Dosimetry impact of Cine Magnetic Resonance Image Gating in Breath Hold Pancreatic Cancer Radiotherapy

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INTRODUCTION

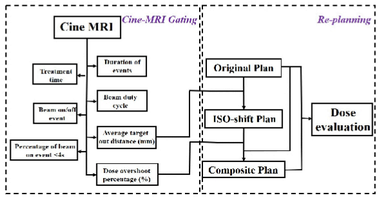
Magnetic resonance guided radiotherapy (MRgRT) has two distinct advantages of better soft tissue contrast for image guidance and real-time imaging for motion management. However, MRgRT is still in an early phase and should be rigorously evaluated. For example, cine MRI enables real-time monitoring of tumor motion. But, cine MRI gating also causes beam on/off latency which could impact the dose delivered to the tumor and critical structures.

AIM

This study is to investigate treatment efficiency in real-time MRI based motion management and to estimate its potential dose impact, specifically, in cine-MRI gated breath-hold pancreatic cancer treatment.

METHOD

Workflow



① 17 pancreatic cancer patients who received MRI guided stereotactic radiotherapy were included.

②Radiation delivery parameters, including treatment time, beam duty cycle, number of beam-on events, target-out distance (L) and beam overshoot ratio (R) were calculated from the cine-MRI data.

③We re-planned the 17 patients' radiotherapy plans. The isocenter was shifted by L to create an iso-shift plan. Then, the iso-shift plan was added to the original plan with a weight R to create a composite plan. PTV coverage and dose to nearby critical structures were compared between the composite and original plan.

RESULTS

1.1 Cine-MRI gated beam-on events

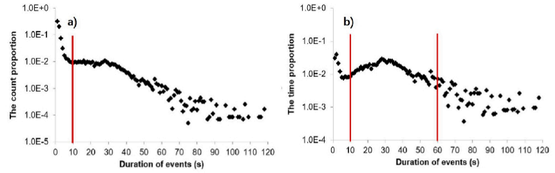


Figure 1. The count proportion and the time proportion of beam on events. The count proportion is the count distribution of beam-on events with specified durations; The time proportion is the time distribution of beam-on events with specified durations. The data was summarized from all 17 patients.

Table 1. Statistics of beam on events.

Duration	Count %	Time %
≤ 2 s	52.5%	7.1%
≤ 10 s	70.1%	15.3%
10-60 s	28.6%	75.2%
>60 s	1.3%	9.5%

➢ According to the Figure 1 and the Table 1, one beam-on event could lasts from 0 to 120 seconds. 52.5% of events breath for less than 2s, 70.1% of events breath for no more than 10s, 28.6% of events breath for 10-60s.

1.2 Treatment Delivery Pattern Analysis

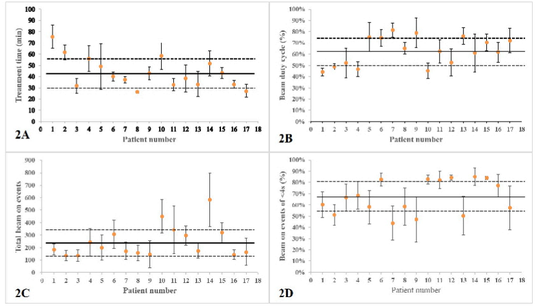


Figure 2. The statistics of treatment parameters per fraction derived based on cine MRI from 17 patients who received cine-MRI gated breath hold pancreas cancer radiotherapy. 2A: treatment time; 2B: beam duty cycle; 2C: total beam-on events; 2D: beam-on events of <4s duration. A beam on was counted when the target-out percentage was ≤5%, and beam off when the target-out percentage >5%.

➢ The mean treatment time, beam duty cycle, total beam-on events, and percentage of beam-on events <4s are 43.4±13.1min, 62.9±12.3%, 244.6±118.1, and 67.0±14.3%, respectively, per fraction.

1.3 Beam-off gating latency

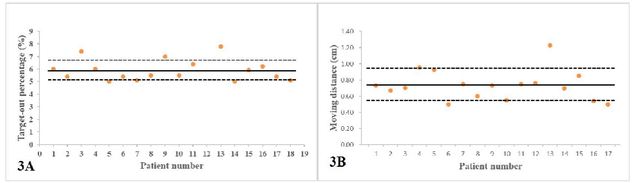


Figure 3. The results of target out per patient derived based on cine MRI from 17 patients who received cine-MRI gated breath hold pancreas cancer radiotherapy. 3A: average target-out percentage (%), 3B: average target-out distance (cm).

I. The average target-out percentage and the average target-out distance are 5.9±0.8%, 0.7±0.2cm, respectively, showed in Figure 3A and 3B. The beam-off latency was caused by image acquisition delay and occurred in every beam-on event, resulting in 6.6±3.1% beam overshoot.

II. This considerable dose overshoot was mainly caused by the surprisingly large number of short beam-on events, i.e., the percentage of beam-on events <4s is 67.0%.

2. Dose Evaluation

Table 2. Statistical results of plan comparison

	Type	Original Plan	Composite Plan	Relative Deviation	T test (p value)
PTV	V33 (%)	97.59±1.30	93.68±1.81	-4.00%	<0.01
Duodenum	Max (cGy)	3118±89	3112±99	-0.19%	0.70
	V12.5(cc)	8.97±0.71	9.51±1.00	6.01%	<0.01
	V18(cc)	3.10±0.70	3.32±0.78	7.12%	<0.01
Stomach	Max (cGy)	2642±637	2613±630	-1.11%	<0.01
	V18(cc)	4.66±3.35	4.66±3.53	-0.05%	0.98
Liver	V21(cc)	1549±487	1550±487	0.03%	0.31

I. The comparison of the original and the composite plans showed significant differences for PTV V33, Duodenum V12.5, Duodenum V18 and Stomach D_{max} ($p<0.01$ for all). The planning prescription was 33 Gy.

II. The relative deviations for PTV V33, Duodenum V12.5 and Duodenum V18 are -4.00%, 6.01% and 7.12%, respectively. For other OARs, the deviations are within 3%.

CONCLUSIONS

The dose overshoot caused by imaging gating latency significantly decreased the dose delivered to PTV, and increased the dose to immediate critical structures. It should be mitigated by implementing patient-initiated beam-on control to reduce unnecessary beam-on events and/or using faster MRI acquisition to reduce the gating latency.

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None

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