Evaluation of MLC errors of LINAC based on log file

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Abstract. This study aimed to investigate the Multi Leaf Collimator (MLC) quality assurance (QA) and fluence monitor unit (MU) reconstruction based on log files of Varian Linear Accelerator. The graphical user interface (GUI) was developed using MATLAB to analyze the Log files. The MLC QA was analyzed using the error root mean square (RMS) of leaf parameters. Meanwhile, the fluence MU were reconstructed based on the information of leaf position, jaw position, and fractional MU for each 50 ms. The gamma index evaluation between actual and expected fluence MU was calculated to analyze the segment potential error caused by the MLC position. The average of mean error RMS leaves for Bank A and Bank B are 0.213 ± 0.098 mm and 0.207 ± 0.073 mm, whereas the average of maximum error RMS leaves for Bank A and Bank B are 0.491 ± 0.056 mm and 0.48 ± 0.061 mm, respectively. The mean gamma index results of 2%, 2mm and 3%, 3mm criteria between actual and expected fluence MU for the composite beam for all case are 98.2 ± 1.0% and 99.4 ± 0.3%, respectively. The error of MLC based on the log file analysis is within the tolerance level. The results showed that parameters irradiation such as MLC position, jaw position and fractional MU proper with planning.

1. Introduction

The purpose of IMRT patient-specific QA is to ensure that delivery radiation parameters conform with treatment planning system. Log file of Varian Linear accelerator has an information of monitor unit (MU) fraction, gantry angle, collimator angle, jaw position, actual and expected MLC position every 50 ms, therefore log file evaluation could be extracted and used for IMRT patient-specific QA [1,2]. The log files have been used to do patient-specific QA and it has an advantage causes about no devices are needed, so there is no setup error on the process [3]. Actual MLC position information was taken by the MLC controller during treatment based on the number of rotation of leaf motor.

Dose distribution on IMRT field extremely depends on the accuracy of MLC position. The error of MLC position can be divided into a random error (error on a certain leaf) or systematic error (error on all leaf). The 2 mm random error or 0.3 systematic error on Varian Millennium 120-leaf MLC can cause 2% error of equivalent uniform dose (EUD) [4]. The tolerances of deviation error between expected and actual leaf position are 0.5 mm and 1 mm [5]. Other literature explained that the tolerance deviation error of leaf gap and leaf position are 1.6 mm and 2 mm respectively [6]. Furthermore, the tolerance of maximum root mean square (RMS) deviation of position leaf is 0.35 cm [7].
2. Methods
The Unique Varian Linear accelerator single energy (6 MV) at Cipto Mangunkusumo hospital was used for this study. The Log files were generated from this LINAC which has 120 MLC (60 MLC at Bank A and Bank B).

2.1. MLC quality assurance evaluation based on log file information
The error between the actual leaf position and expected leaf position could be evaluated through equation (1)

\[ \Delta X(n, t) = X_{actual}(n, t) - X_{expected}(n, t) \]  

(1)

where \( \Delta X(n, t) \) refers to the error between actual leaf position and expected leaf position at \( n \)-leaf, \( t \)-time, \( X_{actual}(n, t) \) refers to an actual \( n \)-leaf position at \( t \)-time and \( X_{expected}(n, t) \) refers to an expected \( n \)-leaf position at \( t \)-time. The error was only considered when the beam is on. The purpose of this error is to evaluate each leaf at certain time meanwhile, the root mean square (RMS) error was used to evaluate each leaf error per treatment. RMS error was calculated through equation (2) [8,9]

\[ \text{RMS}_{\text{error}} = \sqrt{\frac{\sum_{i=1}^{k}(\Delta X(n))^2}{k}} \]  

(2)

where \( k \) is the number of samples error leaf position.

The Graphical User Interface (GUI) was developed using MATLAB 2016a to automatically analyze MLC QA based on log files. This GUI can generate the summary of MLC QA and the histogram of MLC error. The flow chart and GUI interface to evaluate the MLC QA based on log files can be seen in Figure 1 and 2.

The log files were generated when the measurement of IMRT patient-specific QA using portal dosimetry to MLC QA evaluation. The gantry orientation was changed to be 0\(^\circ\) for the reason to make measurement faster. Influence of gravitation to MLC motion was ignored because the influence is very low [10].

![Flow chart](image)

**Figure 1.** Flow chart to made the GUI for MLC QA based on log files
Figure 2. GUI interface to evaluate MLC QA based on log files. a. input, b. log file information, c. the summary results of log files, d. histogram of leaf error

Figure 3. Flow chart to made the GUI for reconstruct and evaluate fluence MU based on log files
2.2. Fluence MU reconstruction based on log file information

Fluence MU was reconstructed based on the information of MU fraction, jaw position, and MLC position. Blank array with the 2 mm pixel resolution that represents a 40 cm × 40 cm field size were prepared to make a fluence MU. The array will have a value same with MU fraction if the array were unblocked by MLC and jaws. The array will have a value of 2% of MU fraction if the array were unblocked by jaws but blocked by MLC (MLC transmission was assumed 2%) [11,12]. The array will have zero value if MLC and jaws blocked the array. The MLC leaves were opened 1 mm bigger than geometrical position because the radiation field offset (RFO) was assumed 1 mm. The measurement of RFO was reported having the value range 0.5 mm – 1.3 mm [13]. The fluence MU were reconstructed and summed every 50 ms at all segments of IMRT field irradiation. Two fluence MU for every pair of log file bank A and bank B have been generated. The expected fluence MU and actual fluence MU were obtained based on the information of expected MLC position and actual MLC position, respectively. The flow chart and the MATLAB GUI interface for fluence MU evaluation based on log file can be seen in Figure 3 and 4.

3. Results and Discussion

3.1. MLC quality assurance evaluation based on log file information

MLC quality assurance based on log file information were conducted for patient-specific QA of 7 cases (2 brain cases, 2 breast cases, inguinal, cervix, and nasopharynx). The evaluation of MLC error used the root mean square (RMS) metrics. Mean RMS error is average of RMS error from all leaves at bank A and bank B whereas maximum RMS error was maximum value RMS error from all leaves at bank A and bank B. For reference, the tolerance deviation error was 0.5 mm for mean RMS error and 1 mm for maximum RMS error.

The results of measurements of mean and maximum RMS error can be seen in Figure 5. Mean RMS error for all case at bank A and bank B are lower than 0.45 mm with the average of mean RMS at bank A and bank B are 0.213 ± 0.078 mm and 0.207 ± 0.073 mm, respectively. The value of mean RMS error of this results are below the accepted tolerance level and support previous work by Kerns et. al [10]. In addition, the value of maximum RMS error at bank A and bank B are lower than 0.8 mm for all cases, with average of maximum RMS error are 0.491 ± 0.056 mm and 0.480 ± 0.061 mm, respectively. These results showed that the actual MLC position still agreed with expected / planning MLC position, in spite of that appropriate dose distribution is not only depend on MLC position, for example, the accuracy of delivering MU for every IMRT field segment.
3.2 The comparison expected fluence MU and actual fluence MU

The comparison between expected and actual fluence MU were using the cases for MLC quality assurance. The accepted tolerance level for 2%, 2mm, and 3%, 3mm gamma evaluation criteria were defined 95% and 98 %, respectively. Figure 6 showed the example composite beam fluence MU and the results of the gamma index picture for nasopharynx case. The illustration of gamma index evaluation composite beam of all cases indicated in Figure 7. The results of gamma evaluation for 2%, 2 mm and 3%, 3mm criteria for all cases are above 95% and 98% with mean gamma index results of 2%, 2mm and 3% and 3mm criteria between actual and expected fluence MU are 98.2 ± 1.0% and 99.4 ± 0.3% respectively. This indicated that the actual fluence MU agreed with expected fluence MU and indicate MLC position and MU deliver were proper with planning.

![Figure 5](image1.png)

**Figure 5.** RMS MLC error results of seven cases. a. Mean RMS MLC error at bankA and bankB. b. Maximum RMS MLC error at bank A and bank B.

![Figure 6](image2.png)

**Figure 6.** a. Expected fluence MU, b. Actual fluence MU. c. The results of 2%,2mm gamma index criteria. d. The results of 3%, 3mm gamma index criteria

![Figure 7](image3.png)

**Figure 7.** The results of gamma index value for seven cases with 2%,2mm criteria and 3%, 3 mm criteria
4. Conclusion
The results showed that based the information of log files, the MLC positions were delivered appropriately with the planning (mean RMS error and maximum RMS error were below 0.5 mm and 1 mm respectively). Irradiation parameters such as MLC position, jaw position, and MU fractionation were delivered in acceptable criteria and proper with planning (gamma evaluation between actual and expected fluence MU for 2%, 2 mm and 3%, 3 mm criteria for all cases are above 95% and 98% respectively).

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