Practical Virtual Compensator Design with Dynamic Multi-Leaf Collimator(dMLC) from Iso-Dose Distribution

Ju-Young Song[a], Tae-Suk Suh[a], Hyung-Koo Lee[a], Bo-Young Choe[a],
Seung-Do Ahn[b], Eun-Kyung Choi[b], Jong-Hoon Kim[b], Sang-Wook Lee[b], Byong-Yong Yi[b]

[a]Dept. of Biomedical Engineering, College of Medicine, The Catholic University of Korea, Banpo-Dong, Seocho-Gu, Seoul 137-040, Korea, [b]Dept. of Radiation Oncology, Asan Medical Center, College of Medicine, University of Ulsan, Pungnap-Dong, Songpa-Gu, Seoul 138-736, Korea
Corresponding Author : Tae-Suk Suh, Ph.D.
e-mail: dandy@catholic.ac.kr, suhsanta@catholic.ac.kr

ABSTRACT

The practical virtual compensator, which uses a dynamic multi-leaf collimator (dMLC) and three-dimensional radiation therapy planning (3D RTP) system, was designed. And the feasibility study of the virtual compensator was done to verify that the virtual compensator acts a role as the replacement of the physical compensator. Design procedure consists of three steps. The first step is to generate the isodose distributions from the 3D RTP system (Render Plan, Elekta). Then isodose line pattern was used as the compensator pattern. Pre-determined compensating ratio was applied to generate the fluence map for the compensator design. The second step is to generate the leaf sequence file with Ma's algorithm in the respect of optimum MU-efficiency. All the procedure was done with home-made software. The last step is the QA procedure which performs the comparison of the dose distributions which are produced from the irradiation with the virtual compensator and from the calculation by 3D RTP. In this study, a phantom was fabricated for the verification of properness of the designed compensator. It is consisted of the styrofoam part which mimics irregular shaped contour or the missing tissues and the mini water phantom. Inhomogeneous dose distribution due to the styrofoam missing tissue could be calculated with the RTP system. The film dosimetry in the phantom with and without the compensator showed significant improvement of the dose distributions. The virtual compensator designed in this study was proved to be a replacement of the physical compensator in the practical point of view.

Keywords: Virtual compensator, Iso-dose distribution, dMLC(dynamic multi-leaf collimator)

1. INTRODUCTION

In the radiation therapy, the unacceptable nonuiformity of dose within the target volume can be occurred due to the surface irregularity and tissue inohomogeneity. The Compensator is one of the methods to solve this problem. The conventional compensator is usually designed according to the missing tissue deficit and fabricated using small metal blocks, lead sheets, or molded metal. In this study, an dMLC was used to investigate the probability of performing the attenuating properties of a conventional, physical compensator with dynamic beam modulation[1-3]. We developed a method for generating and delivering compensated fields using 3D RTP and dMLC, and compared dose uniformity achieved by applying the developed virtual compensator and uncompensated fields.

2. MATERIALS AND METHODS

2.1. Simulation phantom

In this study, the phantom which can simulate the missing tissue was designed as Figure 1. The area of missing tissue is mimicked by styrofoam and the accessory tools for dose measurement and film exposure are designed that can be installed to the mini water phantom.

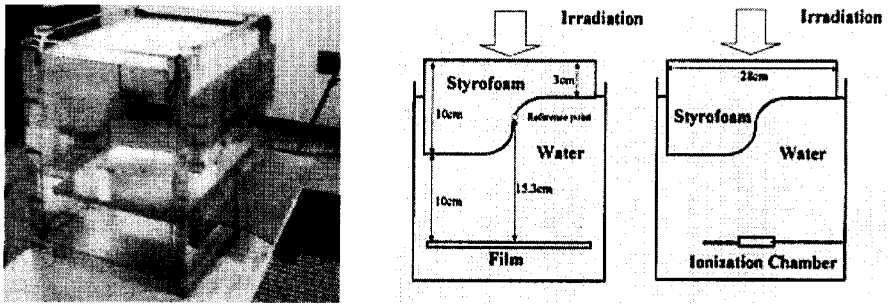

Fig. 1. Photograph of simulation phantom and diagrams for experimental cases

2.2. Calculation of beam intensity file

The phantom image was delineated using digitizer and the dose distribution was calculated by 'Render Plan 3D'(Elekta, USA). The isodose distribution map was used to calculate the beam intensity required to produce uniform dose distribution. The beam intensity map for the design of virtual compensator was derived from the isodose curve calculated in the RTP according to the following equation.

$I(b) = 1/I(a) \times Ref(I(a))$ *where,* I *: relative beam intensity value* Ref *: reference point in the BI map*

2.3. Production of MLC sequence file for virtual compensator

The MLC used in this study was Millenium(Varian, USA). The 'step-and-shoot' technique was adapted as a simplified dMLC technique and the 'MA' algorithm was used to design leaf sequence in the respect of optimum MU-efficiency. The MLC leaf sequence file was programmed with IDL5.5(Intersys, USA)

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2.4. Experiments

In this study, the 21EX(Varian, USA) LINAC was used and the photon beams (6MV, 15MV) of which the field size is 14cm x 18cm were irradiated with the SSD of 100cm. The design of virtual compensator was accomplished by the GUI tool developed in this study(Figure 2). The experiments in this study were performed according to the following procedure.

1) Produce the isodose distribution map in RTP
2) Design the virtual compensator(MLC leaf sequence file) according to the BI(Beam Intensity) map
3) Dose measurements at the two opposite position as Figure 4. with or without virtual compensator- Ionization Chamber : Farmer Chamber, 0.6 cm^3 (PTW FREIBURG, Germany) Electrometer
   : PTW UNIDOS, (PTW FREIBURG FREIBURG, Germany)
4) Exposure to the film with or without virtual compensator (Film : X-OmatV(Kodak, USA))
5) Analysis of the exposed film
   - film scanner : VXR-12 Film Digitizer (Vidal Systems Corp., USA)
   - dose profile & isodose distribution map
   : Poseidon 4.1A (KPU-Data AB & Precitron AB, Sweden)
6) Remove the styrofoam phantom : flat water phantom
7) Performing the QA procedure and review the QA results : use block option in RTP to simulate MLC function of the virtual compensator

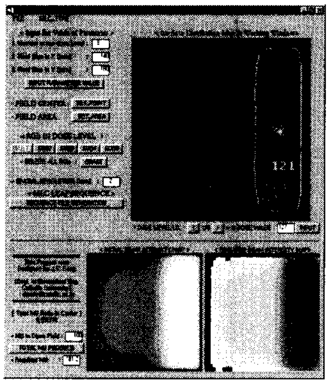


Fig. 2. GUI tool for the design of virture compensator

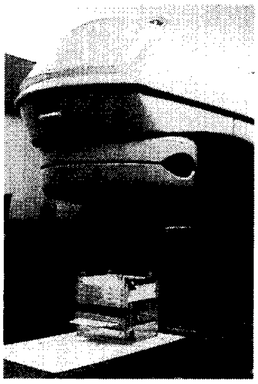
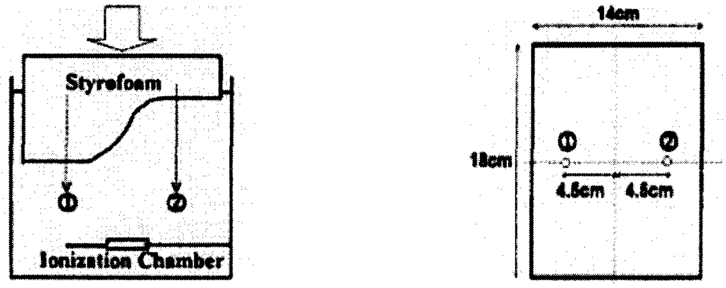


Fig. 3. LINAC and phantom setup



(a) phantom setup (b) field shape

Fig. 4. Diagrams for the dose measurements

3. RESULTS

3.1. Dose Measurements

As shown in Figure 4, the dose was measured at the two opposite position where the difference of tissue thickness is largest. Table 1. shows that the dose difference between the two points were decreased in the case that virtual compensator was applied. This result can be one of the evidences which show the virtual compensator designed in this study do the proper function to make uniform dose distribution.

unit : nC

6MV	Location (1)		Location (2)	
Compensator-OFF	11.12	11.13	8.80	8.80
Compensator-ON	10.37	10.40	9.83	9.82

15 MV	Location (1)		Location (2)	
Compensator-OFF	13.09	13.10	11.23	11.23
Compensator-ON	11.72	11.70	11.83	11.85

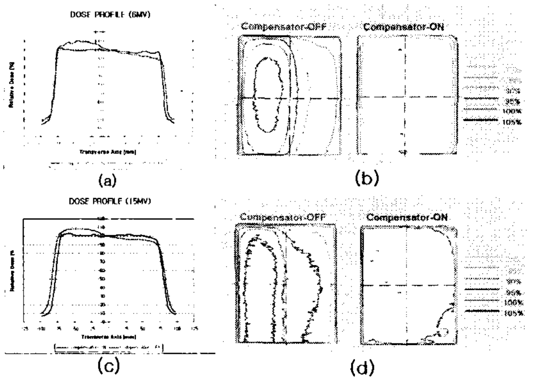
Table 1. Measured doses at the two points where the difference of tissue thickness is largest

3.2. Dose distribution of the exposed film

The dose profiles along the longitudinal field line show the higher degree of flatness when virtual compensator was applied. The higher dose area was removed and overall dose distribution became uniform when the virtual compensator was applied(Figure 5).

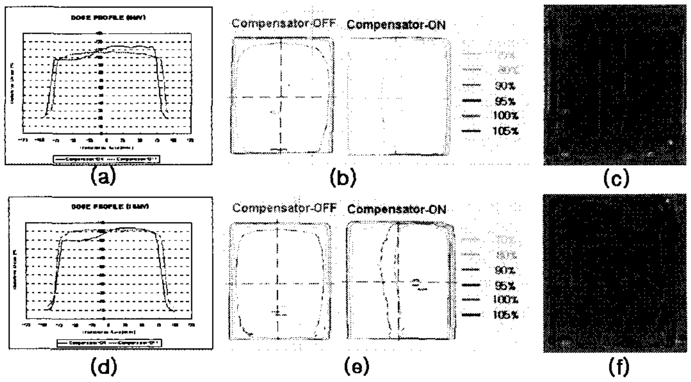
3.3. QA performance

The comparison of the dose distributions which were produced from the irradiation with the virtual compensator and from the calculation by 3D RTP was performed as a quality assurance of the designed virtual compensator. The QA was performed in the subject of flat water phantom which removed the missing tissue area and the block transmission factors were inputted to RTP to simulate virtual compensator. Although the dose distributions were not identical due to the fundamental limitation in simulating the MLC with block, the overall trend was similar as shown in Figure 6.



(a) (b) (c) (d)

Fig. 5. Dose profile and Dose distribution in the case of compensator-on and compensator-off
(a) dose profile (6 MV) (b) dose distribution (6 MV)
(c) dose profile (15 MV) (d) dose distribution (15 MV)



(a) (b) (c) (d) (e) (f)

Fig. 6. Results of QA performance
(a) dose profile in 6 MV (b) dose distribution of the film (6 MV)
(c) dose distribution produced by RTP(compensator, 6MV)
(d) dose distribution in 15MV (e) dose distribution of the film(15 MV)
(f) dose distribution produced by RTP(compensator, 15 MV)

4. DISCUSSION & CONCLUSION

In this study, the virtual compensator designed with MLC and RTP do the proper function of conventional compensator. The virtual compensator can eliminate the works to manufacture conventional physical compensator and increase the accuracy of treatment. When the virtual compensator is designed with CT data, it can correct the effects of inhomogeneity in a body as well as the topological irregularity of surface. The developed virtual compensator can be applied to any clinical environment with dMLC, since the compensator design software is independent of RTP system

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