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Dataset for Beam Commissioning of the Vero4DRT System

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Abstract

We present the results of measurements made using the Vero4DRT radiation therapy system, which is not yet widely used, to assist technicians in achieving reliable and safe radiotherapy to the patient. We measured percent depth dose, beam profile, and relative scatter factor under water and air conditions. The Vero4DRT system has a 150 × 150-mm fixed secondary collimator. Its multileaf collimator (MLC) design is a single-focus type, with 30 pairs of 5 mm thick leaves at the isocenter, and produces a maximum field size of 150 × 150 mm. Profile measurements were performed using a 0.016-cm^3 ionization chamber (PTW31016 pinpoint chamber; PTW, Freiburg GmbH Germany). A brass build-up cap was used for measurements obtained in air conditions. We present a useful measurement dataset for users of the Vero4DRT system.

Keywords

Vero4DRT, Beam Characteristic, Commissioning

1. Introduction

Beamdata commissioning is an important task when delivering radiotherapy doses to patients. The American Association of Physicists in Medicine (AAPM) Task Group 106 reports on phantom and detector setups and measurement techniques to acquire data on beam accuracy [1]. Measurement results may be inaccurate even if beam data are measured according to the reference guide and recommendation files. Even if the sample beam data already may be input into the treatment-planning system (TPS), the vendor may not have provided reliable

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data for verifying the user's commissioning results. Because the TrueBeam (Varian Medical Systems, Palo Alto, CA) and NovalisTx devices have been used widely and investigated at many institutions, useful information is available regarding commissioning of this type of linear accelerator [2] [3]. The reliability of measurement results should be enhanced by comparison with these published data.

The Vero4DRT (MHI-TM2000) system was newly developed by Mitsubishi Heavy Industries, Ltd., Japan (MHI) in collaboration with Kyoto University and the Institute of Biomedical Research and Innovation (IBRI). The characteristics of the Vero4DRT system have been described previously [4]-[6]. Briefly, the device is equipped with a 6 MV X-ray beam and an output dose rate of up to 500 MU/min. The Linac head is composed of a compact C-band 6-MV accelerator tube, target, flattening filter, primary collimator, fixed secondary collimator, and multileaf collimator (MLC). The MLC is positioned just below the fixed secondary collimator. The MLC design is a single-focus type, with 30 pairs of 5 mm thick leaves at the isocenter, and produces a maximum field size of 150 × 150 mm.Vero4DRT system has a high precision isocenter at the mechanical center of the gantry, which is shaped like an O-ring. The X-ray head with the gimbals can be rotated on the O-ring and moved to pan and tilt directions for dynamic tumor tracking (DTT). The Vero4DRT system is not yet widely in use worldwide (24 Linac devices as of October 2015); thus, no useful information for commissioning is available to compare measurement data. We present our measurement results for percent depth dose (PDD), beam profile, and relative scatter factor in water and air conditions for the Vero4DRT system.

2. Materials and Methods

The current Vero4DRT system supports only the iPlan RT dose TPS (BrainLAB, Feldkirchen, Germany), which is available with pencil-beam (PB) and Monte Carlo (MC) algorithms.

2.1. Measurement Devices

Measurements were made using the OmniPro-I'mRT software (OmniPro-I'mRT 1.6 IBA dosimetry, Germany) in a Blue Phantom water tank (IBA Dosimetry GmbH, Germany). Profile measurements were performed using a 0.016-cm^3 ionization chamber (PTW31016 pinpoint chamber; PTW, Freiburg GmbH, Germany). A brass build-up cap was used for measurements in air to remove electron contamination of the Linac head from the measurement signal. MLC leakage was measured with a Farmer-type ionization chamber (Model N30013; PTW, Freiburg, Germany) with a RAMTEC Smart^{TM} electrometer (Toyo Medic, Tokyo, Japan).

2.2. Measurement

The measurement procedure is described in the "BRAINLAB PHYSICS Technical Reference guide" [7] and are summarized in **Tables 1-3**. Briefly, the beam dataset for the PB algorithm was acquired on the basis of the following setup conditions: the source surface distance (SSD) was always set at 1000 mm for profile measurements and the depth was set at 100 mm for the measurement of relative scatter data. Beam profiles were measured directly under the MLC in such a way that they are not influenced by the interleaf or intraleaf gap. The origin's coordinate is located at the surface of the water phantom.

The beam dataset for the MC algorithm was acquired on the basis of the following setup conditions: the SSD was set at 900 or 1000 mm for PDD and profile measurements, and the depth was set at 100 mm for the mea-

Table 1. Dataset for Pencil Beam in water.

	Field size (mm)	Depth (mm)	SSD (mm)
PDD	10 × 10, 20 × 20, 30 × 30, 40 × 40, 60 × 60, 80 × 80, 100 × 100, 120 × 120, 150 × 150	0 - 350	1000
Relative scatter factor	10 × 10, 20 × 20, 30 × 30, 40 × 40, 60 × 60, 80 × 80, 100 × 100, 120 × 120, 150 × 150	100	1000
Diagonal beam profile	150 × 150	5, 14, 25, 50, 100, 200, 350	1000
Transverse beam profile	predefined MLC pattern	dmax, 100, 200	1000
MLC leakage	closed MLC closed/opened MLC	100	1000

Table 2. Dataset for Monte Carlo in water.

	Field size (mm)	Depth (mm)	SSD (mm)
PDD	100 × 100	0 - 350	1000
Transverse beam profile	100 × 100	dmax, 100, 200	1000
PDD	10 × 10, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	0 - 350	900
Transverse beam profile	10 × 10, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	dmax, 100, 200	900
Relative scatter factor	10 × 10, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	100	900

Table 3. Dataset for Monte Carlo in air.

	Field size (mm)	Depth (mm)
Cax profile	20 × 20, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	850 - 1150
Transverse beam profile	20 × 20, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	850, 1000, 1150
Relative scatter factor	20 × 20, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, 150 × 100	1000

surement of relative scatter data in water. The MC algorithm requires the measurement to be made in air. For measurements in air, the origin of the coordinate system is not located in the isocenter, but in the target. An ionization chamber with a brass build-up cap was used to measure the profiles in air.

For measurement results in water, PDD were normalized to the depth of 14 mm (maximum depth) and the cross-plane and in-plane profiles were normalized at the central axis (CAX). Beam profiles were normalized at the CAX. Relative scatter data were calculated by dividing the measured data for each MLC setting by the measured data at the MLC setting of 100 × 100 mm.

3. Results

3.1. Measurement for the PB Algorithm

Figure 1 shows the PDD curves with an SSD of 1000 mm. Nine fields were measured and depth ranged from 0 to 350 mm. **Figure 2** shows the diagonal beam profiles with SSD of 1000 mm measured at different depths at 150 × 150 mm^2. For diagonal beam profiles, seven depths were measured and radius ranged from −220 to 220 mm. **Figure 3** shows the transverse beam (**Figure 3(a)**) cross-plane and (**Figure 3(b)**) in-plane profiles with a predefined MLC pattern (**Figure 3(c)**) measured at 14 (dmax), 100, and 200 mm depths at 150 × 150 mm^2. The relative scatter data were measured with various field sizes at the depth of 100 mm with an SSD of 1000 mm. The relative scatter factors ranged from 0.697 at 10 × 10 mm to 1.046 at 150 × 150 mm (**Table 4**). The leakage for closed MLC was 0.14%.

3.2. Measurement for MC Algorithm in Water

Figure 4 shows the percent depth dose curves with SSD of 1000 mm normalized to the depth of 14 mm. The 100 × 100 mm fields were measured and depth ranged from 0 to 350 mm. **Figure 5** shows the transverse beam cross-plane and in-plane profiles measured at 14 (dmax), 100, and 200 mm depths with 100 × 100 mm. **Figure 6** shows the percent depth dose curves with SSD of 900 mm normalized to the depth of 14 mm in water. Ten fields were measured and depth ranged from 0 to 350 mm. **Figure 7** shows the transverse beam cross-plane and in-plane profiles measured at 14 (dmax), 100, and 200 mm depths with various fields in water. The relative scatter data were measured with various field sizes at the depth of 100 mm with SSD of 1000 mm in water. The relative scatter factors ranged from 0.686 at 10 × 10 mm to 1.046 at 150 × 150 mm (**Table 5**).

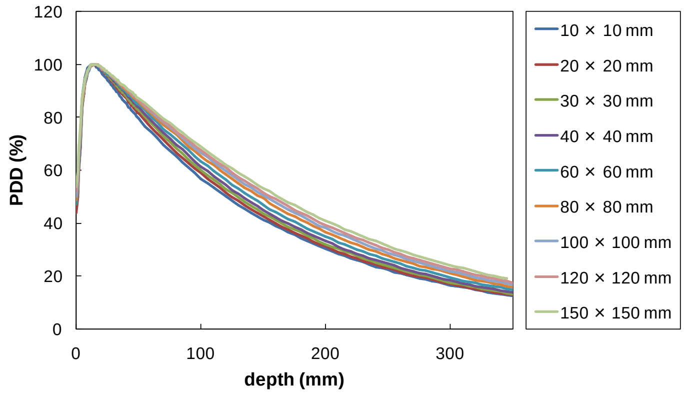

Figure 1. The percent depth dose curves with SSD of 1000 mm for the PB algorithm at nine field settings: 10 × 10, 20 × 20, 30 × 30, 40 × 40, 60 × 60, 80 × 80, 100 × 100, 120 × 120, and 150 × 150 mm.

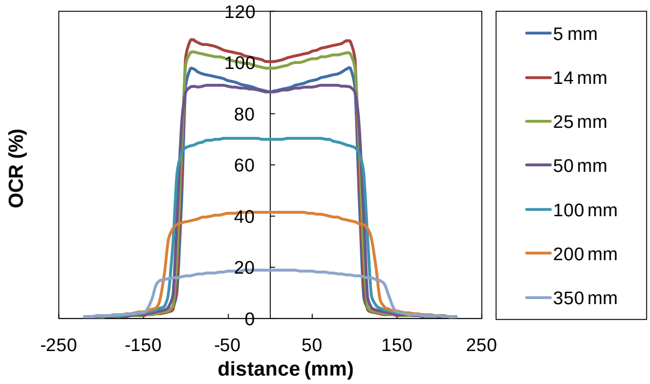

Figure 2. The beam profiles with SSD of 1000 mm for the PB algorithm with MLC size of 150 × 150 mm at the diagonal direction and different depths: 5, 14, 25, 50, 100, 200, and 350 mm.

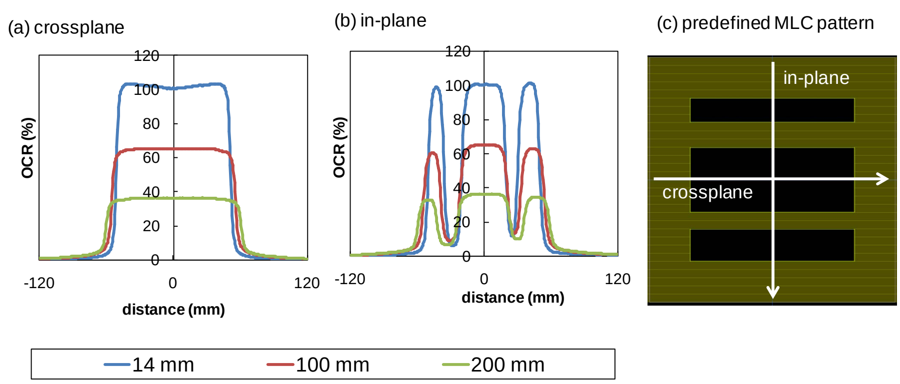

Figure 3. (a) The cross-plane and (b) in-plane transverse beam profiles with SSD of 100 mm at depths of 14 (dmax), 100, and 200 mm. (c) predifined MLC pattern.

3.3. Measurement for MC Algorithm in Air

Figure 8 shows the CAX profile ranged from 850 to 1150 mm. **Figure 9** shows the transverse beam cross-plane and in-plane profiles measured at 850, 1000, and 1150 mm depths with various fields in air. The relative scatter data were measured with various field sizes with source-chamber distance (SCD) of 1000mm in air. The relative scatter factors ranged from 0.974 at 20 × 20 mm to 1.001 at 150 × 150 mm (**Table 6**).

Table 4. Relative scatter factor with SSD of 1000 mm at 100-mm depth in water.

Field size (mm)	Relative scatter factor
10 × 10	0.697
20 × 20	0.820
30 × 30	0.866
40 × 40	0.896
60 × 60	0.941
80 × 80	0.974
100 × 100	1.000
120 × 120	1.022
150 × 150	1.046

Table 5. Relative scatter factor with SSD of 900 mm at 100 mm depth in water.

Field size (mm)	Relative scatter factor
10 × 10	0.686
30 × 30	0.868
50 × 50	0.921
70 × 70	0.958
100 × 100	1.000
150 × 150	1.046
50 × 150	0.964
100 × 150	1.023
150 × 50	0.961
150 × 100	1.019

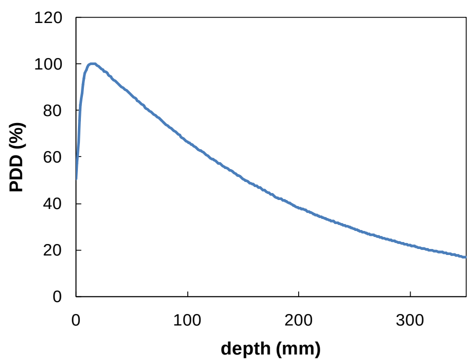

Figure 4. The PDD curves with SSD of 1000 mm for the MC algorithm at 100 × 100 mm in water.

4. Discussion

Most reports on the Vero4DRT system describe characteristics of the dynamic tracking system [8] [9]. For typical dosimetric characterization, Nakamura *et al.* investigated the field characteristics and leaf position accuracy

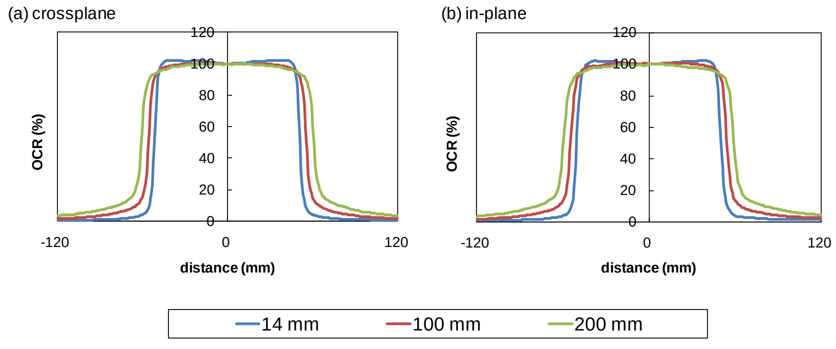

Figure 5. (a) The cross-plane and (b) in-plane beam profiles with SSD of 1000 mm for the MC algorithm at 100 × 100 mm in water.

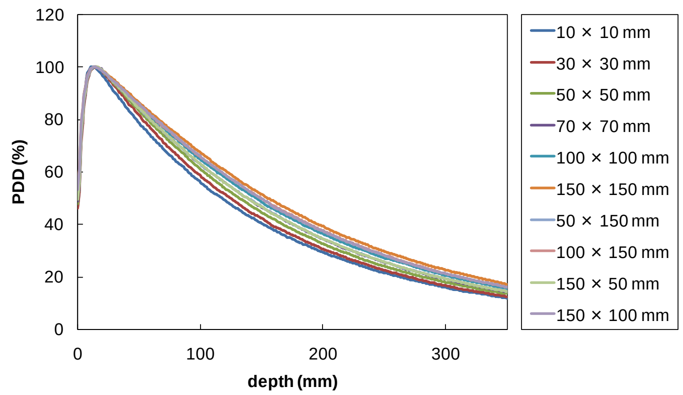

Figure 6. The percent depth dose curves with SSD of 900 mm for the MC algorithm at 10 field settings in water: 10 × 10, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, and 150 × 100 mm.

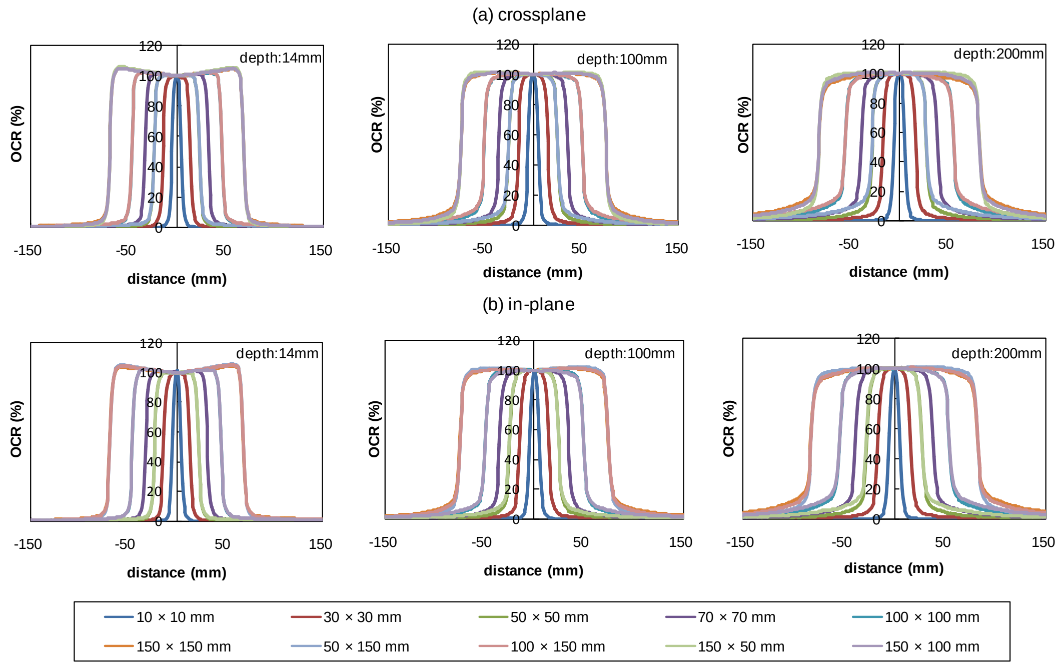

Figure 7. (a) The cross-plane and (b) in-plane transverse beam profiles at depths of 14 (dmax), 100, and 200 mm for the MC algorithm at ten field settings in water: 10 × 10, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, and 150 × 100 mm.

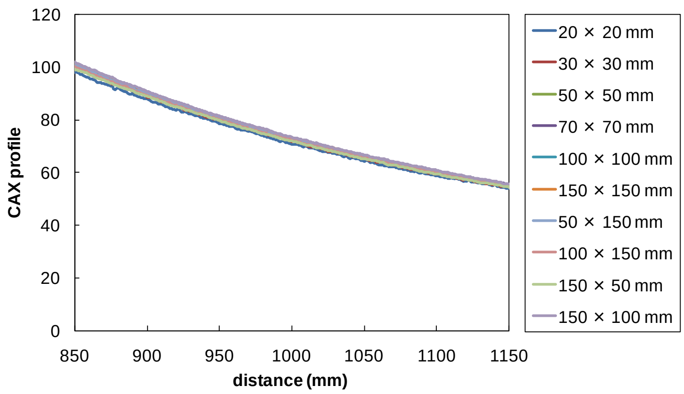

Figure 8. The CAX profile for the MC algorithm at 10 field settings in air: 20 × 20, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, and 150 × 100 mm.

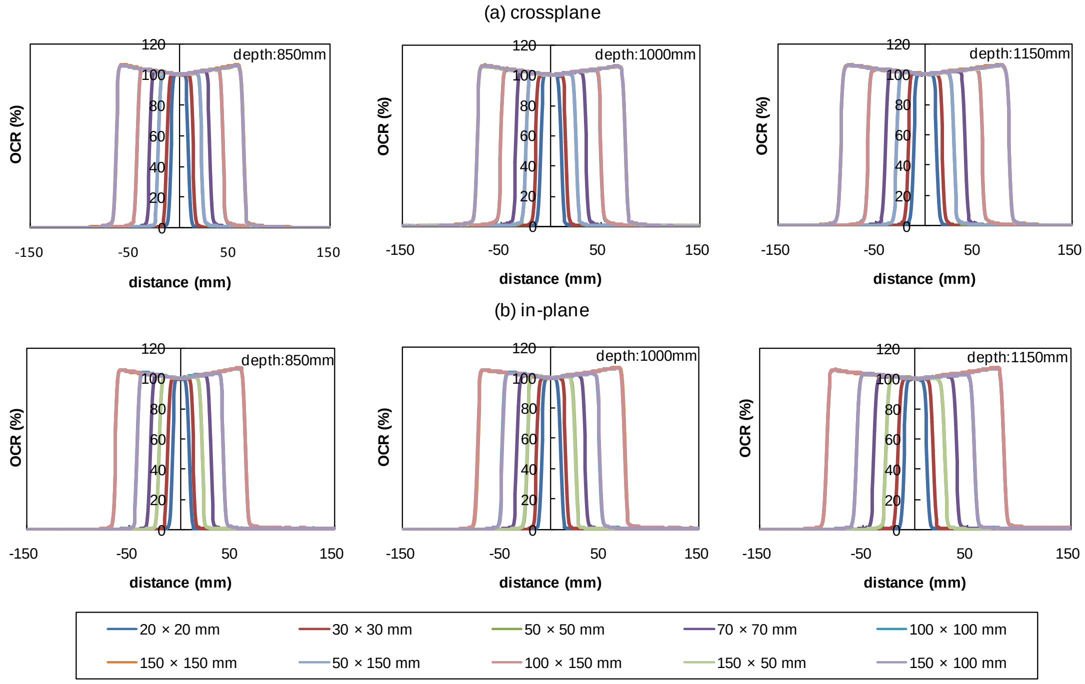

Figure 9. (a) The cross-plane and (b) in-plane transverse beam profiles at distance of 850, 1000 and 1150 mm for the MC algorithm at ten field settings in air: 20 × 20, 30 × 30, 50 × 50, 70 × 70, 100 × 100, 150 × 150, 50 × 150, 100 × 150, 150 × 50, and 150 × 100 mm.

of the MLC for MHI-TM2000 using a well-commissioned 6-MV photon beam, EDR2 films, and water-equivalent phantoms [5]. Miura *et al.* reported the dose linearity and profile flatness/symmetry under low-MU settings of Vero4DRT under low-MU settings [10]. Because the Novalis system likewise supports only iPlan RT, dosimetric characteristics of the Novalis may serve as a reference [11].

The detectors should be selected carefully to improve the accuracy of the dose calculation. Field profile is affected by chamber volume and indicates that a small volume detector is preferred. The detector should be mounted perpendicular to the gun-target direction such that there is minimum volume in the scan direction. Note that the effective measurement point for the PTW31016 pinpoint chamber is 2.4 mm from the detector top when the detector is positioned in the vertical direction. We also compared relative scatter factor data measured using an EDGE detector (Sun Nuclear Corporation, Melbourne, FL) (data not shown). All measured data in water and air are not used directly during dose calculation in iPlan RT. The commissioning data were sent to BrainLAB and the parameters of the Linac head model were adjusted correspondingly. Check measured data is considered

Table 6. Relative scatter factor with SCD of 1000 mm in air.

Field size (mm)	Relative scatter factor
20 × 20	0.974
30 × 30	0.988
50 × 50	0.995
70 × 70	0.997
100 × 100	1.000
150 × 150	1.001
50 × 150	0.997
100 × 150	1.002
150 × 50	1.000
150 × 100	1.001

to be more important than measuring beam data. The user must validate the correctness before performing any patient treatment. The incidence of troubles with measured data might be decreased by referral to this study. However, a limitation of this study is that the results are obtained from only one institution. Comparative studies from multiple institutions are needed to verify whether there is a difference with each machine. All the measured PDD and OCR data matched well across the three TrueBeam machines [2].

5. Conclusion

We presented a useful measurement dataset for users of the Vero4DRT system. This dataset may help other institutions embarking on Vero4DRT commissioning.

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