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Stability assessment of radiation isocenter with the gimbaled linac system

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Technical Report

Abstract

Purpose: We report the results of our year-long radiation isocenter accuracy verification for daily quality assurance (QA) implementation on a Vero4DRT system. **Methods:** The radiation isocenter was calculated using a cube phantom with a steel ball of diameter 10 mm fixed to the center of the phantom. A single photon beam was set with a field size of 100 × 100 mm^2. Coincidence of the centroid of the steel ball at kiloVolt X-ray imaging isocenter and megaVolt beam radiation isocenter at each gantry and ring angle was tested. This procedure was performed for gantry angles of 0°, 90°, 180°, and 270°, and ring angles of 0°, 20°, and 340°. The centroid of the steel ball and the center of the radiation field were calculated to analyze the radiation isocenter error. This analysis was automatically calculated using the Daily Check tool in the Vero4DRT system. This QA was implemented between 24 August 2015 and 23 August 2016. **Results:** The average and standard deviation for pan and tilt directions were 0.12 ± 0.10 mm and -0.20 ± 0.13 mm, respectively. The maximum radiation isocenter accuracy error was 0.50 mm in both directions. **Conclusion:** The radiation isocenter alignment for the one year duration of the experiment was performed with high accuracy.

Keywords: Isocenter accuracy verification, Quality assurance, Vero4DRT, Electronic portal image device

1. Introduction

Stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT) can deliver increased doses of radiation to a target, while decreasing the dose delivered to the normal tissue. Image graticule and radiation isocenter coincidence are regarded as important quality assurances (QA) for SRS and SBRT treatment. The American Association of Physicists in Medicine (AAPM) Task Group Report 142 recommended that the imaging and treatment coordinate coincidence should be within 1 mm for SRS and SBRT types of treatment machines.[1] Several methods have been proposed to measure the radiation isocenter using film and electronic portal imaging devices (EPID). The position of the radiation isocenter with respect to those of the lasers is accurately measured using the Winston–Lutz test.[2]

In the Vero4DRT system, indirect dynamic tumor tracking (DTT) using an internally implanted marker can be used as a breathing-induced organ motion compensated treatment technique. Several authors reported that the largest variation in beam axial position from the isocenter was less than 0.5 mm for the Vero4DRT system.[3, 4] However, their studies only included data collected for a short time. The gimbaled X-ray head can swing along the pan and tilt directions to capture the irradiation; therefore, megaVolt (MV) X-ray head axis is not always fixed. The Vero4DRT system provides not only DTT, but also three-dimensional conformal radiation therapy (3D-CRT) and intensity modulated radiation therapy.

To achieve safe and accurate delivery, the QA of radiation isocenter accuracy verification is clinically important. From an operational perspective, it is mandatory to perform radiation isocenter accuracy verification before clinical use. In this work, we report the results of our year-long radiation isocenter accuracy verification for the daily QA implementation on a Vero4DRT system.

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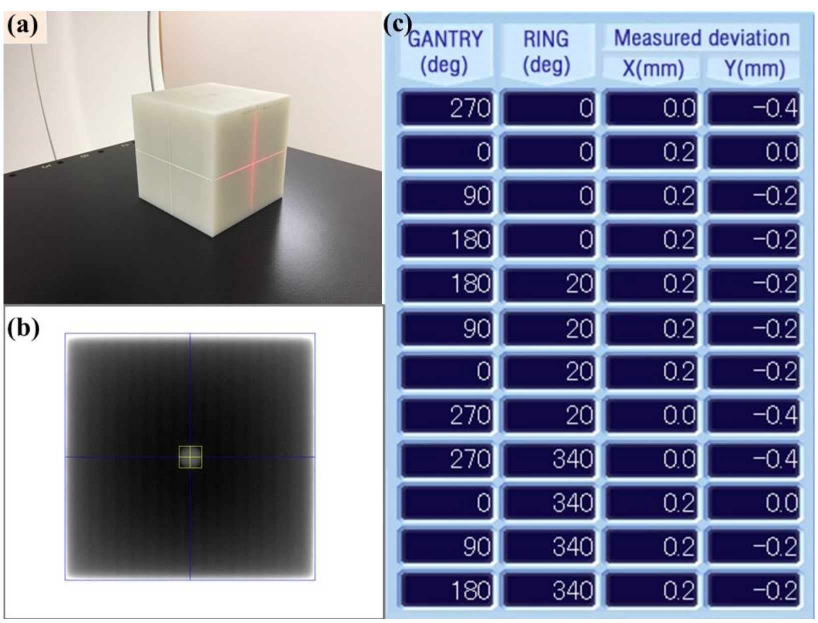
2. Methods and Materials

The Vero4DRT system (Mitsubishi Heavy Industries Tokyo, Japan, and BrainLAB, Feldkirchen, Germany) is described elsewhere.[5, 6] In brief, the Vero4DRT is equipped with a dual orthogonal kilovolt (kV) imaging system, which can perform cone beam computed tomography. Imaging angle and position in the Vero4DRT system are different from those in other ExacTrac systems (BrainLAB AG, Feldkirchen, Germany), such as the Novalis (BrainLAB AG, Feldkirchen, Germany). The gantry, which is located inside the O-ring can be rotated ±180˚ around the isocenter at a nominal maximum speed of 7°/s. The O-ring itself can be rotated ± 60˚ around its vertical axis through the isocenter at a nominal maximum speed of 3°/s. The gimbaled X-ray head can swing along the two orthogonal gimbals up to 2.5°. A gimbaled mechanism is used for tracking toward the predicted target positions, based on 4D-modeling.

A water-equivalent cube phantom (130 × 130 × 130 mm^3) with a 10-mm-diameter steel ball fixed to the center of the phantom was used to evaluate the radiation isocenter accuracy verification (Figure1: Panel (a)). The experiment was implemented as follows. The cube phantom was initially aligned with the lasers, such that it was placed close to the radiation isocenter of the linac. The cube phantom was automatically moved to the isocenter of the kV X-ray imaging by using a robotic couch correction. A single photon beam was set with a field size of 100 × 100 mm^2. Coincidence of the centroid of steel ball at kV X-ray imaging isocenter and MV beam radiation isocenter at each gantry and ring angles were tested. This procedure was performed for gantry angles of 0°, 90°, 180°, and 270°, and ring angles of 0°, 20°, and 340°, irradiated from a total of 12 directions. The centroid of the steel ball and the center of the radiation field were calculated from the MV X-ray image using the Daily Check tool in the Vero4DRT system (Figure 1: Panel (b)). The MV beam axis errors can be automatically detected at pixel resolution. The spatial resolution of the MV X-ray image was 0.18 × 0.18 mm^2 at the isocenter level and a matrix size of 1024 × 1024 pixels. The MV beam axis error values in pan and tilt directions are displayed in Figure 1: Panel(c). The Daily Check tool in the Vero4DRT system is confidence tool compared with film measurement, with 0.02 ± 0.11 mm.[4] We assessed the radiation isocenter accuracy verification for daily QA between 24 August 2015 and 23 August 2016 (except for weekends and holidays).

3. Results

The radiation isocenter accuracy verification results were calculated as the average and standard deviation during 12 months and were summarized in Table 1. The average and standard deviation for pan and tilt directions during 12 months were 0.12 ± 0.10 mm and -0.20 ± 0.13 mm, respectively. The maximum radiation isocenter accuracy error was 0.50 mm in both directions during 12 months. In addition, the maximum deviation was 0.14 mm in both directions during the same period.



GANTRY (deg)	RING (deg)	Measured deviation X(mm)	Measured deviation Y(mm)
270	0	0.0	−0.4
0	0	0.2	0.0
90	0	0.2	−0.2
180	0	0.2	−0.2
180	20	0.2	−0.2
90	20	0.2	−0.2
0	20	0.2	−0.2
270	20	0.0	−0.4
270	340	0.0	−0.4
0	340	0.2	0.0
90	340	0.2	−0.2
180	340	0.2	−0.2

Figure 1. (a) Photograph of the cube phantom exterior, (b) EPID image of the cube phantom, and (c) screenshot of the isocenter accuracy verification result that can automatically calculated from the centroids of the ball and square.

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Table 1. Daily radiation isocenter accuracy QA results of 12 directions.

Gantry angle (°)	Ring angle (°)	Pan direction (mm)	Tilt direction (mm)
270	0	0.07 ± 0.12 (-0.20 - 0.20)	-0.32 ± 0.13 (-0.50 - 0.20)
0	0	0.14 ± 0.09 (-0.20 - 0.20)	-0.12 ± 0.10 (-0.40 - 0.20)
90	0	0.18 ± 0.06 (-0.20 - 0.20)	-0.21 ± 0.14 (-0.40 - 0.20)
180	0	0.17 ± 0.08 (-0.20 - 0.20)	-0.17 ± 0.09 (-0.40 - 0.20)
180	20	0.19 ± 0.04 (-0.20 - 0.20)	-0.18 ± 0.09 (-0.40 - 0.20)
90	20	0.18 ± 0.06 (-0.00 - 0.20)	-0.11 ± 0.13 (-0.40 - 0.40)
0	20	0.15 ± 0.09 (-0.20 - 0.20)	-0.17 ± 0.10 (-0.40 - 0.40)
270	20	0.06 ± 0.13 (-0.40 - 0.20)	-0.35 ± 0.11 (-0.50 - 0.20)
270	340	0.04 ± 0.14 (-0.20 - 0.20)	-0.27 ± 0.13 (-0.50 - 0.20)
0	340	0.12 ± 0.10 (-0.20 - 0.20)	-0.14 ± 0.10 (-0.40 - 0.40)
90	340	0.14 ± 0.09 (-0.20 - 0.20)	-0.21 ± 0.12 (-0.40 - 0.40)
180	340	0.09 ± 0.11 (-0.20 - 0.20)	-0.17 ± 0.10 (-0.40 - 0.20)

The analyzed data were displayed as mean and standard deviation, with ranges in parentheses.

4. Discussion

We report our year-long experimental analysis of radiation isocenter accuracy verification for daily QA using the Daily Check tool. In our study, the average and standard deviation for both directions were 0.12 ±0.10 mm and -0.20 ±0.13 mm, respectively and the maximum radiation isocenter accuracy was 0.50 mm. The results of the isocenter accuracy verification indicate that the Vero4DRT system has an ability to be a highly accurate and responsible treatment over a period of one year.

Kamomae *et al.*[4] reported that the mean and standard deviation of the difference in isocenter accuracy and values from the same Daily Check tool were 0.00 ± 0.10 mm, ranging from -0.30 mm to 0.20 mm. Miyabe *et al.*[3] reported that isocenter accuracy using an in-house software with similar gantry and ring angles were 0.14, 0.23, and 0.36 mm in the vertical, longitudinal, and lateral directions, respectively. The radiation isocenter accuracy verification in our study is similar to that in the studies mentioned above.

Gantry rotation of linac is deviated from the ideal trajectory due to the weight of several tons of radiation generating and shielding materials inside the gantry. Regarding other manufacturers, several authors have been reported that the gantry sag was varied, depending on the linac and the collimator angle. For example, Du *et al.*[7] reported the maximum gantry sag was found to be varying from 0.7 to 1.0 mm on three Varian linacs. The Vero4DRT system has a lock-on system, which can correct any drift in the MV X-ray beam axis caused by its own weight. Compared with this result, we demonstrated that the lock-on system made the Vero4DRT system more efficient in terms of alignment accuracy.

Our year-long radiation isocenter accuracy verification for daily QA for the Vero4DRT system showed no drift with time during our one year measurement. The isocenter radiation accuracy was within 0.50 mm during our one-year measurement. Therefore, if the radiation isocenter accuracy for daily QA exceeds 0.50 mm, an external correction is required. A limitation of this study was that it was performed only for a one-year experiment. Our Vero4DRT system was installed in August 2015, and therefore, is relatively new. However, there is relatively high usage cycle of DTT in our institution, because we performed the tracking accuracy verification with DTT technique recurrently.[8-10]. Further investigations need to be performed to evaluate the radiation isocenter accuracy verification for long-term stability.

5. Conclusion

The radiation isocenter accuracy verification daily QA of our one-year evaluation with the Vero4DRT system demonstrates excellent isocenter precision and accuracy, thereby providing 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. Klein EE, Hanley J, Bayouth J, *et al*. Task Group 142 Report: Quality assurance of medical accelerators. Med Phys. 2009;36:4197–212.

2. Lutz W, Winston KR, Maleki N. A system for stereotactic radiosurgery with a linear accelerator. Int J Radiat Oncol Biol Phys. 1988;14:373–81.
3. Miyabe Y, Sawada A, Takayama K, et al. Positioning accuracy of a new image-guided radiotherapy system. Med Phys. 2011;38:2535-41.
4. Kamomae T, Monzen H, Nakayama S, *et al.* Accuracy of image guidance using free-breathing cone-beam computed tomography for stereotactic lung radiotherapy. PLoS One. 2015;10:e0126152.
5. 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;66:271-8.
6. 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. Med Phys. 2010;37:4684-91.
7. Du W, Gao S, Wang X, *et al.* Quantifying the gantry sag on linear accelerators and introducing an MLC-based compensation strategy. Med Phys. 2012;39:2156-62.
8. Miura H, Ozawa S, Tsuda S, *et al.* Quality assurance for dynamic tumor tracking using the Vero4DRT system. Int J Cancer Ther Oncol. 2016;4(1):4112.
9. Miura H, Ozawa S, Hayata M, *et al.* Simple quality assurance method of dynamic tumor tracking with the gimbaled linac system using a light field. J Appl Clin Med Phys. 2016;17:177–183.
10. Miura H, Ozawa S, Enosaki T, *et al.* Quality assurance of a gimbaled head swing verification using feature point tracking. J Appl Clin Med Phys. 2017;18:49–52.

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