International Journal of Cancer Therapy and Oncology
www.ijcto.org

Multileaf-collimator daily quality assurance of Vero4DRT system: Our one-year experience

Hideharu Miura[1], Shuichi Ozawa[1,2], Shintaro Tsuda[1], Kiyoshi Yamada[1], Yasushi Nagata[1,2]

[1]Hiroshima High-Precision Radiotherapy Cancer Center, Hiroshima, Japan
[2]Department of Radiation Oncology, Institute of Biomedical & Health Science, Hiroshima University, Hiroshima, Japan

Received December 07, 2016; Revised June 25, 2017; Accepted July 15, 2017; Published Online August 10, 2017

Original Article

Abstract

Purpose: We assessed the daily quality assurance (QA) of multi-leaf collimator (MLC) using the Vero4DRT system. **Methods:** As part of daily MLC QA, the irradiation field was set to 100 × 150 mm^2 with a gantry angle of 0 º. Only the leaf positioning error values only were displayed. We developed an in-house program to easily acquire these values using an open source optical character recognition engine. This test was implemented between 24 August 2015 and 23 August 2016. **Results:** The maximum leaf positioning error was 0.40 mm in both banks. In addition, the maximum deviation was 0.10 mm in both banks. The average and standard deviation for left and right banks were 0.19 mm ± 0.11 mm and 0.15 mm ± 0.09 mm, respectively. In our one-year measurement, the leaf positioning error was less than 0.50 mm. Therefore, if the leaf position error for daily MLC QA exceeded 0.50 mm, then an external intervention is required. **Conclusion:** The daily MLC QA of our one-year evaluation of the Vero4DRT system demonstrates an excellent leaf accuracy and reproducibility, thereby giving confidence in the quality of the treatment.

Keywords: Multi-leaf collimator, Electronic portal image device, Quality assurance, Vero4DRT

1. Introduction

Quality assurance (QA) for multi-leaf collimator (MLC) plays an important role in treatment planning and dose delivery in intensity-modulated radiation therapy (IMRT) and volumetric-modulated radiotherapy (VMAT), because the variation between the planned and actual leaf positions can lead to incorrect dose distributions. The IMRT is typically categorized into dynamic MLC (DMLC) mode (referred to as sliding window)[1] and static MLC (SMLC) mode (referred to as step-and-shoot).[2] Several authors have studied for QA of MLC position in IMRT. The garden fence test is used to verify the stop position between the actual and planned MLC. [3, 4] The strip test devised by Chui et al. has been widely used to identify submillimeter leaf positioning errors.[5] Several authors have been reported same test was performed with electronic portal image device (EPID) because it is time-consuming and analysis is costly with radiographic film.[6, 7]

The Vero4DRT is a unique image-guided radiotherapy system, consisting of an O-ring gantry that is designed to rotate ± 185° around a patient and ± 60° around its vertical axis. [8, 9] As DMLC-IMRT and VMAT are unavailable in the current commercial version of Vero4DRT, the system should be operated in the SMLC-IMRT mode. From a mechanical perspective, it is mandatory to confirm the MLC position and perform isocenter verifications before clinical use. The report of the American Association of Physicists in Medicine (AAPM) Task Group (TG) 142 [10] is an update of AAPM TG 40 [11], and has added recommendations for MLC QA that are integrated with the linear accelerator. Leaf positioning accuracy and the responsibility of MLC with daily QA have not been reported for Vero4DRT.

To perform the IMRT safely and accurately, the QA of MLC is clinically important. In this work, we report the results of our one-year daily MLC QA implementation on a Vero4DRT system.

2. Methods and Materials

The measurements were performed on a Vero4DRT system (Mitsubishi Heavy Industries (MHI), Ltd., Hiroshima, Japan, and BrainLAB, Feldkirchen, Germany).

Corresponding author: Hideharu Miura; Hiroshima High-Precision Radiotherapy Cancer Center, Hiroshima, Japan.

***Cite this article as**: Miura H, Ozawa S, Tsuda S, Yamada K, Nagata Y.. Multileaf-collimator daily quality assurance of Vero4DRT system: Our one-year experience. Int J Cancer Ther Oncol. 2017; 5(1):5112. **DOI:** 10.14319/ijcto.51.12*

ISSN 2330-4049

The MLC for Vero4DRT system is a single-focus type, has 30 pairs of 5-mm thick leaves at the isocenter, and produces a maximum field size of 150 × 150 mm^2. Leakage between adjacent leaves is minimized to avoid tongue-and-groove effect. The leaf height and length are 110 and 260 mm, respectively. Each leaf end is circular, with a radius of curvature of 370 mm.[12] In the Vero4DRT system, a method of measuring the leaf positioning accuracy for daily QA is the irradiation of a known MLC position on an EPID. The EPID detector of Vero4DRT system has 1024 × 1024 pixels with a size of 0.18 mm. The irradiation field was set to 100 × 150 mm^2 (Fig. 1) with a gantry angle of 0º. As part of the daily QA, the leaf positioning accuracy and reproducibility are estimated using a water-equivalent cube phantom (130 × 130 × 130 mm^3) with a 10-mm diameter steel ball fixed to the center of the phantom. The QA procedures have been implemented to assure proper functioning of the MLCs and can be easily performed in a clinical environment. The Sobel filter is used to detect the edge of the leaf and its peak value position, which corresponds to the half value of penumbra. Knowing both the isocenter and pixel size, the absolute position of the leaves can be calculated from the isocenter position. The measured leaf positions were compared against the nominal ones. This information was obtained by personal communication with the MHI on the algorithm of leaf positioning detection. The leaf positioning error values were only displayed. We developed an in-house program to easily acquire these values using an open source optical character recognition engine (Tesseract version 3.00; developed at Hewlett Packard and now partially funded by Google).[13] We assessed the leaf positioning accuracy of daily QA between 24 August 2015 and 23 August 2016 (except for weekends and holidays).

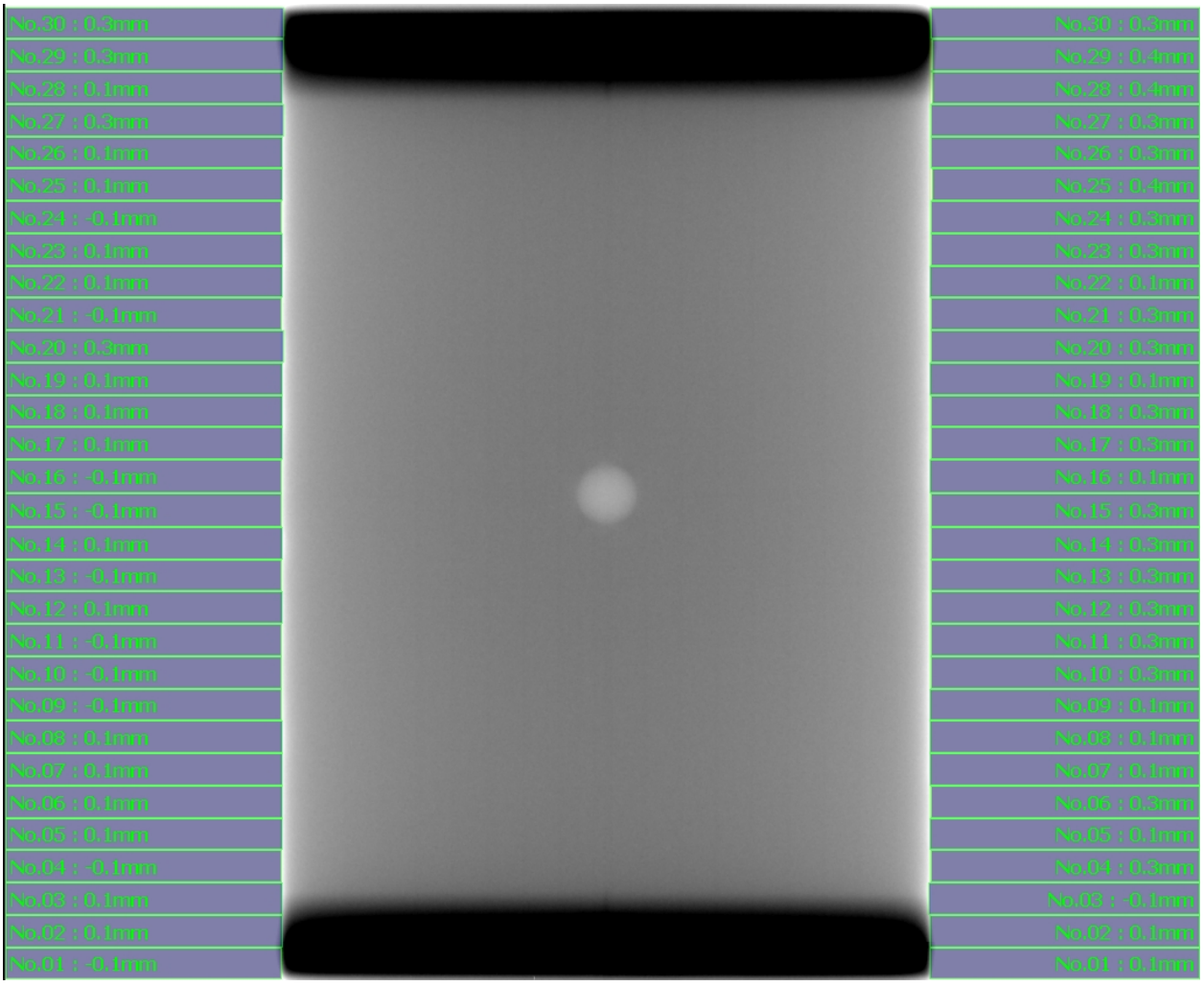

Figure 1: Screenshot of the MLC daily QA result that can automatically detect the edge of the leaf.

 ISSN 2330-4049

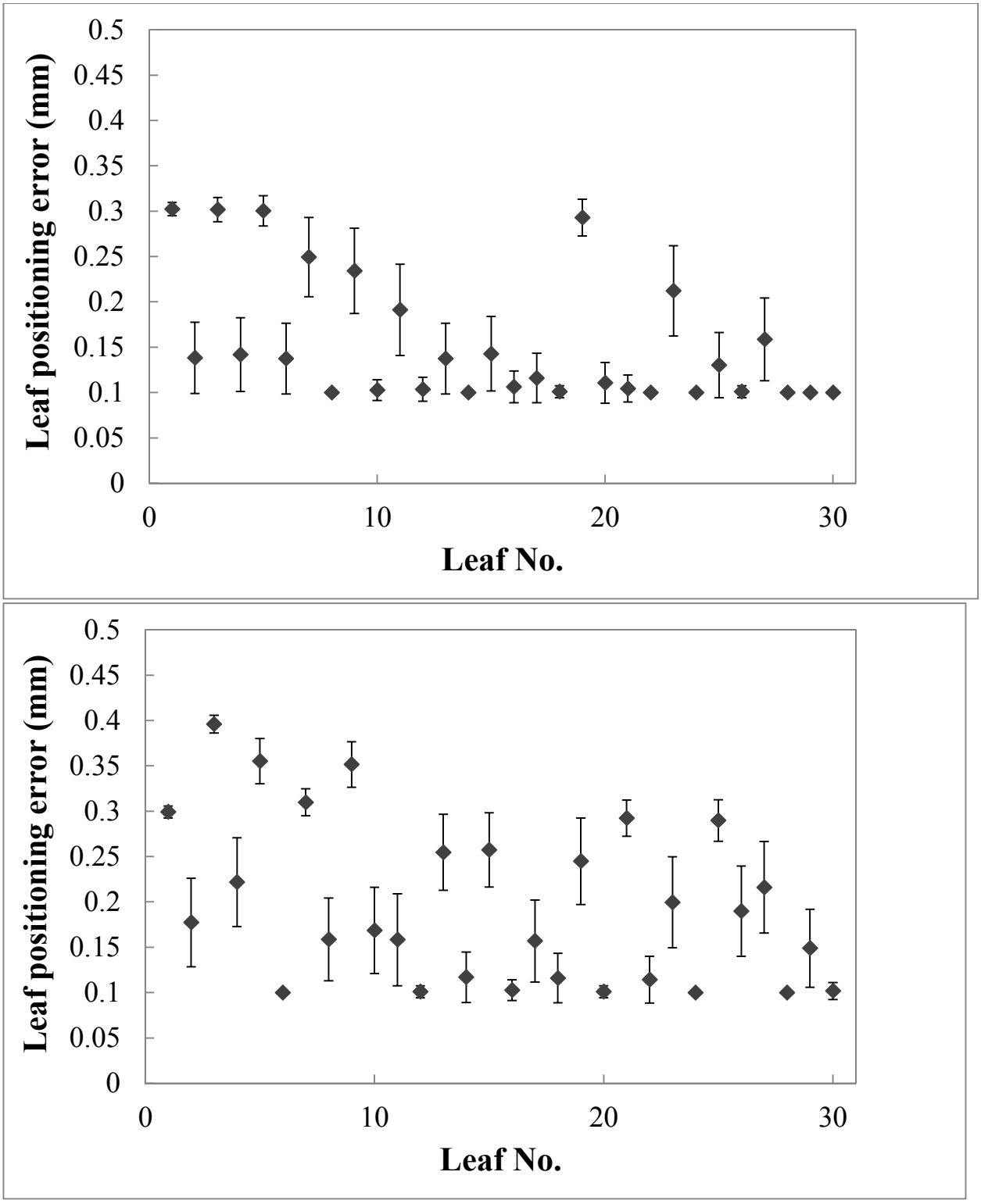

Figure 2: Accuracy and reproducibility for (a) left and (b) right banks measured as the average and standard deviation of the absolute positioning leaf error over 12-month measurements on each leaf. The error bars for each leaf correspond to the standard deviation.

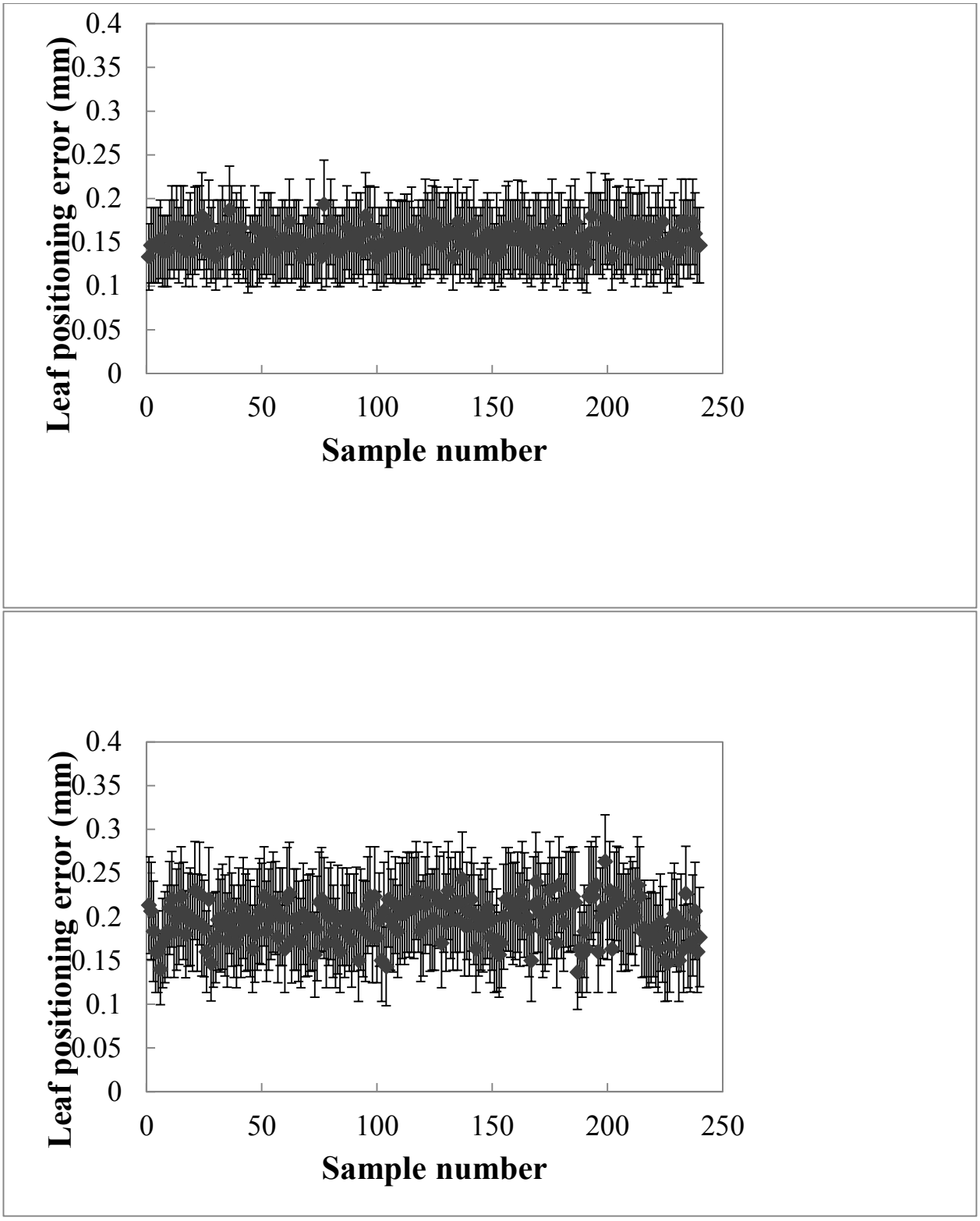

Figure 3: Average and standard deviation of the absolute leaf positioning error for (a) left and (b) right banks over a period of 12 months. The error bars for each measurement correspond to the standard deviation.

ISSN 2330-4049

3. Results

The leaf positioning accuracy and reproducibility were calculated as the average and standard deviation of absolute values during 12 months and are shown in Figure 2. The maximum leaf positioning error was 0.40 mm in both banks during 12 months. In addition, the maximum deviation was 0.10 mm in both banks during the same period. Figure 3 shows the average and standard deviation of the absolute values of the left and right banks each day. The average and standard deviation for left and right banks were 0.19 mm ± 0.11 mm and 0.15 mm ± 0.09 mm, respectively. The average difference between the leaf positioning errors in the left and right banks was less than 0.04 mm. It was found that the MLC positioning errors in the left and right banks were almost the same every day.

4. Discussion

We reported the analysis of leaf position errors for daily QA using an EPID. Variation between the planned and actual leaf positions is lead to different amounts of dose discrepancy. Palta *et al.*[14] recommended that the tolerance limit of leaf position for SMLC should be within 1.00 mm. In our study, the average and standard deviation for all leaves were 0.17 mm ± 0.10 mm and the maximum positioning error was 0.40 mm, which are within the tolerance limit. The results of the leaf positioning error indicate that the Vero4DRT system is able to deliver a highly accurate IMRT treatment over a period of one year.

Nakamura *et al.*[12] reported that the mean ± standard deviation of the difference was 0.00 ± 0.10 mm, ranging from −0.30 mm to 0.20 mm on the leaf position accuracy testing film for Vero4DRT system at the gantry angle of 90° with pan rotational angle of 2.5°. Their reported results were obtained with only one measurement at the time of commissioning. Our long-term leaf positioning accuracy and reproducibility test for the Vero4DRT system showed no drift in positioning with time during our one-year measurement. The results presented in this study are specific to the MLC of Vero4DRT system. Regarding other manufacturers, such as Varian, ELEKTA, and SIEMENS, LoSasso *et al.*[1] reported that the assessment of leaf precision using alternating dynamic and static fields showed that the leaf precision was about 0.25 mm. Parent *et al.*[15] reported that the maximum positional difference for a given leaf was 1.0 mm and the average maximum difference was 0.10 mm, and Bayouth *et al.*[16] reported nine separate leaf reproducibility studies over a 90-day period that evaluated 600 measurement points on each film showing 0.30 mm precision for 95% confidence interval. These reports are the result of relatively short-term studies. We can assess the leaf position and accuracy every day, as daily MLC QA for the Vero4DRT is mandatory and is not time-consuming. The MLC QA measurement results can be gradual changes as a result of the aging of the leaf motor. These patterns of failure must be considered when establishing a periodic QA program. In our one-year measurement, the leaf positioning error was within 0.50 mm. Therefore, if the leaf positioning error for daily MLC QA exceeded 0.50 mm, then an external intervention is required.

A limitation of this study is that it was only involved the measurement of two positions for each leaf (−5 and +5 cm). Another limitation was only performed at a gantry angle of 0°. The load on the leaf motor due to the gravity of the leaf is well known.[17] The picket fence test was performed at our department with an EPID at gantry angles of 0°, 90°, 180°, and 270° to account for several leaf positional errors due to the gravity effect for monthly QA.

5. Conclusion

The daily MLC QA of our one-year evaluation of the Vero4DRT system demonstrates an excellent leaf accuracy and reproducibility, thereby giving confidence in the quality of treatment.

Conflict of Interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. LoSasso T, Chui CS, Ling CC. Physical and dosimetric aspects of a multileaf collimator system used in the dynamic mode for implementing intensity modulated radiotherapy. Med Phys. 1998;25:1919-27.
2. Kuperman VY, Lam WC. Improving delivery of segments with small MU in Step-and-Shoot IMRT. Med Phys. 2006;33;1067-73.
3. Sastre-Padro M, van der Heide UA, Welleweerd H. An accurate calibration method of the multileaf collimator valid for conformal and intensity modulated radiation treatments. Phys Med Biol. 2004;49:2631–43.
4. Sastre-Padro M, Welleweerd J, Malinen E, *et al.* Consequences of leaf calibration errors on IMRT delivery. Phys Med Biol. 2007;52:1147–56.
5. Chui CS, Spirou S, LoSasso T. Testing of dynamic multileaf collimation. Med Phys. 1996;23:635–41.

6. Vieira SC, Dirkx MLP, Pasma KL, *et al.* Fast and accurate leaf verification for dynamic multileaf collimation using an electronic portal imaging device. Med Phys. 2002;29:2034–40.
7. Mamalui-Hunter M, Li H, Low DA. MLC quality assurance using EPID: a fitting technique with subpixel precision. Med Phys 2008;35:2347–55.
8. Kamino Y, Takayama K, Kokubo M, *et al.* Development of a four-dimensional image-guided radiotherapy system with a gimbaled X-ray head. Int J Radiat Oncol Biol Phys. 2006;66:271–78.
9. Kamino Y, Miura S, Kokubo M, *et al*. Development of an ultrasmall C-band linear accelerator guide for a four-dimensional image-guided radiotherapy system with a gimbaled x-ray head. Med Phys. 2007;34:1797–808.
10. Klein EE, Hanley J, Bayouth J, *et al.* Task Group 142 report: quality assurance of medical accelerators. Med Phys. 2009;36:4197–212.
11. Kutcher GJ, Coia L, Gillin M, *et al.* Comprehensive QA for radiation oncology: report of AAPM Radiation Therapy Committee Task Group 40. Med Phys. 1994;21:581–618.
12. Nakamura M, Sawada A, Ishihara Y, *et al.* Dosimetric characterization of a multileaf collimator for a new four-dimensional image-guided radiotherapy system with a gimbaled x-ray head, MHI-TM2000. Medical Physics 2010;37: 4684-91.
13. Tesseract Homepage. Available at https://code.google.com/p/tesseract-ocr/
14. Palta JR, Mackie TR. Intensity-modulated radiation therapy: the state of the art. Madison. Medical Physics Publishing, 2003.
15. Parent L, Seco J, Evans PM, *et al.* Evaluation of two methods of predicting MLC leaf positions using EPID measurements. Med Phys. 2006;33:3174-82.
16. Bayouth JE, Wendt D, Morrill SM. MLC quality assurance techniques for IMRT applications. Med Phys.2003;30:743–50
17. Okumura M, Obata Y, Shimomura K, *et al.* The effect of gantry and collimator angles on leaf limited velocity and position in dynamic multileaf collimator intensity-modulated radiation therapy. Phys Med Biol. 2010;55:3101-13.

ISSN 2330-4049