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EASTERN TIME [GMT-4]

Detectability of MLC Stop Position Error During Treatment by Gantry-Mounted Transmission Detector

H. Honda[1,2], M. Tominaga[3], M. Sasaki[3], Y. Uto[4], M. Oita[5], Y. Hamamoto[6], T. Mochizuki[7], T. Kido[7], Y. Ishii[1], R. Yamamoto[1], K. Omoto[1]

1. Ehime University Hospital, Ehime, Japan
2. Graduate School of Advanced Technology and Sciences, Tokushima University, Tokushima, Japan
3. Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan
4. Graduate School of Technology, Industrial and Social Science, Tokushima University, Tokushima, Japan
5. Okayama University Graduate School of Interdisciplinary Science and Engineering in Health Systems, Okayama, Japan
6. Department of Radiation Therapy, National Hospital Organization Shikoku Cancer Center, Matsuyama, Japan
7. Department of Radiology, Ehime University School of Medicine, Ehime, Japan

INTRODUCTION

IMRT and VMAT are irradiation methods that can administer a higher dose to the target and reduce the dose to normal tissue simultaneously due to the steep dose gradient. However, IMRT and VMAT present more complex irradiation methods compared to 3D-CRT [1]. Consequently, IMRT and VMAT are more likely to cause serious accidents than 3D-CRT. There has been serious radiation accidents reported in clinical radiotherapy [2]. To prevent such accidents patient-specific pre-treatment verification was deemed necessary. Furthermore, a report from the Netherlands in 2010 found that dose errors which could not be detected even after patient-specific pre-treatment verification were detected by in vivo dosimetry (IVD) using an electronic portal imaging device during treatment [3]. The importance of dose verification during treatment has been brought to attention [3]. The UK, "Towards Safer Radiotherapy", recommends that IVD monitoring protocols should be prepared for most patients at all sites, at the start of treatment [4]. This research is to investigate the possibility of detecting errors during treatment by performing basic experiments that create an error plan for the stop position of MLC using a gantry-mounted transmission detector.

AIM

The purpose of this research is to investigate the possibility of detecting errors during treatment using a gantry-mounted transmission detector.

MATERIAL AND Method

Material

A real-time monitoring system to detect errors of dose and MLC position during treatment system: the Delta^4 Discover® (D4D) system (ScandiDos AB, Uppsala, Sweden).

This system consists of Delta^4 Phantom + (D4P) (ScandiDos AB, Uppsala, Sweden) used for patient-specific pre-verification and D4D gantry-mounted transmission detector.

Medical Linear Accelerator: TrueBeam energy 10X (Varian medical systems, California, USA)

Treatment planning system: Eclipse versions 11.0 (Varian medical systems California, USA)

Method

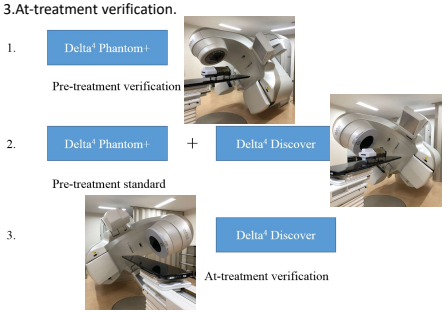
We compared the result of dose verification using D4D of a gantry-mounted transmission detector and D4P.

- Ten prostate treatment plans were evaluated.
- The simulation plan for detecting errors during treatment consists of the MLC of all control points was displaced from B side (X1 side) to A side (X2 side) by 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0mm from the original plan.
- Dose deviation (DD), distance-to-agreement (DTA), and gamma index analysis (GA) were used to validate the dose distribution.
- The evaluation criteria were DD at 3%, DTA at 2mm, and GA at 3.0% / 2.0mm, and the threshold was evaluated at 10%.
- We performed a significant difference test using Welch's t-test as an evaluation of the significant difference between the original plan (no MLC error) and the simulated plans.

DELTA^4 DISCOVER SYSTEM

Flowchart of D4P and D4D use

1.Pre-treatment verification.
2.Pre-treatment standard.
3.At-treatment verification.

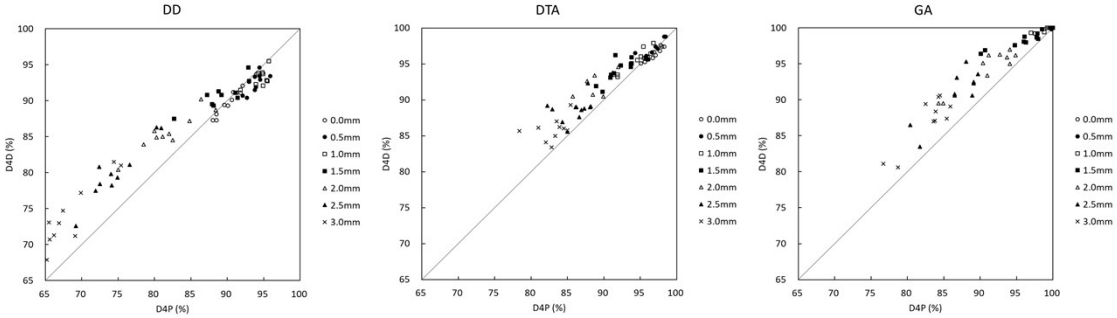


- As shown in flowchart 1, D4P was set up, and the dose distributions as prescribed by the original plan, and for six types of simulated plans, were measured.
- As shown in flowchart 2, D4D was mounted on the gantry of the linear accelerator, and the original plan was measured by D4D and D4P simultaneously to acquire data that would be used as the reference values for D4D. As a result, the dose distribution on the isocenter was obtained using D4D only, as shown in flowchart 3, and the dose could be verified during treatment.
- Using D4D, as shown in flowchart 3, we have measured the dose distribution of the original plan and the six types of error induced plans.
- The process shown in flowcharts 1 to 3 was repeated for each case and the dose distribution of D4P and D4D was measured once.

RESULTS

Evaluation of VMAT for ten prostate cancer patients

The horizontal axis shows the D4P pass-ratio, and the vertical axis shows the D4D pass-ratio.
The line connecting the values where D4P and D4D are equal is defined as the reference line.



D4P variation 1.96SD

Evaluation method	MLC error (mm) 0.0	0.5	1.0	1.5	2.0	2.5	3.0
DD (%)	90.1±2.8%	93.9±2.1%	94.5±2.2%	89.2±6.1%	81.9±7.7%	74.7±7.2%	68.6±7.2%
DTA (%)	96.9±2.1%	96.6±2.5%	94.7±3.3%	91.7±3.3%	88.9±4.2%	85.7±4.0%	83.0±4.1%
GA (%)	100.0±0.0%	100.0±0.2%	99.1±2.0%	95.6±5.8%	91.1±7.4%	86.7±6.3%	82.9±5.8%

D4D variation 1.96SD

Evaluation method	MLC error (mm) 0.0	0.5	1.0	1.5	2.0	2.5	3.0
DD (%)	89.7±3.4%	92.5±2.6%	93.2±2.3%	90.8±3.8%	85.6±5.3%	80.0±7.9%	74.2±8.8%
DTA (%)	96.4±1.7%	96.8±2.4%	95.6±2.9%	94.0±3.2%	91.8±4.0%	88.6±3.4%	85.9±3.1%
GA (%)	100.0±0.0%	100.0±0.2%	99.8±0.7%	98.2±2.0%	94.4±5.4%	90.9±6.9%	87.1±6.9%

Comparison of p-value that all MLC position error simulation plans can detect in ten plans.

Statistical tests were performed on the significance of the original design and the simulated design (MLC position error 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 mm) using Welch's t-test. Both D4P and D4D were evaluated. *Statistically significant (P<0.01), (-) incalculable because D4P and D4D are 100%.

Evaluation method	Device	MLC error (mm) 0.0	0.5	1.0	1.5	2.0	2.5	3.0
DD	D4P	1.000	<0.001*	<0.001*	0.419	<0.001*	<0.001*	<0.001*
	D4D	1.000	0.001*	<0.001*	0.194	0.001*	<0.001*	<0.001*
DTA	D4P	1.000	0.528	0.003*	<0.001*	<0.001*	<0.001*	<0.001*
	D4D	1.000	0.397	0.175	0.001*	<0.001*	<0.001*	<0.001*
GA	D4P	-	0.168	0.018	0.001*	<0.001*	<0.001*	<0.001*
	D4D	-	0.168	0.084	<0.001*	<0.001*	<0.001*	<0.001*

CONCLUSIONS

Pass-ratio

- When the MLC position error exceeds 1.5 mm, the D4D DD pass-ratio gets higher than that of D4P, and this tendency increases as the MLC position error increases.
- When the MLC position error exceeds 0.5 mm, the value of D4D becomes higher than the value of D4P, and the tendency is similar to that of DD.
- When the MLC position error exceeds 1.0 mm, the value of D4D becomes higher than the value of D4P, similar to DD and DTA.

Welch's t-test

- For D4D When DD, DTA, and GA parameters were used, the detection of MLC error was 2.0 mm for DD and 1.5 mm for DTA and GA.
- For D4P, MLC error detection was 2.0 mm for DD, 1.0 mm for DTA, and 1.5 mm for GA.
- We compared the result of dose verification using D4D of a gantry mounted transmission detector and the D4P. D4D has almost the same detection power as D4P, and can be detected with an MLC position error of 1.5 mm or more by using DTA or GA. Based on our results, the transmission detector Delta^4 Discover is suitable for In-vivo Dosimetry.

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CONTACT INFORMATION

hhonda@m.ehime-u.ac.jp