Impact of breathing pattern variations on respiration-gated treatment of gastrointestinal cancer

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INTRODUCTION

For hypofractionated ablative radiotherapy (in 15–25 fractions), proper organ motion management is crucial to avoid severe complications for three reasons: First, the pancreas is in proximity to several critical structures such as duodenum, stomach, kidneys, and spinal cord[1]. Second, the pancreas undergoes significant respiration-induced motion[2], which may lead to underdosage in parts of the tumor and overdosage to the organs at risk. Third, the target doses significantly exceed the tolerance of the surrounding normal tissues. Respiratory-gating is one strategy to manage respiration-induced tumor and organ motions[3–5].

AIM

To quantify the impact of breathing pattern variations on the implementation of respiration-gated treatment for gastrointestinal cancer.

METHODS

An institutional review board data exemption was approved before the study. Breathing patterns based on external surrogates were collected during four-dimensional computed tomographic simulation scans and respiration-gated treatment sessions from twelve patients with pancreatic cancer and one patient with bile duct carcinoma. Nine patients were treated in 25 fractions and four in 15 fractions. The Varian Real-time Position Management (RPM) system was used to monitor the breathing, represented by the displacement of an external surrogate, namely a plastic block with reflective markers placed on the patient's abdomen. The respiration-gated treatment was centered at end-expiration with ∼ 40% duty cycle (DC). Amplitude-based gating was used for all patients, with the threshold determined from simulation and adjusted during treatment when necessary. The actual DC and gated motion (GM) were calculated from the motion management waveform files recorded at the treatment console.

In an attempt to eliminate the need to adjust the threshold throughout the course of treatment, the DC and GM was retrospectively evaluated with two fixed-threshold protocols:

- Protocol A: Fixed threshold determined at simulation;
- Protocol B: Fixed threshold determined from the first treatment session.

Also evaluated was the GM from phase-based gating with exact DC of 40%.

RESULTS

In average 3 hr of motion management waveform data was recorded and analyzed for each patient throughout the whole course of treatment (range 1–5 hr). The actual DC and GM achieved were 50% and 4.6 mm, respectively. The DCs for seven patients (54%) were within 30–50%.

Amplitude-based gating was shown to be more robust than phase-based gating in limiting the GM while allowing a practical duty cycle (∼ 40%) (Figure 1). Phase-based gating resulted in 9 mm average GM (Figure 2).

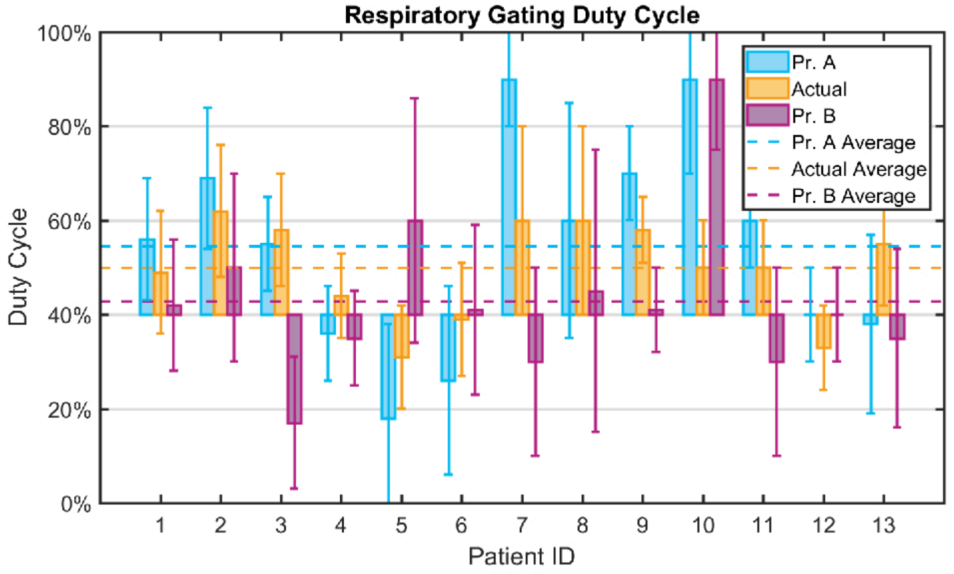

Figure 1: *Duty cycle achieved by two protocols compared with the actual record. Protocol A dictated amplitude-gating threshold from simulation. Protocol B dictated threshold from the first treatment session. It was concluded that Protocol A was inferior in this evaluation. Significant baseline variation was observed from Patient 3 which was not effectively corrected by the software. The motion of Patient 5 dropped linearly over days. The motion of Patient 10 dropped dramatically on Day 3 and stayed low afterwards. Protocol B may not be optimal for those three patients.*

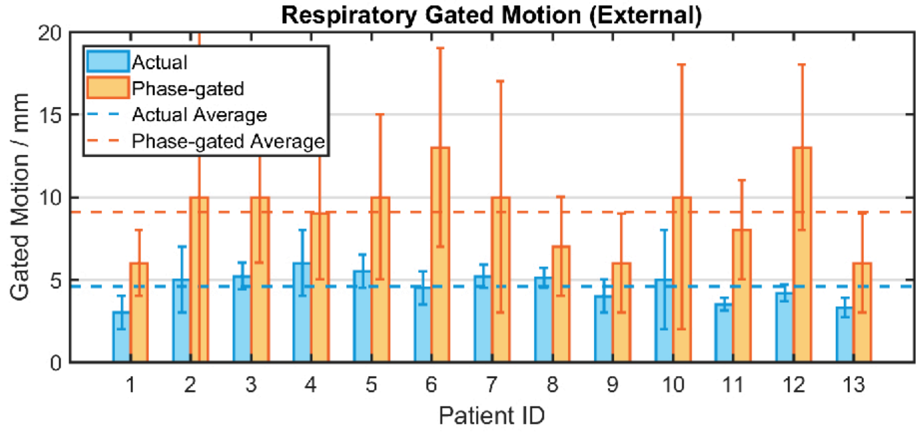

Figure 2: *Comparison of phase-gated motion and amplitude-gated motion (actual record). Amplitude-based gating was more robust than phase-based gating in limiting the gated motion.*

For amplitude-based gating, the threshold determined at simulation (Protocol A) was sub-optimal due to the breathing pattern variation between simulation and treatment (Figure 1). The simulation-determined threshold, if unadjusted, would result in DCs beyond 30–50% for ten patients (77%). Threshold determined from the first treatment session (Protocol B) was shown be superior than that from simulation (Figures 1 and 3). With the threshold determined at the first treatment session and fixed thereafter, the average DC was 40% and within 30–50% for ten patients (77%); the average GM was 4.4 mm. For three out of thirteen patients (23%), however, Protocol B may not be optimal and adjustment of the threshold during the treatment course may be necessary (Figure 1).

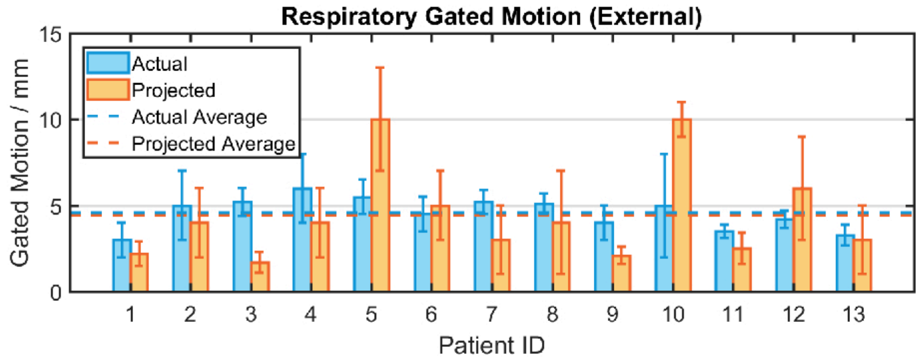

Figure 3: *Comparison of gated motion (GM) projected from the application of Protocol B (Figure 1) and the actual record. Protocol B dictated threshold from the first treatment session. Patients 3, 5, and 10 were not good candidates for Protocol B and the GM could be improved by adjusting the threshold during the treatment course.*

CONCLUSIONS

In the presence of breathing pattern variations between simulation and treatment and between different treatment days, the RPM software was more robust with amplitude-base gating than with phase-based gating. The amplitude threshold was better determined during the first treatment session than from simulation.

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