Evaluation of the optimal collimator angle in a prostate VMAT Plan using a novel MLC QA with a high sampling rate log file

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4]

INTRODUCTION

The evaluation of multi-leaf collimator (MLC) performance using machine log files has been described by Task Group 142[(1)]. We developed in-house software to analyze MLC positions and errors using a high sampling rate log file (HLF) on an Elekta linear accelerator (linac). Additionally, we identified mismatches between control points (CPs) and MLC positions at the edges of segment during a volumetric modulated arc therapy (VMAT) delivery. We further developed a new algorithm in our software to evaluate the influence of the collimator angle in a prostate VMAT plan.

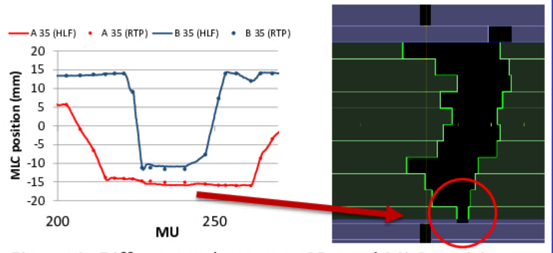


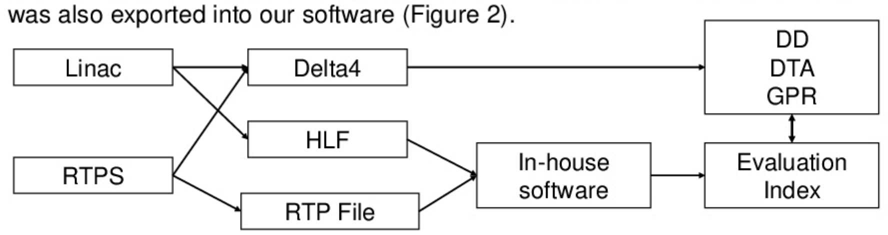
Figure 1. Differences between CPs and MLC positions from the HLF at the edges of segments during prostate VMAT planning (Left).

AIM

The purpose of this study was to develop an algorithm to detect MLC position errors from HLFs recorded by an Elekta linac and investigate the effectiveness of this algorithm in optimizing the collimator angle for prostate VMAT plans.

METHOD

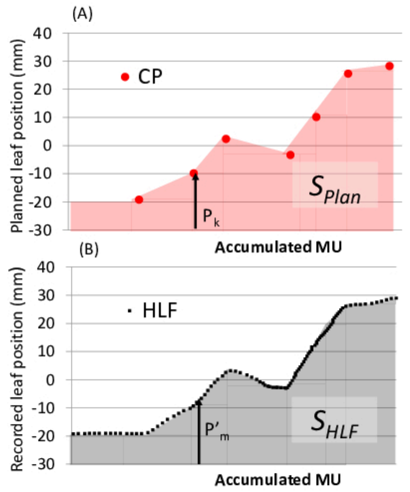
Four prostate VMAT plans were prepared. The collimator angle was varied from 0 to 50 degrees in increments of 5 degrees, and the radiation was detected by a three-dimensional semiconductor detector (Delta4). Each HLF acquired from the linac was also exported into our software (Figure 2).



Linac: Synergy with Agility (Elekta)
RTPS: Monaco version 5.11.02 (Elekta)
3D semiconductor detector: Delta4 phantom+ (Scandidos)

Figure 2. Flowchart comparing the EI and dose evaluation indexes of Delta4.

The corresponding areas in the MLC positions and monitor units (MUs) were obtained from a radiotherapy planning system (RTPS) and HLF, respectively. The evaluation index (EI) was defined as the ratio between the two areas (Figure 3). The relationships between the EI and the dose evaluation indexes (DD: dose difference, DTA: distance to agreement, and GPR: gamma pass rate) of the Delta4 were investigated to identify the optimal collimator angle that yields the highest irradiation accuracy.



$$S_{plan} = \sum_{n=1}^{n'} \sum_{k=1}^{k'} \left((P_k + P_{k+1})(MU_{k+1} - MU_k) * 0.5\right)$$

$$S_{HLF} = \sum_{n=1}^{n'} \sum_{m=1}^{m'} \left((P'_m + P'_{m+1})(MU_{m+1} - MU_m) * 0.5\right)$$

- S_{Plan} : area under the planned leaf position curve during VMAT
- S_{HLF} : area under the recorded leaf position curve during VMAT
- k : control point index
- K' : total number of control points
- m : recording point index
- m' : total number of sampling points in the log file
- P : planned position for a particular leaf
- P' : recorded position for a particular leaf
- n : active leaf index
- n' : total number of active leaves
- MU : monitor unit

$$EI = \frac{S_{HLF}}{S_{plan}}$$

Figure 3. Design of a novel MLC QA. (A) S_{plan} represents the moving sum of active MLCs within a VMAT delivery in the RTPS. (B) S_{HLF} represents the moving sum of active MLCs within a sliding window in the HLF.

RESULTS

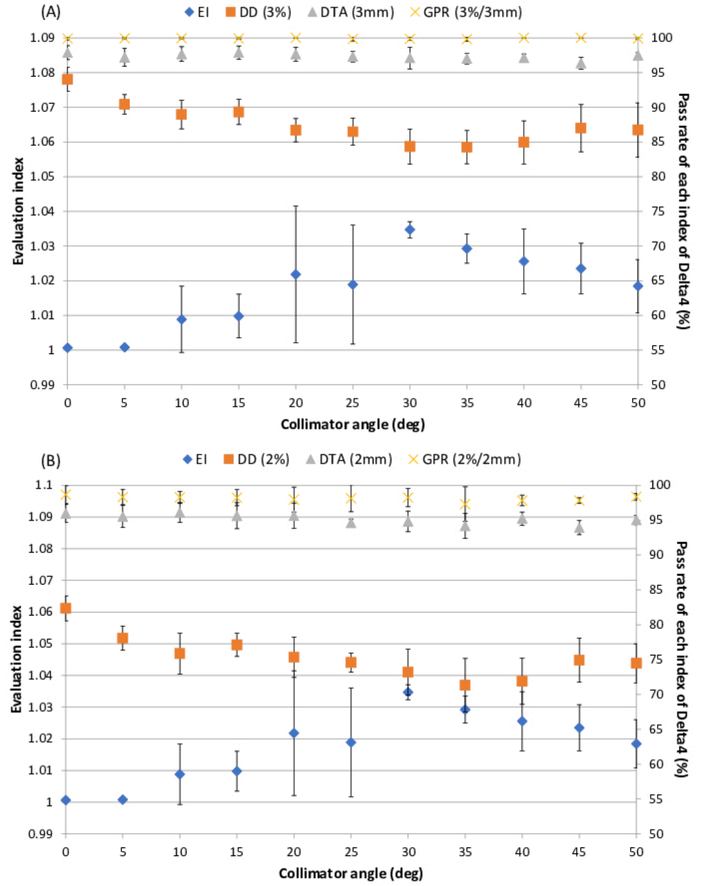


Figure 4. Relationship between the EI and the pass rates for the three dose evaluation indexes (DD, DTA, GPR) of Delta4 as functions of the collimator angle. (A) DD: 3%, DTA: 3 mm, GPR: 3%/3 mm, (B) DD: 2%, DTA: 2 mm, and GPR2%/2 mm. GPR: gamma pass rate

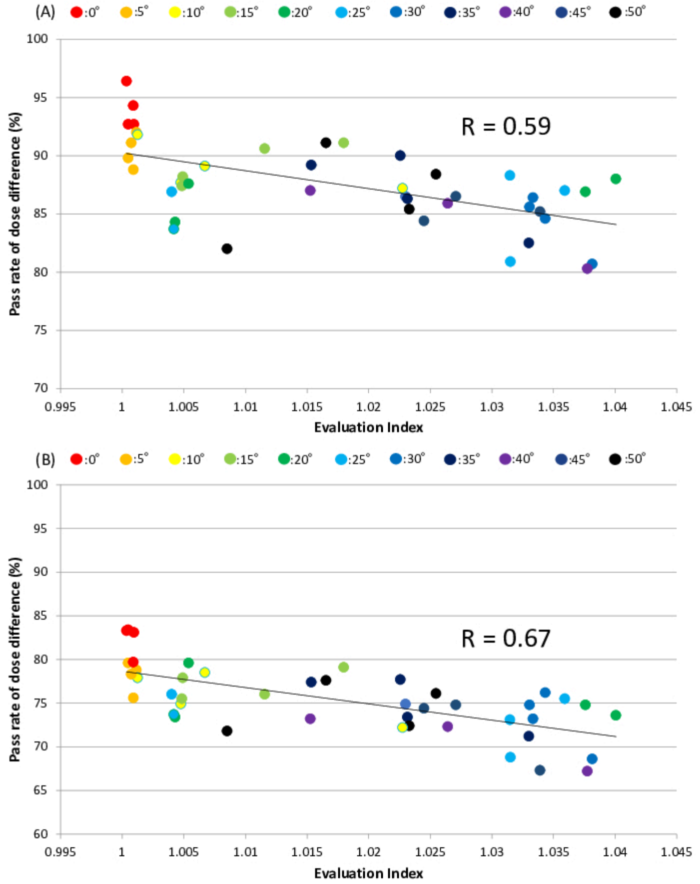


Figure 5. Correlation between the pass rate of the dose difference and the EI for several collimator angles in prostate VMAT planning. (A) DD: 3%. (B) DD: 2%.

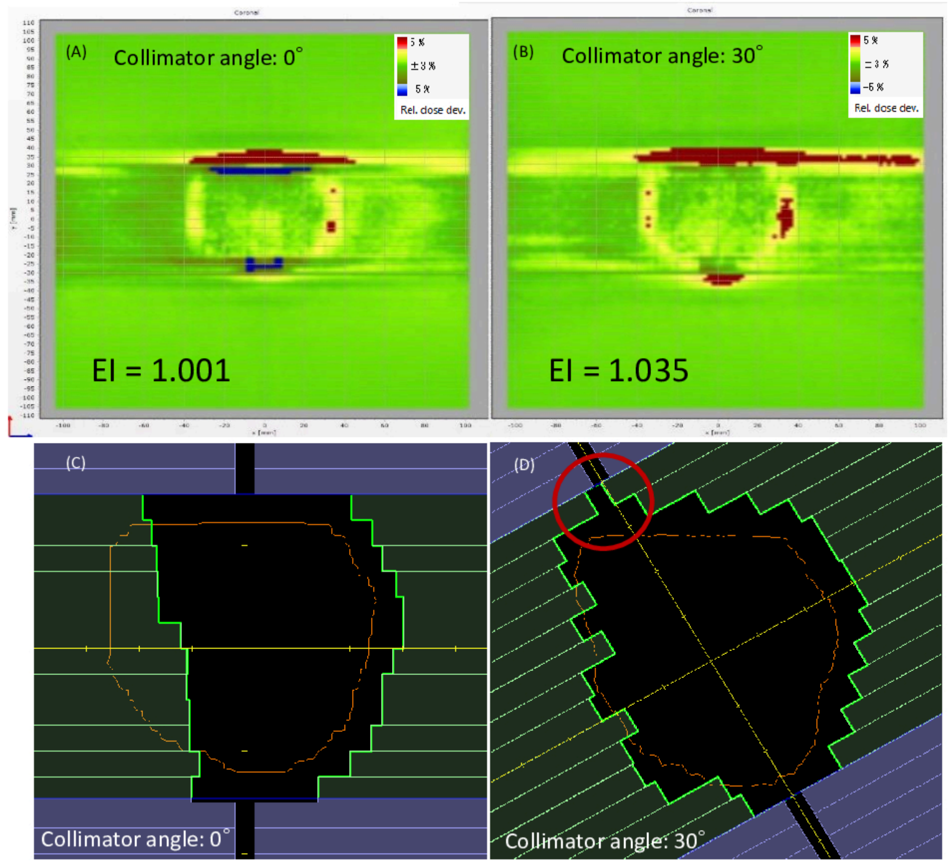


Figure 6. Coronal images used in the evaluation of DD in Delta4 software with different collimator angles: (A) 0 degrees and (B) 30 degrees. Red areas are those that received a dose outside the tolerance range around the prescription dose (± 5%). The lower images show the corresponding beam's eye view with collimator angles of (C) 0 degrees and (D) 30 degrees. The orange lines delineate the PTV structure, and the red circle indicates the difference portion between the control point from the RTP and the MLC position from the HLF.

CONCLUSIONS

Figure 4 shows that, among the three Delta4 indexes, the DD varied the most when the collimator angle was changed in the prostate VMAT plan. In contrast, the DTA and GPR did not change significantly under the same conditions. When the collimator angle was 0 degrees and 30 degrees, the DD values with a 3% tolerance were 94% and 84.3%, respectively, and those with a 2% tolerance were 82.4% and 73.2%, respectively. Additionally, the EIs were 1.001 and 1.035 when the collimator angle was 0 degree and 30 degrees, respectively. Figure 5 shows that a decreasing DD was moderately correlated with increasing EI, which can be attributed to a mismatch between the setting of the minimum MLC gap on the RTPS and that on the linac, as shown in Figure 6. In our institution, when Monaco RTPS and Synergy are paired, a mismatch was detected in the superior and inferior edges of the segment during VMAT delivery with increasing collimator angle. As the EI can be easily acquired from the HLF without special devices, this metric may be useful for quality assurance (QA) in patient VMAT plans. In addition, the EI can be calculated as a characteristic value for each MLC and, therefore, can be used for periodic MLC QA. Miften et al. recommended that the universal tolerance limits for the GPR be used for intensity modulated radiation therapy (IMRT) QA analyses2). However, their tolerances limit will not allow such mismatch errors as seen in these VMAT plans to be detected. Based on the above results, the EI we propose here is highly effective for estimating the VMAT plan quality before delivering radiation to the patient.

REFERENCES

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2) Moyed Miften, Arthur Olch et al. Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No.218. Med Phys. 2018; 45(4):e53-e83

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