm, $(0.31 \pm 0.12)$ mm, and $(1.02 \pm 0.13)$ mm. From the average error value of MLC leaf position showed line 6 has the highest average value. The percentage of the total leaf was 14.91%. The cause was due to scattering from the horizontal line and vertical line.

## 4. Conclusion
Overall the average error value of MLC aperture measurements using Matlab on Linac 1 and Linac 2 was still within the AAPM tolerance limit of TG 142. The average value of leaf position accuracy on Linac 1 was also within tolerable limits.

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