ABSTRACT SUBMISSION FORM

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PRESENTATION TITLE
Evaluation of MR-guided motion management on a prototype inline MRI-Linac

AUTHOR(S)
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ABSTRACT

Purpose:
The development of MRI-Linac systems presents the opportunity of using MR-guidance for intrafraction motion management of increasing sophistication from gating to real-time tracking. This work describes investigations using a respiratory simulation phantom to evaluate the accuracy and efficacy of a prototype 1.0 Tesla inline MRI-Linac for motion monitoring and treatment control.

Materials & Methods:
All imaging studies were performed using either a large transceiver or smaller receive-only RF coil. A respiratory simulation phantom (QUASAR, Modus QA) was used to provide controlled movement and enabled experiments to be performed with the radiation beam. The phantom consists of a moving cylinder containing different target inserts: a standard 3 cm diameter sphere and an in-house 3D printed irregular shape approximately 2 cm in length, filled with gadolinium doped water. The following tests were performed:

(i) The efficacy of a modified real-time sequence (TrueFISP) was assessed for the tracking of the irregular target moving with various sinusoidal waveforms (10-15 mm amplitude, 10-30 breaths per minute).
(ii) To provide an end-to-end test of system integration a simulated patient waveform was used to acquire the target volume during a 20 s breath hold. This dataset was sent to the TPS and used to provide a treatment aperture of PTV for subsequent tracking.
(iii) An assessment of the system latency was made using an ionisation chamber attached to the spherical insert. The charge was recorded every 187 ms and changes used as a
surrogate for position. The phantom was driven to 5 mm and 10 mm displacements and latency was determined taking into account the motor encoder signal and chamber response.

(iv) Gafchromic film was used to compare the effect of tracking on the intended delivery of a 3 x 3 cm radiation field to the moving target at different speeds and 15 mm amplitude.

Results:
Real-time image quality provided sufficient SNR and contrast to enable target motion to be replicated with a high degree of accuracy (range 0-0.4 mm and 0.04-0.36 s) for each sinusoidal waveform. It was also possible to obtain an accurate volume reconstruction (<8 %) during the simulated breath hold and use this dataset in the TPS to contour and subsequently track a PTV in real-time. System latency was estimated to be 490 ms and 663 ms for the 5 & 10 mm movements respectively. Comparisons of the film profiles showed an upper limit in tracking efficacy (Figure 2).

Figure 1: (left) photo of standard and in-house inserts. (right) plot of phantom and image position during patient simulated waveform experiment. (inset) 3D volume acquired during the breath hold period.

Figure 2: (below left) chamber response to target displacement over time as a measure of latency. (below right) Comparison of radiation field profiles for moving targets at different speeds with and without tracking.

Conclusions:
The phantom has been used in benchmarking several aspects of system integration required for motion control and developing a QA procedure. Sub second system latency will be further improved, chiefly by means of using parallel imaging to augment the gradient specifications.