3D dosimetry with gels and optical tomography of dynamic MLC tracking based on an electromagnetic transponder system

P S Skyt[1,2,3,4], P R Poulsen[2], T S Kinnari[3], I Wahlstedt[3], T Ravkilde[2], P J Keall[5], J B B Petersen[1], P Balling[3] and L P Muren[1,2,4]

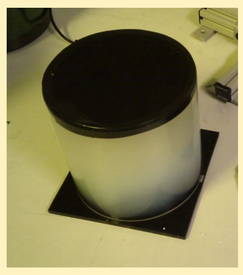
[1] Dept of Medical Physics, Aarhus University Hospital, Denmark
[2] Dept of Oncology, Aarhus University Hospital, Denmark
[3] Dept of Physics and Astronomy, Aarhus University, Denmark
[4] Dept of Clinical Medicine, Aarhus University, Denmark
[5] University of Sydney, Australia

Introduction

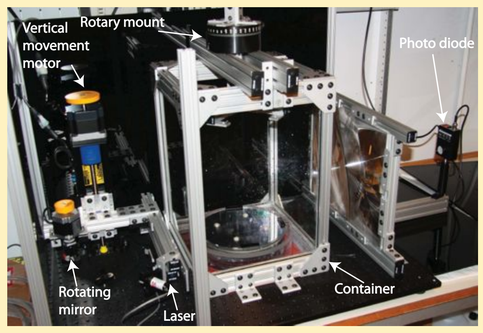
Complex treatment methods such as rotational intensity modulated radiotherapy (rIMRT) offer highly conformal dose delivery but are at risk of being compromised due to target motion. Dynamic MLC tracking has been developed to compensate for target motion online. Due to the complex 3D patterns of tumour motion, tracking would benefit from a full 3D dosimetric verification.

In this study we have therefore investigated the use of 3D dosimetry - with gels and optical computed tomography (optical CT) - for measuring the effect of tracking on 3D dose distributions with the use of a clinically measured prostate trajectory.

3D dosimetry

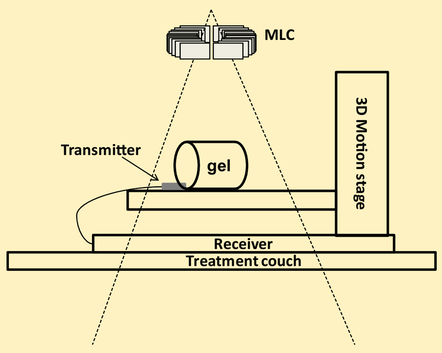


The gel dosimeter:
Left: An example of the normoxic polyacrylamide dosimeters used in the experiments.
Right: A picture trough the side of a gel after irradiation. The dose distribution can clearly be seen as a white area due to scattering from radiation induced polymer particles.

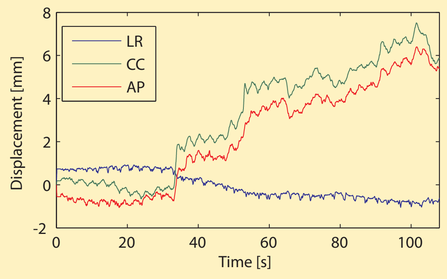


Optical CT:
Dose read-out was performed with the use of an optical-computed-tomography scanner (MGS Research, CT, USA). The scanner measures the intensity of a laser scanned across the dosimeter. The dose delivered to the gel is then proportional to the measured optical density.

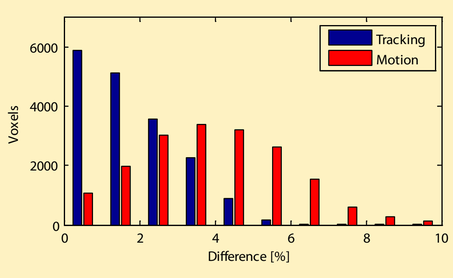
Experimental setup and results



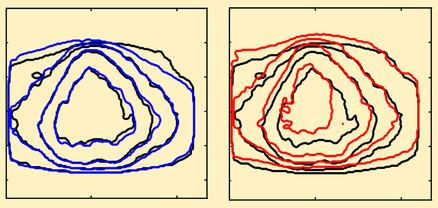
Experimental setup:
The 3D gel dosimeters were placed on a three axis motion stage together with an electromagnetic transponder (RayPilot, MicroPos AB, Gothenburg Sweden). The 3D transponder position was detected at 30 Hz in real time by antennas placed in a board below the motion stage support and used for the dynamic MLC tracking.



Irradiation and dosimeter motion:
The dosimeters were irradiated with a rotational IMRT prostate plan while the motion stage performed a continuous drift motion (see figure above). A total of three dosimeters were irradiated. The dosimeters were irradiated under motion, with and without tracking, as well as stationary (without tracking or movement), the latter to obtain a reference measurement.

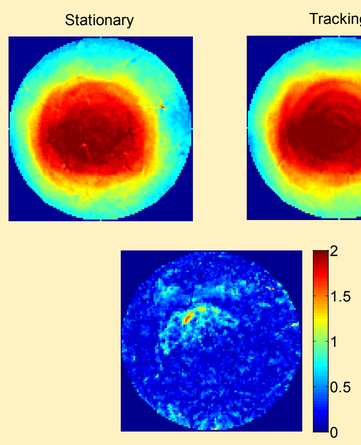


1D voxel-to-voxel comparison:
After dose read-out the dose distributions of the three dosimeters were compared. Here with a 95 % region of interest histogram. It shows the difference in dose for corresponding voxels in the tracking and in the motion dosimeters compared to the stationary dosimeter. Larger differences is clearly observed during motion of the dosimeter when tracking is not induced.

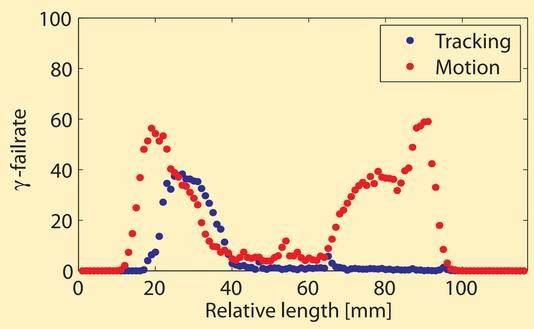


2D contour comparison:
Contours of the dose distributions. Left: Motion with tracking (blue) compared with the stationary dosimeter. Right: Motion without tracking (red) compared with the stationary dosimeter. A clear mismatch is observed due to motion when tracking is not enabled.

3D gamma analysis



Dose distribution and 3D gamma analysis:
Top: A single transversal slice of the measured dose distribution for the stationary gel and the gel induced with motion and tracking.
Bottom: The corresponding gammamap slice from a 3%/3mm 3D gamma analysis.



3D gamma comparison:
Each point in the graph above illustrates the mean gamma-failrate for a specific transversal slice through the dosimeter. High failrates is observed in the dosimeter with induced motion without tracking compared to motion with tracking. The total failrate decreased from 23 % to 8 % due to tracking.

Conclusion

In this study the use of 3D dosimetry with optical methods has been demonstrated. The analysis illustrates the large amount of data obtainable from such dosimeters. In addition the results show the larger accuracy of the dose delivery and thereby the benefit that can be obtained by target tracking.

Optical 3D dosimetry is a valuable tool to quantify the impact of motion and motion compensation on the delivered dose distribution to a moving target. Improved knowledge about the dose distribution is obtained due to (i) the three-dimensional nature of the measurements and (ii) the high resolution compared to competing techniques.

AARHUS UNIVERSITET

Aarhus University Hospital

CIRRO The Lundbeck Foundation Center for Interventional Research in Radiation Oncology

E-mail adress:
skyt@phys.au.dk