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<원저>

VitalBeam 선형가속기의 심부선량백분율과 측방선량분포 측정을 위한 새로운 기준 전리함으로서 스텔스 전리함의 성능 평가

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Performance Evaluation of Stealth Chamber as a Novel Reference Chamber for Measuring Percentage Depth Dose and Profile of VitalBeam Linear Accelerator

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Abstract The purpose of this study is to evaluate the performance of a "stealth chamber" as a novel reference chamber for measuring percentage depth dose (PDD) and profile of 6, 8 and 10 MV photon energies. The PDD curves and dose profiles with fields ranging from 3 × 3 to 25 × 25 cm^2 were acquired from measurements by using the stealth chamber and CC 13 chamber as reference chamber. All measurements were performed with Varian VitalBeam linear accelerator. In order to assess the performance of stealth chamber, PDD curves and profiles measured with stealth chamber were compared with measurement data using CC13 chamber. For PPDs measured with both chambers, the dosimetric parameters such as d_{max} (depth of maximum dose), D_{50} (PDD at 50 ㎜ depth), and D_{100} (PDD at 100 ㎜ depth) were analyzed. Moreover, root mean square error (RMSE) values for profiles at d_{max} and 100 ㎜ depth were evaluated. The measured PDDs and profiles between the stealth chamber and CC13 chamber as reference detector had almost comparable. For PDDs, the evaluated dosimetric parameters were observed small difference (<1%) for all energies and field sizes, except for d_{max} less than 2 ㎜. In addition, the difference of RMSEs for profiles at d_{max} and 100 ㎜ depth was similar for both chambers. This study confirmed that the use of stealth chamber for measuring commission beam data is a feasible as reference chamber for fields ranging from 3 × 3 to 20 × 20 cm^2. Furthermore, it has an advantage with respect to measurement of the small fields (less than 3 × 3 cm^2 field) although not performed in this study.

Key Words: Percentage depth dose, Dose profile, Commissioning, Reference chamber
중심 단어: 심부선량백분율, 측방선량분포, 커미셔닝, 기준 전리함

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Ⅰ. Introduction

Prior to use the new linear accelerator (LINAC) in clinical practice, the commissioning which acquires accurate beam data should be performed. It is important that beam data commissioning is performed with proper knowledge and appropriate tools[1-4]. Recently, a VitalBeam LINAC (Varian Medical Systems, Palo Alto, CA) was introduced newly in our institution. A major challenging task in collecting the beam data is to measure the PDD and profile for small field sizes, since the position of reference chamber must be moved. Moreover, this process increases the time spent in the measurement of beam data[5-7].

In IBA dosimetry, a new reference chamber, called a "stealth chambers" which can be mounted on linear accelerators and used for beam data commissioning have recently been released. The transmission type chamber of a rectangular design has an active detection area of 22 × 22 cm^2 and a thickness equivalent of 0.05 ㎝ aluminum. The characteristic of this chamber is to take advantage of continuous scanning efficiency without compromising measurement accuracy[8].

In this study, we aimed to evaluate the performance of a stealth chamber as a novel reference chamber through comparison of the percentage depth doses (PDDs) and dose profiles measured with CC13 and stealth chambers while measuring commissioning beam data of 6, 8 and 10 MV photon energies for a newly introduced linear accelerator.

Ⅱ. Materials and methods

1. Measurement of PDD and profile

Fig. 1 shows the setup of stealth chamber mounted on head of LINAC as reference chamber. As shown in Figure 1, PDD curves and depth dose profiles were measured in 3D blue water phantom (IBA Dosimetry GmbH, Germany) using CC13 (Scanditronix-Wellhofer, IBA Dosimetry GmbH, Schwarzenbruck, Germany) and stealth chamber for 6, 8 and 10 MV photon energies.

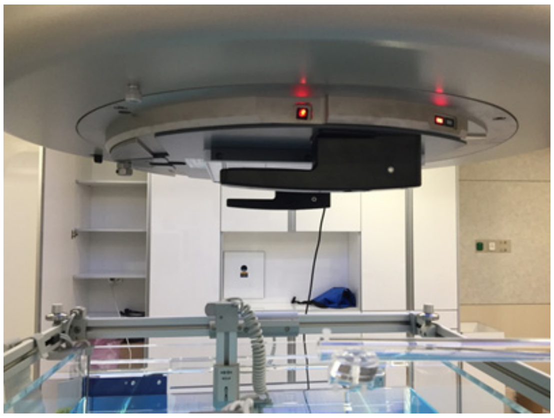

Fig. 1 Setup of stealth chamber mounted on head of LINAC and stealth chamber

All measurements for both chambers were performed with Varian VitalBeam linear accelerator[9].

Percentage depth dose (PDD) measurements were taken with a fixed source-to-surface distance (SSD) customarily at 100 ㎝ distance for various open fields ranging from 3 × 3 to 25 × 25 ㎠. Chamber correction for effective depth of measurement (0.6 × r_{cav}) is taken into account in software setting itself. All measured PDD curves were fitted by the least-square method. Dose profiles of open beam were measured for all beam energies for various field sizes at the maximum dose depth (d_{max}) 10 ㎝ depth (d_{100}). Beam profile data were first smoothened by the least-square method and were corrected to make symmetrical them. After that beam profiles were rescaled at the central axis.

2. Comparison in PDD and profile

To compare the PDD curves and dose profiles measured for both chambers, beam data measurement condition using the CC13 chamber for both the field chamber and the reference chamber were considered as gold standard. For the PDD curves, the dosimetric parameters such as d_{max}, PDD at 10 ㎝ (d_{100}) and 5 ㎝ (d_{50}) were compared for selective field sizes (3 × 3, 5 × 5, 10 × 10, 20 × 20 and 25 × 25 ㎠) to assess the differences between both chambers as reference chamber. In addition, the root mean square error (RMSE) was calculated to compare the profiles at d_{max} and d_{100} by using

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=0}^{n}(\mathrm{Dose}_{cc13}(i) - \mathrm{Dose}_{stealth}(i))^2}$$

where n is the number of calculation points for the dose profiles and $\mathrm{Dsee}_{cc13}(i)$ and $\mathrm{Dose}_{stealth}(i)$ are the doses using the CC13 chamber and stealth chamber at the ith calculation point for the profiles.

Ⅲ. Results

1. Percent depth dose agreement

Fig. 2 shows PDD curves obtained from measurements with the Stealth chamber and CC13 chamber as a reference chamber for 6, 8, and 10 MV with fields ranging from 3 × 3 to 25 × 25 ㎠ at 100 ㎝ SSD. In addition, the differences for the evaluated dosimetric parameters of PDD curves measured with both chambers were summarized in Table 1. As example of the data agreement, PDD comparison for a 8 MV beam with fields ranging from 3 × 3 to 25 × 25 ㎠ is shown in Fig. 3. For depth after d_{max}, PDDs measured for three beam energies with fields ranging from 3 × 3 to 20 × 20 ㎠ agreed well (within a 1%) between the Stealth chamber and CC13 chamber. However, the deviation in the measured PPDs at shallow depths was relatively large as shown in Fig. 3. Similar trends were observed in the other photon beams, with 3 × 3 to 25 × 25 ㎠ fields. Among the evaluated dosimetric parameters for PDD, the d_{max} for a 10 MV photon beam of 25 × 25 ㎠ field was significantly different (up to 2 ㎜). However, differences for the other energies with fields ranging from 3 × 3 to 20 × 20 ㎠ were always smaller than 1 ㎜.

2. Dose profile agreement

Fig. 4 shows dose profiles measured at d_{max} and d_{100} for 6, 8, and 10 MV with fields ranging from 3 × 3 to 25 × 25 ㎠. Table 2 indicates RMSE of dose profiles measured at d_{max} and d_{100} with the stealth chamber and CC13 chamber. RMSE values calculated for three beam energies with fields ranging from 3 × 3 to 25 ×

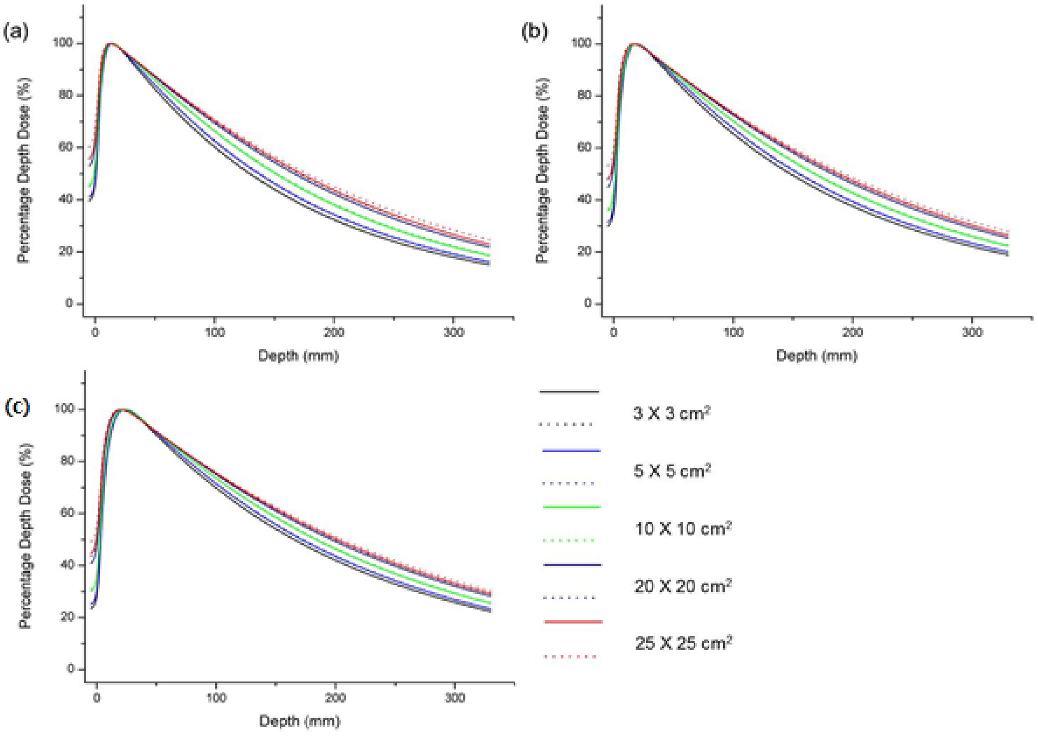

Fig. 2 Percentage depth dose (PDD) measured with the stealth (dot line) and CC13 (solid line) chamber for a) 6, b) 8, and c) 10 MV beams with fields ranging from 3 × 3 to 25 × 25 ㎠.

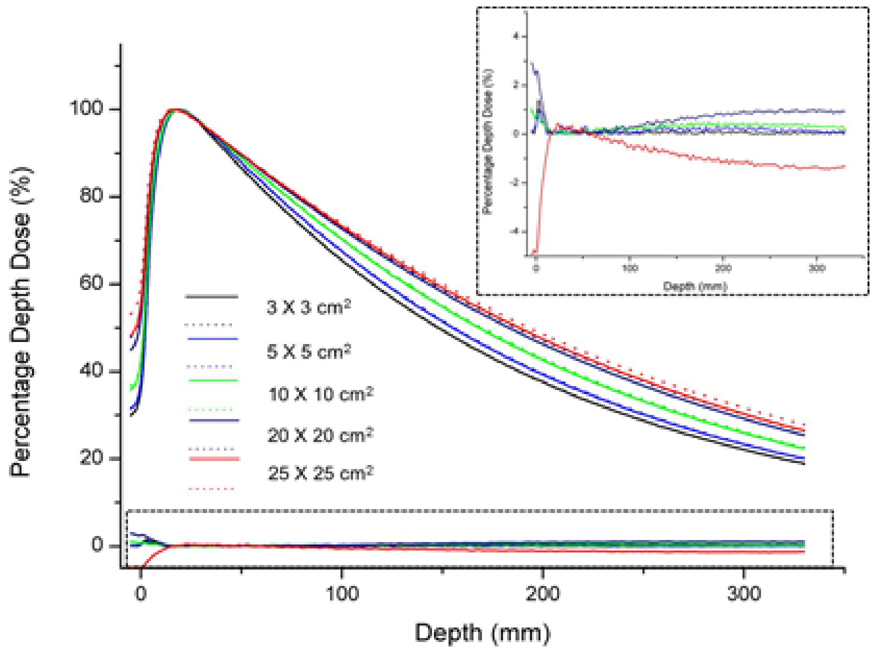

Fig. 3 Comparison and difference of PDD between the stealth (dot line) and CC13 (solid line) chamber for a 8 MV beam with fields ranging from 3 × 3 to 25 × 25 ㎠.

Table 1 Summary of the differences for the evaluated dosimetric parameters of PDD curves measured with both chambers for 6, 8, and 10 MV with fields ranging from 3 × 3 to 25 × 25 ㎠.

Field size (cm^2)		6 MV D_{100}(%)	6 MV D_{50}(%)	6 MV d_{max}(mm)	8 MV D_{100}(%)	8 MV D_{50}(%)	8 MV d_{max}(mm)	10 MV D_{100}(%)	10 MV D_{50}(%)	10 MV d_{max}(mm)
	CC13	60.33	82.50	14.50	65.49	86.92	19.10	69.80	90.22	23.80
3 x 3	Stealth	60.32	82.57	14.30	65.52	86.70	19.10	69.84	90.06	23.10
	Diff.	0.02	-0.08	0.20	-0.05	0.25	0.00	-0.06	0.18	0.70
	CC13	62.47	84.14	14.10	67.61	87.91	18.90	71.34	91.07	23.20
5 x 5	Stealth	62.86	84.13	13.70	67.57	87.97	19.20	71.55	91.00	23.80
	Diff.	-0.62	0.01	0.40	0.06	-0.07	-0.30	-0.29	0.08	-0.60
	CC13	66.37	85.89	13.00	70.36	88.94	19.00	73.54	91.54	23.00
10 x 10	Stealth	66.65	86.08	13.80	70.55	88.99	19.00	73.72	91.44	22.70
	Diff.	-0.42	-0.22	-0.80	-0.27	-0.06	0.00	-0.24	0.11	0.30
	CC13	69.43	87.19	13.30	72.70	89.58	17.70	75.10	91.45	20.40
20 x 20	Stealth	69.95	87.32	11.80	73.00	89.53	17.00	75.26	91.27	20.20
	Diff.	-0.75	-0.15	1.50	-0.41	0.06	0.70	-0.21	0.20	0.20
	CC13	70.38	87.65	12.8	73.28	89.79	16.90	75.51	91.60	21.00
25 x 25	Stealth	70.94	87.60	12.3	73.77	89.58	15.80	75.80	91.33	19.00
	Diff.	-0.80	0.06	0.50	-0.67	0.23	1.10	-0.38	0.29	2.00

25 ㎠ agreed within 0.7. There was no obvious trend in RMSE depending on energy, field size, and depth.

Ⅳ. Discussion

Commissioning beam data, such as PDD and profile by introducing a new linear accelerator, should be

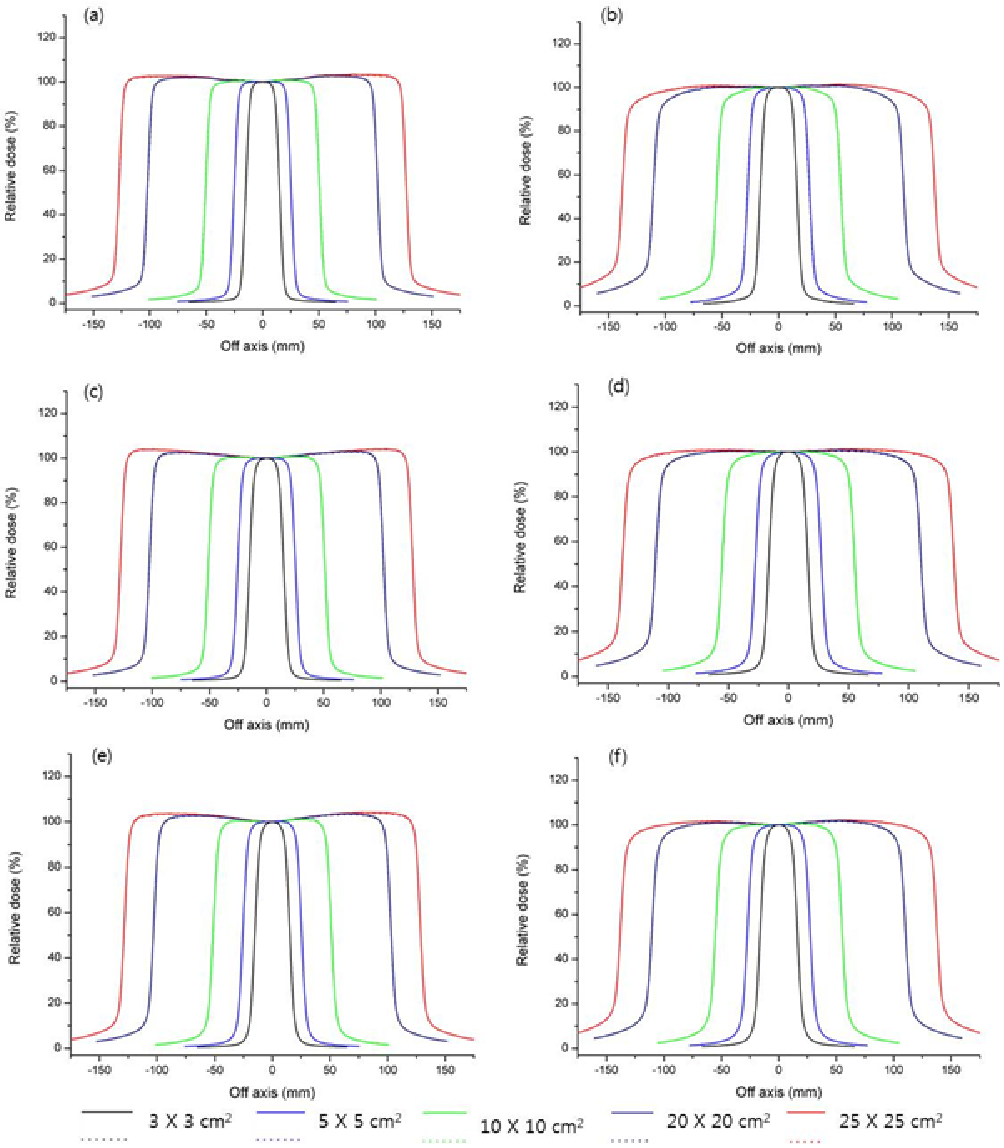

Fig. 4 Open dose profiles measured with the stealth (dot line) and CC13 (solid line) chamber. (a) d_{max} and (b) d_{100} of 6 MV, (c) d_{max} and (d) d_{100} of 8 MV, (e) d_{max} and (f) d_{100} of 10 MV.

Table 2 RMSE of dose profiles measured by CC13 chamber and Stealth chamber at d_{max} and d100.

	6 MV		8 MV		10 MV	
Field size (cm^2)	d_{max}	d_{100}	d_{max}	d_{100}	d_{max}	d_{100}
3 x 3	0.19	0.22	0.18	0.08	0.16	0.08
5 x 5	0.11	0.82	0.16	0.09	0.11	0.11
10 x 10	0.70	0.65	0.23	0.20	0.19	0.17
20 x 20	0.42	0.19	0.42	0.35	0.29	0.25
25 x 25	0.27	0.11	0.19	0.24	0.23	0.13

performed with appropriate measurement devices and thoroughly validated prior to clinical use. It takes a considerable amount of time to collect the commissioning beam data for the open beam[1]. Specially, adjustment of a reference chamber for the small filed is needed to prevent the field chamber being covered with shadow of reference chamber. In this study, PDD and profiles revealed comparable dosimetric parameters measured with the Stealth chamber and our gold standard, the CC13 chamber, as reference and field chamber, respectively.

The previous studies reported that relative difference of PDDs and profiles measured with the stealth chamber and CC13 chamber were consistent at 1%, 1 mm criteria for open beam[9,10]. These results are similar to our study. As noted earlier, results of PDDs between both chambers were observed difference smaller than 1%, but there was a relative larger difference in buildup region than the depth of d_{max} or more, especially in the measured PDDs at shallow depth. This is because the stealth chamber has an equivalent thickness of 0.5 ㎜ aluminum. The feature of the chamber has affected on beam data in buildup region close to the surface of the water phantom due to generate the spatially non-uniform attenuation.

For dose profiles measured for various fields with the stealth and CC13 chamber, good agreement of RMSE was obtained for the three energies with fields ranging from 3 × 3 to 20 × 20 cm^2. However, the relative difference for dose profile of a 25 × 25 cm^2 field was observed in the shoulder region due to the insufficient inner clearance of the stealth chamber than CC13 chamber.

As a result, when comparing the PDDs and dose profiles, the matching measurements of both chambers reveal that the agreement holds for all measurements from the three energies not only small field (3 × 3 cm^2) but for field up to 20 × 20 cm^2.

In this study, we confirmed that the use of the stealth chamber has the following advantage; since there is no need to change the reference chamber position in a small field, the speed from measurement of open fields can be improved. Therefore, it was effective and saved time during data collection for commissioning of LINAC and treatment planning system.

Ⅴ. Conclusion

This study found that PDDs and profiles measured with the stealth chamber and CC13 chamber as reference detector is small difference between both chambers. Therefore, this study suggest that the use of stealth chamber is a feasible and efficient for measuring commissioning beam data of the open fields ranging from 3 × 3 to 20 × 20 cm^2, although the relative large difference for PDD was observed in build-up region and large fields. However, for clinical use, careful recheck must be taken at large fields, especially more than 20 × 20 cm^2.

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