Time-resolved evolvement of target dose distribution during IMAT with and without dynamic MLC tracking

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1 Background

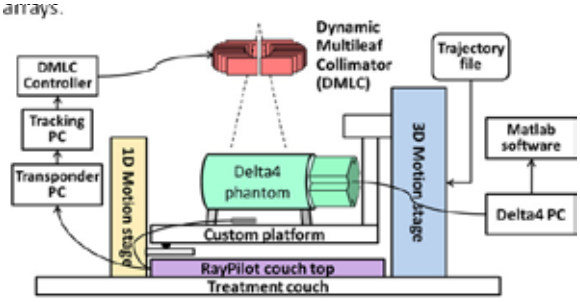
Although dynamic multi-leaf collimator (DMLC) tracking has been shown to substantially mitigate the impact of target motion on the accumulated dose during intensity modulated arc therapy (IMAT), the questions of when and why dose quality is compromised during dose delivery remains unanswered.

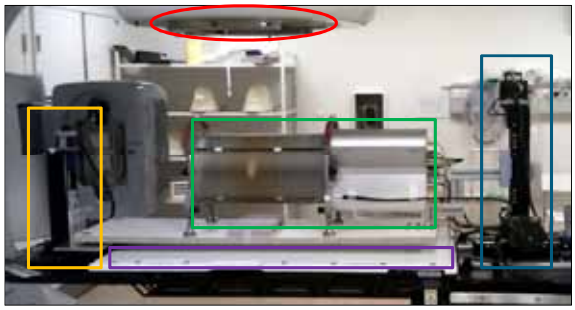
2 Aim

The aim of this study was to investigate the ability of DMLC tracking to maintain the dose distribution throughout dose delivery using time-resolved dose distribution measurements.

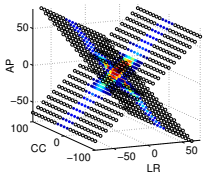
3 Materials and methods

A three-axis motion phantom, carrying a Delta⁴ phantom with two orthogonal detector arrays on a custom built platform, reproduced four representative lung tumor trajectories. For each trajectory, the same highly modulated IMAT lung plan was delivered with and without DMLC tracking on a linear accelerator. The real-time 3D target position signal for tracking was provided by a RayPilot electromagnetic transponder during treatment. The DMLC leaves were continuously refitted to the measured 3D position. Motion predicton of 140 ms was used to account for the tracking latency. The delivered dose distribution was measured at a rate of 72 Hz with the detector arrays.





Off-line, the measured dose distributions were down-sampled to 50 Hz to reduce noise and compared with a static reference dose distribution using a time-resolved 3%/3mm γ-test. The γ-evaluation only included detectors with doses above 5 % of the maximum dose in the accumulated reference dose distribution (436 detectors).



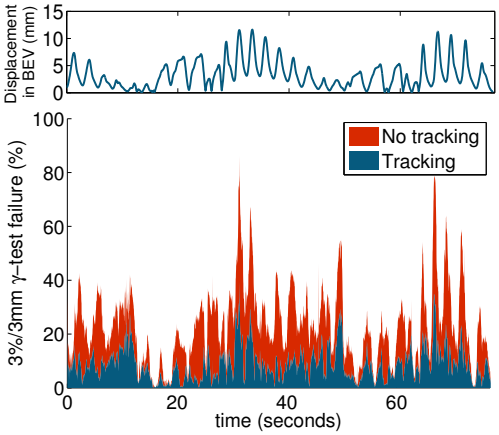
5 Conclusions

The tracking substantially mitigated motion induced errors in the dose delivery. The time-resolved measurements allow pinpointing of transient errors in dose delivery as well as monitoring of erroneous dose evolvement in key target positions.

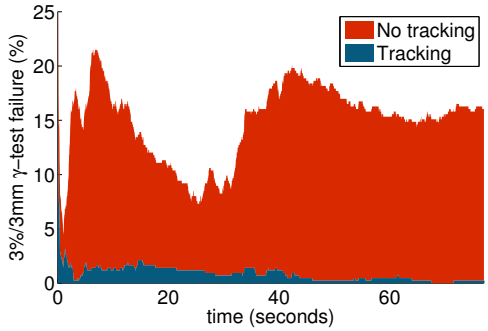
4 Results

The static reference dose distribution was measured four times with 100 % reproducibility (3%/3mm criteria).

γ-test failure rates of transient dose. The γ-test failure rates reflect the motion patterns in beam's-eye-view (BEV). Large transient dose deviations were observed during delivery both with and without tracking.



γ-test failure rates of cumulative dose. Tracking tended to remove the systematic component of erroneous delivery allowing the errors to cancel out.



Overview of results.

	3%/3mm γ-test failure rate (%)			
	Without tracking		With tracking	
Trajectory	Mean of transient dose errors	Error in total dose	Mean of transient dose errors	Error in total dose
Typical	30.3	59.9	4.4	0
High frequency breathing	23.1	18.4	4.2	0
Predominantly Left-right	14.3	16.7	7.8	0
Baseline shifted	14.4	15.8	8.7	0.2

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The authors acknowledge help from Varian Medical Systems, Micropos Medical and Scandidos.