Time-resolved dose reconstruction of VMAT delivery to moving targets with and without dynamic MLC tracking

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1 Background

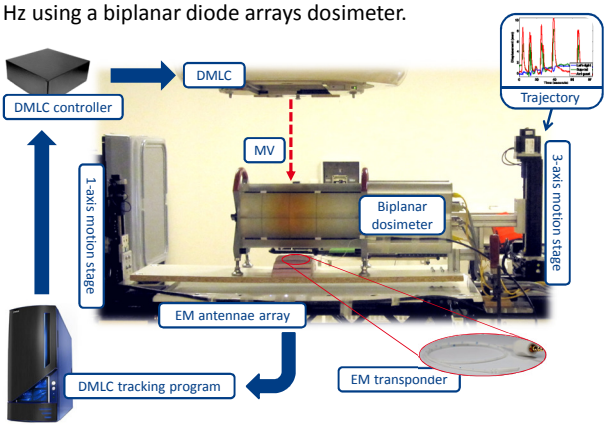
It is important to be aware of dosimetric errors occurring within a radiotherapy fraction. Dynamic multi-leaf collimator (DMLC) tracking can mitigate the dosimetric impact of target motion during volumetric modulated arc therapy (VMAT). However, residual dosimetric errors still exist.

2 Aim

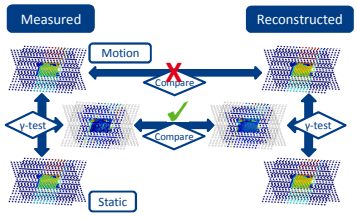
The purpose of this study was to create a simple model for time-resolved reconstruction of the delivered dose distribution and to validate its ability to predict the time-resolved dosimetric errors measured during VMAT of moving targets with and without DMLC tracking.

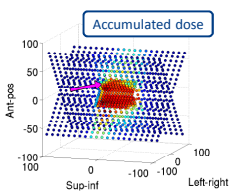
3 Materials and methods

Tracking experiments were performed on a linear accelerator connected to prototype DMLC tracking software. A three-axis motion stage reproduced eight representative clinical tumor trajectories; four lung and four prostate. For each trajectory, two VMAT treatment plans (low and high modulation) were delivered with and without DMLC tracking. During tracking the DMLC leaves were continuously refitted to the 3D target position measured by an electromagnetic (EM) transponder at 30 Hz. Dose distributions were measured continuously at 72 Hz using a biplanar diode arrays dosimeter.



Offline, the measured doses were compared to a reference dose measured without target motion by use of time-resolved γ-tests (3%/3mm), excluding detectors receiving less than 5% of d_{max}. For all experiments, the time-resolved dose delivered to each detector in the dosimeter was calculated by a simple model that included the target position, the DMLC aperture convolved with a 2D dose kernel, the dose rate, and a percentage depth dose. Like for the measurements, the time-resolved γ-test was also performed for the reconstructed doses by comparison with the reconstructed dose to a static dosimeter. Finally, the reconstructed and the measured γ-test failure rates were compared for each experiment.





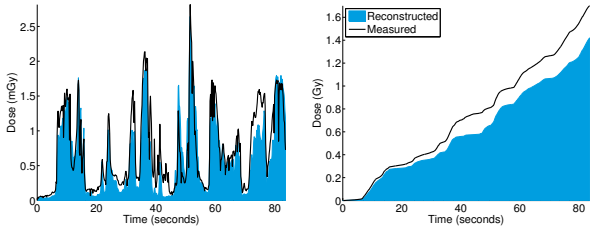
5 Conclusions

A simple time-resolved dose delivery reconstruction model was created. Its ability to predict dose delivery errors was validated experimentally for VMAT treatments with and without DMLC tracking. The time-resolved reconstruction was in very good agreement with measurements. With an online implementation, it may be used for treatment intervention in case of erroneous dose evolvement in both tracking and non-tracking treatments.

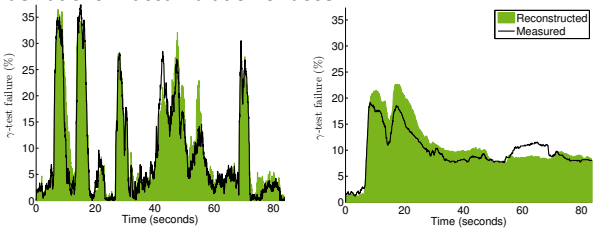
4 Results

Transient ◆ Cumulative

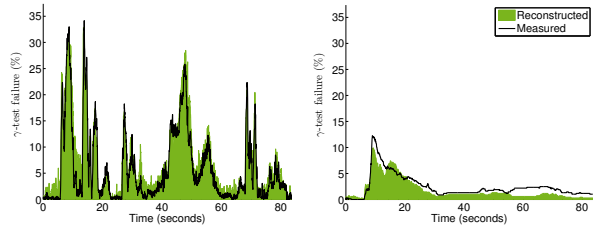
Dose in a single detector. The sample detector is placed in a high dose gradient region (marked by a pink arrow in section 3 bottom). This exemplifies a ”worst case” dose reconstruction.



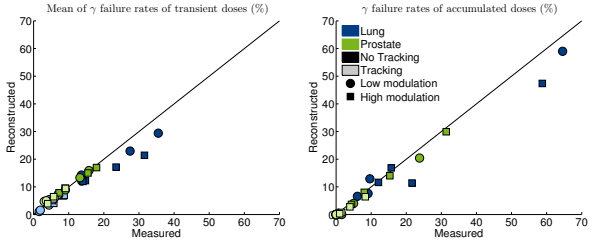
γ-test failure rates *without* tracking. γ-test failure rates are closely reconstructed for transient dose. For cumulative dose, γ-test failure rates are also in good agreement, despite small deviations in accumulation of dose.



γ-test failure rates *with* tracking. Tracking tends to remove the systematic component of erroneous delivery allowing the errors to cancel out.



Overview of results. Reconstructed vs measured γ-test failure rates of all experiments. Excellent agreement is seen. There is a slight tendency to underestimate γ-test failure rates for very erroneous deliveries (γ-test failure rate above 20%).



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