Phantom for Moving Organ Dosimetry with Gel

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Abstract. The displacements caused by the cardiac and respiratory motions cause smearing of the dose distribution that defeats the purpose of high precision radiotherapy. A phantom that holds a gel cylinder and radiochromic film, was designed and developed to simulate the respiratory motion in the superior and inferior directions. The effect of lung movement on dose distribution was studied by exposing gel as well as a radiochromic film using the phantom. The results obtained with Gel was comparable to those obtained with the radiochromic films.

1. Introduction

Precision in delivery of radiotherapy has been successfully addressed due to the development of radiation delivery techniques such as 3D-CRT, IMRT and IGRT. However organ motions such as respiratory and cardiac motions and in bladder, prostate and bowel negate the clinical benefits of these highly conformal radiotherapy techniques. Though techniques have been developed to treat the organs that have predictable movements such as respiratory and cardiac motions, these are not widely practised as they need sophisticated equipment and skilled personnel to perform these treatments. The respiratory and cardiac motions, though predictable, cause the largest displacements in intra-thoracic tumors. The magnitude of displacement varies markedly with patient, position and size of the tumor and respiratory pattern of the patient. These organ motions during treatment results in an increase in the treated volume and the delivered dose distribution does not match the intended dose distribution. A few authors have performed dosimetry of these moving targets with ion chamber, diode arrays and gel dosimetry [1,2]. A few organ motion phantoms have been developed to study the effect of dose distribution due to moving organs [3]. The purpose of this study is to develop an organ motion phantom that could simulate the tumor motion in the lung and investigate the resultant dose distribution due to the longitudinal motion of the lung with Radiochromic Fe Gel and with GafChromatic films.

2. Material and Methods

2.1. The Thorax Phantom:

A thorax shaped phantom made of acrylic filled with water was designed and developed to study the dosimetry due to organ motion. The phantom has two cylindrical inserts that represent the lungs and
one of them is attached to a movement system that can simulate the longitudinal respiratory motion of the lung with varying frequencies and amplitude. The lung cylinder has a frame insert that can hold a GafChromic film and a cylindrical insert for Fe gel.

The thorax phantom developed is shown in Figure 1 and the inserts for the film and Gel are shown in Figure 2. The inserts are connected to a stepper motor with a free wheel arrangement that enables the longitudinal motion. The respiratory motion in the phantom could be altered to simulate the respiratory movement of the patient. The amplitude of the movement is decided by the angle of rotation of the wheel and the frequency is decided by the timer that passes the pulses for driving the stepper motor. The stepper motor is driven by a PC and an in-house software developed in Visual Basic 6.

2.2. Measurement with GafChromic films:

GafChromic films were mounted on the lung insert and placed in the thorax phantom. The films were exposed to a 4cm² field first without any respiratory movement and then with varying frequencies of the respiratory motion. The GafChromic film was calibrated and read using a flat bed transmission scanner. The films were read four hours after exposure. The dose distribution obtained with no movement of the lung insert was compared with the dose distribution obtained with various respiratory movements.

2.3 Measurement with Fe Gel:

The experiment was repeated with Fe Gel. The Gel was prepared by adding 4% Gelatin to 50 mM H₂SO₄, 0.5 mM Ferrous Ammonium Sulphate and 0.05mM Xylenol Orange. This was prepared in the acrylic cylindrical insert made for the thorax phantom. The Gel was exposed initially with no respiratory movement and then with varying frequencies and amplitudes of respiratory motions.

The exposed gels were read with optical cone beam CT scanner developed in-house. The cylindrical insert with the Fe Gel was scanned before exposure and then 30 minutes after exposure. The projection data were acquired for every degree for 194 degrees and reconstructed using the software developed for the optical cone beam CT scanner.
3. Results and Discussion:

The developed phantom has longitudinal motion and can hold film and cylinder containing the Gel. The frequency and the amplitude of longitudinal motion can be controlled with the computer. The dosimetry performed with both the film and the gel showed significant smearing of the dose distribution with the respiratory movement. No variation was observed in the dose distribution with varying frequencies for both film and the gel. Increasing the amplitude of the movement resulted in further smearing of the dose distribution and also the volume receiving the prescribed dose reduced significantly.

4. Conclusion:

A phantom has been successfully developed to study the effect of dose due organ motion with Gel and film. The dose distributions obtained with Fe Gel was compared with those obtained with the Gafchromic film and found to match reasonably well. This study shows that Gel dosimetry could be used to study the 3D dosimetry of moving organs.

References

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