Picket fence test of Agility MLCs using linac log data

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Abstract. The multileaf collimator (MLC) performance is critical during intensity modulated radiotherapy (IMRT) delivery. Picket fence test is typically performed by acquiring images of MLC gaps using film or electronic portal imaging device (EPID) to assess the MLC positional accuracy as part of a comprehensive weekly quality assurance (QA) programme. This study aims to investigate the accuracy of MLC position of Agility MLCs (Elekta, Stockholm, Sweden) using linac log data. The positions of MLCs were tracked during picket fence test using Elekta’s propriety optical tracking system on the linac head. The data were recorded at four cardinal gantry angles over six weeks. The fluence from the picket fence was constructed using the tracked MLC positions and compared with the fluence obtained from EPID. The fluence of the picket fence pattern constructed from the tracking data of MLC position showed that the measured range of gap size error within -0.3 mm to 0.8 mm. The average MLC positional error tracked was 0.07 mm ± 0.14 mm (mean ± 1 SD). Gap size measured from tracking data was within the range of the results obtained from EPID. Tracking the MLC position using the optical tracking system provide a more accurate test method for routine QA of the MLC performance. Over the period of investigation, it was found that the MLC performance was within the tolerance of ± 1 mm recommended by AAPM TG142.

1. Introduction
IMRT delivers highly conformal and complex dose distributions that utilise dynamic movement of the multileaf collimator (MLC) [1,2]. The MLCs are continuously changing the shape without any beam hold-off in between the irradiation. Bayouth et al. [3] and Losasso et al. [4] have studied the impact of leaf positioning accuracy on the delivered IMRT fields. For complex treatment fields, dose delivery throughout the target volume is sensitive to leaf positioning error and leaf transmissions. Therefore, it is essential to routinely monitor the MLC performance to ensure the accuracy of the leaf motion in every treatment [5]. According to TG-142 [6], the MLC performance tests should be conducted on weekly and monthly basis by delivering picket fence test pattern described by Losasso et al. [5]. The tolerance level of MLC positional accuracy suggested by TG-142 is ± 1 mm. Qualitative test was used conventionally for the assessment of leaf positional accuracy by the matching of sequential segments and leaf transmission during the beam modulated by dynamic MLCs. Alternatively, the MLC positions can be obtained from the linac control system during delivery. This method provides an efficient way for routine quality assurance (QA) of the MLC performance. Thus, this study focuses on assessment of MLC performance of an Agility MLC system (Elekta AB, Stockholm, Sweden) using the optical tracking system in the linac [7]. The measurement from the tracking data is verified with measurement...
using EPID. The tracked data is recorded at a sampling frequency of 0.25 s from the linac control computer.

2. Materials and methods

2.1. Picket fence beam delivery
The Agility MLC consists of 160 MLCs arranged in two MLC banks, each bank consists of 80 leaves. The maximum field size of the beam is 40 cm × 40 cm. The nominal leaf width is 5 mm and has a leaf tip radius of 17 cm. The leaves moved with a speed of up to 6.5 cm/s. The Agility MLC consists of an optical tracking system to track the MLC position.

The MLC leaves were configured using iCOM Customer Acceptance Testing (iCOM CAT) software (Elekta, Stockholm, Sweden) to deliver a picket fence test pattern for the investigation of MLC performance [8]. The central 40 pairs of leaves (leaf number 21 to 60) from the right bank, Y1 and the left bank, Y2 were instructed to move dynamically to the left. The leaves moved stopping at every 2 cm and formed seven gaps of size 0.5 cm × 20 cm. The beam was delivered at nominal gantry angle of 0°, 90°, 180° and 270° at each time on a weekly measurement for 6 weeks.

The beam parameters were logged using the linac control computer throughout delivery. The delivered parameters were saved in .xml file at the end of the delivery. The accuracy of leaf position was measured from the gap size between a pair of leaf from the opposite banks. Rowshanfarzad et al. [9] suggested the measurement is verified with an independent method to validate the ability of a tracking system to record the linac log data accurately, thus EPID was used in this study. The beam delivery was simultaneously acquired using EPID. The .xml files from the linac control computer and the images from the EPID system were retrieved.

2.2. Data analysis
All parameters that were tracked during the picket fence test delivery were recorded in an .xml file for each gantry angle. An algorithm was developed using MATLAB (Mathworks, Natick, MA, USA) to extract the data in .xml file and reconstruct the fluence map of the delivered beam. The profile of every leaf was plotted from the fluence map and the MLC positional accuracy was measured from the gap size between a pair of leaf from the two opposite banks. Meanwhile, the images acquired from EPID were read out and analysed for the accuracy of individual leaf using MATLAB. The image consists of the radiation fluence that has seven gaps and six background areas. Intensity profile across the cross-plane of each leaf was plotted to find the gap size of a pair of leaves from the two opposite banks. The methods of MLC position measurement using EPID were adapted from Rowshanfarzad et al., Vial et al. and Zwan et al. [9–11].

3. Results and discussion
Figure 1 shows the histogram of gap size measured from the fluence map of the tracking data for 6 weeks. The range of gap size measured from the fluence constructed using the linac tracking data is 4.7 mm to 5.8 mm. Since the prescribed gap size was 5.0 mm thus, the uncertainties of gap size measured by the tracking data were within -0.3 mm to 0.8 mm. Meanwhile, Figure 2 shows the histogram of gap size measured from the fluence map of the EPID for 6 weeks. The range of gap size measured from the EPID is 4.4 mm to 5.7 mm in which gives the uncertainties of within -0.6 mm to 0.7 mm. The uncertainties yielded from both techniques were within the tolerance level of ± 1 mm. Budge et al. also suggested the accuracy of dynamic MLC should be within ± 1 mm to ensure the dose delivered for IMRT field is accurate [12].

The mean +/- standard deviation (STD) of gap size measured from the tracking data and EPID is 5.07 ± 0.14 mm and 4.95 ± 0.22 mm, respectively. The STD of gap size measured from tracking data and EPID were 0.14 mm and 0.22 mm, respectively. This indicates that the variation of gap size measured from tracking data is smaller than from the EPID. The trend coincides with result obtained by Agnew et al., in which the uncertainties of leaf position measured by using trajectory file (similar to
Tracking data in this study is smaller than using EPID [13]. The inconsistency of EPID panel position with respect to the front face of the gantry head during weekly test may rise the variations of gap size measured from EPID [14]. Besides, the variations maybe also from the high speed MLC movement during beam delivery [13,15]. The dynamic movement of MLC during beam delivery may resulted noise in the EPID image. Therefore, the MLC positions measured from the tracking data can reduce the uncertainty of the MLC performance.

![Figure 1. Histogram showing the gap size measured from tracking data.](image1)

![Figure 2. Histogram showing the gap size measured from EPID.](image2)
The difference of gap size measured from tracking data and EPID was plotted in histogram as shown in Figure 3. The histogram was plotted by combining all the four gantry angles for each week. The difference of gap size measured from the tracking data and EPID at all gantry angles for 6 weeks are ranged between -0.9 mm to 0.7 mm. The mean ± STD of gap size difference is -0.12 ± 0.23 mm. The differences were within ± 1 mm. Besides, the histogram also demonstrates that gap size differences are normally distributed for all weeks and 97% of the gap size differences measured throughout the study are within ± 0.5 mm. Therefore, this indicates that the gap size measured from the tracking data and EPID are comparable and the MLC positions are accurate within 1 mm.

![Figure 3. Histogram showing the gap size difference between tracking data and EPID.](image)

4. Conclusions
The results of MLC position accuracy measured from the tracking data and the EPID were within ± 1 mm over the 6-week measurements. Although the discrepancy between the MLC position measured from the tracking data and the EPID ranged from -0.90 mm to 0.70 mm, nevertheless 97% of the results were within ± 0.5 mm. This indicates that the MLC positional accuracy measured from the tracking data is comparable to the EPID. Therefore, the tracked MLC position from optical tracking system is an efficient and accurate tool to assess the MLC performance.

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