3 - 74 A Motion Platform System with Independently Programmable 3D Target Motion for Dosimetric Measurements in Carbon Ion Radiotherapy

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Organ motion in the thorax and abdomen during breathing is problematic in radiotherapy (RT). For lung tumors, it has been reported that the amplitude of respiratory motion can be more than 2 cm. Such motion presents significant limitations during the entire RT process. Interplay between target motion and scanned ion beam can cause clinically intolerable under- and over-dosages within the target volume. Several motion mitigation techniques such as gating, beam tracking and rescanning are currently being investigated to overcome this restriction. To enable detailed experimental studies of potential mitigation techniques, a complex motion platform system was developed as shown in Fig. 1. The platform is capable of simulating sin and $\sin^{2n}$ motion with varying movement frequency and amplitude. The motion platform's 3D motion can be programmed independently, allowing motion in almost any direction between the superior-inferior (SI), anterior-posterior (AP) and left-right (LR) directions. In this motion platform system, two-dimensional motion platform was used to simulate the lateral movement orthogonal to the beam direction, and a double wedge system was designed to simulate motion-induced radiological depth changes along the beam direction. Radiographic films or phantoms can be placed on the motion platform for dosimetric measurement.

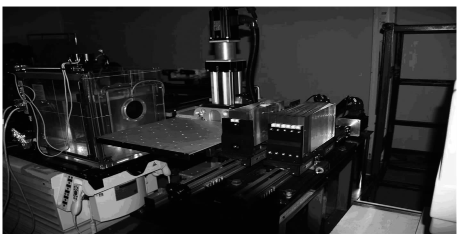

Fig. 1 The motion platform system.

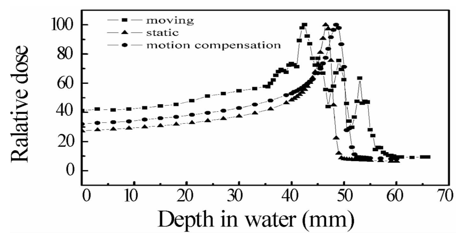

Fig. 2 Performance of the (LMC).

Preliminary dosimetric tests have been carried out based on this motion platform system. To perform motion compensation in longitudinal direction, a multi-wedge system was developed. The system consists of five pairs of opposing wedge absorbers that are mounted on a liner motor, which compensates the beam range changes induced by double wedge system by moving the wedges apart (together) with the linear motor to adapt the beam range at isocenter fast and continuously. The precision of the longitudinal motion compensation(LMC) is presented in Fig. 2. During the irradiation, the double wedge system was moved with an amplitude of 2 cm and a period of 4 s. The energy modulation system successfully restored a single, effective particle energy at isocenter. Fluctuation around the reference depth dose distribution is mainly attributed to calibration uncertainties of the double and multi-wedge systems.

Tests were also carried out for lateral motion treatment with scanned carbon ions to evaluate the dosimetric impact caused by motion in spot-scanning beam delivery and the feasibility of rescanning beam delivery in experiment. A uniform circular field (60 mm in diameter) was delivered using a 350 MeV/u carbon ion beam with an 5 mm spot spacing. These spot beams were delivered to a radiographic film placed on the motion platform. The platform motion was moved in a manner of sin motion with 4 s period and varying amplitudes of 5, 10 and 20 mm, respectively. The dose distributions for each motion condition and the effect of 2, 5 and 10 times repainting were compared with the reference distributions without motion. For the comparison, the dose homogeneity was calculated for each condition inside of target volume.

For motion of 5 mm amplitude, the dose homogeneity was 87.5% for single painting, and 90.11%, 90.51%, 91.84% for 2, 5 and 10 times rescanning. However, the dose homogeneity was 83.62% and 80.87% for 10 mm and 20 mm motions in the case of single painting. These worst-case results were improved to 89.81%, 91.77% and 85.26%, 89.25% by 5 and 10 times rescanning for 10 mm and 20 mm motion, respectively. The delivered dose pattern can tolerate motion less than 5 mm. For motion amplitude more than 10 mm, 10 times rescanning beam delivery seems to achieve the same dose distribution as that in the case of motion amplitude less than 5 mm.

References

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3 - 75 4D Imaging with a Siemens CT using a Respiration Monitoring System

He Pengbo and Li Qiang

Modern radiotherapy aims to concentrate the dose to a tumor and to spare the normal tissue around as much as possible. However, organ motion poses a severe obstacle and leads to increased safety margins around the clinical target volume, hence increasing the volume of the irradiated normal tissue. A well-known example is the treatment of lung tumors, which may show respiratory motion of up to several centimeters. Adaptive radiotherapy techniques attempt to compensate such organ motion e. g. by gating on a predefined breathing phase or by tracking the tumor with the therapeutic beam. To simulate the delivered dose distribution in treatment planning, both techniques require time-resolved computed tomography (CT) images, known as four dimensional CT (4D-CT). 4D-CTs are generated by scanning the patient while acquiring a surrogate signal of the tumor motion. The acquired projections are sorted according to this signal. Several 3D-CT datesets are reconstructed depending on local clinical protocols.

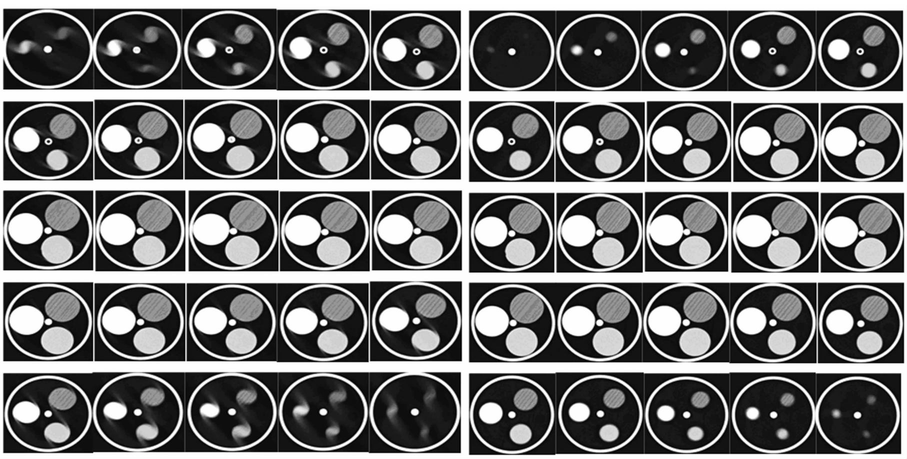

Fig. 1 Axial slices of the moving phantom. Window level 1200 centred at −600. 1.5 mm slice, 1.5 mm reconstruction increment, 50% exhalation (left) and 0% exhalation (right).

Using a moving phantom, a belt with an integrated pressure sensor (AZ-733V, Anzai) was simultaneously operated to provide a signal related to the motion of the phantom, where the signal got stronger with inhalation and weaker with exhalation. The wave deck received the signal from the sensor port and converted it to a digital signal to be sent to the host computer of the CT system. The signal was displayed real-time in the CT console, and the breathing information was stored at the reconstruction PC together with the raw data of the CT-acquisition. Image reconstruction was done with a local amplitude-based sorting algorithm, for which the breathing signals were divided into inspiration and exhalation parts. The acquired projections in this work were reconstructed with five different amplitude percentages such as 0, 20, 50, 80 and 100% of the exhalation phase.

Artifacts were still observed in gated scans with 20, 50 and 80% of the exhalation phase while almost no artifacts appeared with 0 and 100% exhalation. Fig. 1 shows 50% exhalation reconstruction of the phantom moving orthogonally to the scan plane (amplitude 2 cm, period 4 s), where the images had a window level of 1200 centred at -600 and the reconstruction thickness was 1.5 mm. The poles of the spheres