Fluoroscopic Demonstration of Thoracic Tumor Immobilization with High Frequency Percussive Ventilation

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Introduction

High frequency percussive ventilation (HFPV) is a novel immobilization technique that utilizes high frequency low tidal volume ventilation to produce endotracheal percussion. The device is an adaptation of a pneumatic high frequency ventilator in which high flow jets of gas are delivered to the airways by a flow interrupter called a Phasitron. This device allows for bursts of gas at frequencies of 100 to 400 bursts per minute within a tightly controlled ratio of gas delivery and passive exhalation. In a previous departmental study of chest wall motion immobilization, it was found that volunteers were able to tolerate HFPV for varying lengths of time – from a few to tens of minutes. A sample trace of thoracic wall motion is shown in Fig 1. The time between onset of HFPV and stable chest wall motion ranged between 3 to 6 seconds. By investigating a novel process to immobilize the chest wall, and thus thoracic tumors, it can allow for more localized radiation delivery and reduction of healthy tissue irradiation.

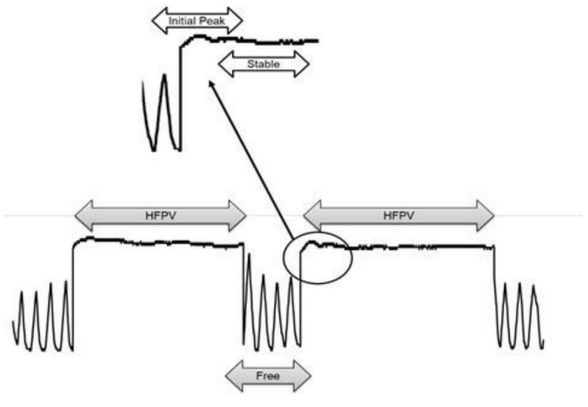

Figure 1: Sample trace of the thoracic wall motion. HFPV indicates the chest wall motion during HFPV and Free indicates the chest wall motion during free breathing as well as the initial peak at onset of HFPV

Aims and Objectives

1) Design percussive ventilation protocol to be utilized in prospective study

2) Recruit patients to measure motion with and without motion mitigation by percussive ventilation

3) Analyze motion mitigation outcomes

Methods

Patient Selection

105 patients with a conspicuous lung tumor on imaging

≥ 10 mm motion on CT

27 patients

Excluded due to:
-Age
-Pulmonary history
-Personal reasons

69 year old female with Stage IB (cT2a, cN0, cM0) adenocarcinoma of the left lower lobe

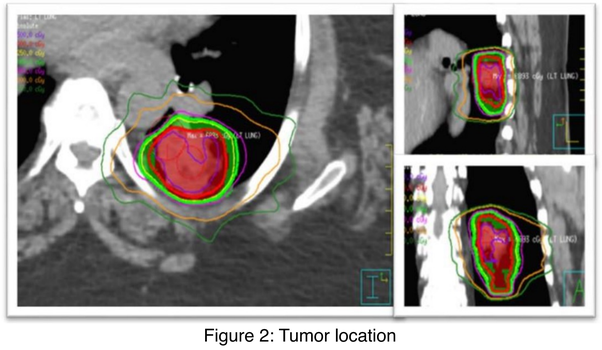

Figure 2: Tumor location

Prior to fluoroscopy, the patient underwent an initial 30-minute training session to become acclimated with the high frequency percussive ventilation technique. The patient was connected to the intrapulmonary percussive ventilation (IPV-2C) device through the Phasitron and the Fischer & Paykel Oracle 452 CPAP interface. The patient was then transferred to the treatment room where she was setup supine using her three-point isocenter tattoos with a cushion under her knees for comfort and arms above her head. We acquired two sets of consecutive fluoroscopy frames during multiple breathing cycles. One set was acquired while the patient was freely breathing and the other approximately 10 seconds post HFPV initiation. The settings of the Percussionaire IPV-2C (pressure, frequency, CPAP, inspiration time) were set by a certified respiratory therapist, but at the direction and comfort of the patient

Results

A total of 92 fluoroscopy frames were acquired while the patient was in free breathing and 147 in HFPV. A few of the fluoroscopy frames with contours of the tumor motion visualized during free- and HFPV breathing is shown in Fig. 3.

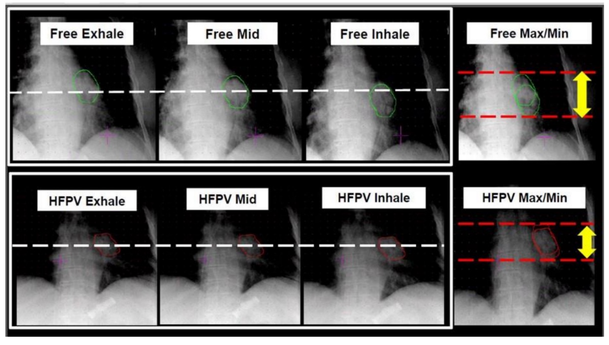

Figure 3: Green contour represent the target in free breathing and red in HFPV for inhale, mid and exhale position. Far right: overlay of the max and min contour for free-(green) and HFPV- (red) breathing.

A graph representation of points A and B traced along each frame is shown in Fig. 4. Time 0 to 100 represents target motion during free breathing and time 100 to 230 target motion during HFPV

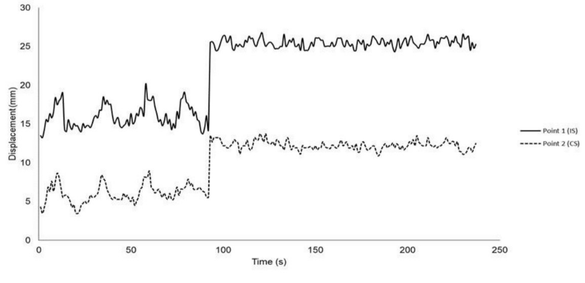

Figure 4: Direct Tumor Motion Graph. Point 1 and 2 represent two different points within the tumor.

The mean peak-to-peak motion for free breathing for both points was 6.2 mm (slightly lower than 11.0 mm measured during 4DCT). The mean peak-to-peak motion for HFPV breathing for both points was 2.7 mm. Therefore, the mean reduction in tumor motion while in HFPV, for both selected points, was at 57 %. The relative % reduction is comparable to the results found in the teams initial chest wall study.

Conclusions

Providing consistent and direct tumor motion control is critical in escalating delivery doses, while maintaining good sparing of the healthy tissue. In this first-in-man study, we show a direct tumor motion reduction of 57 % that was consistently maintained for longer periods of time (minutes) than a typical breath-hold. Although patients last reported FEV1 score was in the normal range (>50 %), the patient had a previous history of COPD which might have hampered our ability to maintain a pressure of 20 cm H_2O, like that seen in the volunteer cohort. However, even with the low peak pressure of 12 cm H_2O, motion was drastically reduced relative to patients' free breathing. Tumor motion recorded during the 4DCT simulation was about 11.0 mm however; free breathing motion during fluoroscopy was approximately 6.2 mm. We attributed this difference to the 4x10 Gy SBRT fractions that the patient had already received as part of her care, prior to this fluoroscopy study. We believe that tumor size/motion might have changed from what was initially recorded during the 4DCT session. In this study we did not evaluate prolonged HFPV times that the patient could have tolerated, but rather acquired several hundred fluoroscopic frames that would allow us to calculate direct tumor motion. Patient was however comfortable with the device and the length of time that she was in HFPV (~5 minutes). To our knowledge, this is the first study to ever show direct tumor motion reduction using such a novel technique for radiotherapy.

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Acknowledgements

Great appreciation to the patient enrolled in this study, the research team involved, and the clinical staff who referred this patient.