PhD Thesis Title: High Frequency Percussive Ventilation (HFPV) For Tumor Motion Immobilization

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ABSTRACT:

This work investigates the use of High Frequency Percussive Ventilation (HFPV) as a technique for respiratory motion mitigation in radiotherapy. This technique was extensively investigated in several prospective and retrospective studies.

In an initial prospective study, we evaluated the feasibility of HFPV and the chest-wall motion reduction by recruiting 15 healthy volunteers to undergo HFPV with three commercially available interfaces. For direct tumor motion immobilization, a second prospective study was performed with ten lung cancer patients who underwent HFPV while imaged with a high frame rate fluoroscopy. Diaphragm motion and image artifacts were quantified in a prospective study of a healthy volunteer who underwent magnetic resonance imaging (MRI) while undergoing HFPV. Several retrospective studies were performed to quantify the interplay effects as well as gradient effects of HFPV vs. free breathing in photon and proton radiotherapy. Furthermore, a retrospective phantom study was performed for quantifying planning target volume (PTV) reduction as well as doses to the organs at risk (OARs). Reproducibility of the HFPV was evaluated in a prospective study of five volunteers who underwent five sessions of HFPV on three different days. Lastly, as part of this study, a HFPV mask was designed and prototyped for better comfort, prolonged percussive time, minimal baseline drifting with a patient-controlled valve.

HFPV provides prolonged breath-hold like apnea in awake patients that could last as long as 16 minutes. In this first ever study, direct tumor motion was drastically reduced from > 10 mm to < 3 mm. Similarly, diaphragm motion was reduced by as much as > 90 %. HFPV proved significantly beneficial in reducing the effects of interplay in proton radiotherapy and photon dose gradient measurements, increasing the gamma index by as much as 20 to 30 % from free breathing to HFPV. Similarly, hot and cold spots were reduced by > 50 %. HFPV is reproducible within < 2 mm both intra- and inter- fractionally, but it can be further improved by applying minor adjustments to the pressure and frequency of the Percussionaire unit. Although further modifications will be made, the newly designed prototype provided less leakage and better comfort as well as providing patients with the direct ability to switch between room air and HFPV. HFPV is a novel and promising technique for tumor immobilization in a radiotherapy setting.

References to author publications that relate specifically to the dissertation:

MANUSCRIPTS:

1) **Ina M. Sala**, Girish B. Nair, Beverly Maurer, Thomas M. Guerrero, *"High frequency percussive ventilation for respiratory immobilization in radiotherapy."* Technical Innovations & Patient Support in Radiation Oncology, Volume 9, 2019, Pages 8-12, ISSN 2405-6324, https://doi.org/10.1016/j.tipsro.2018.11.001

2) **Ina M. Sala,** Beverly Maurer, Cristian Solano, and Thomas M. Guerrero, "*Fluoroscopic demonstration of thoracic tumor immobilization with high frequency percussive ventilation*." Global Journal of Cancer Case Reports, Volume 01, Issue 02, 2020, Pages 1-06, DOI: http://dx.doi.org/10.47733/GJCCR.2020.1207

ABSTRACTS

1) **Ina M. Sala,** Hazel Ramirez, Mark Pankuch, Thomas M. Guerrero, *Particle Therapy Co-Operative Group (PTCOG) North America: Annual Meeting, Miami, FL. Interplay evaluation of high frequency percussive ventilation (HFPV) for motion greater than 10 mm during proton beam scanning,* October 2019.

2) Afua Yorke, **Ina Sala**, David Solis, and Thomas Guerrero: American Association of Physicists in Medicine (AAPM): Annual Meeting, San Antonio, TX. *A statistically Characterized Reference Data Set for Image Registration of Pelvis Using Combinatorial Affine Registration Optimization*, July 2019.

3) Nicholas Myziuk, Gukan Sakthivel, Lauren Foster, David Solis, **Ina Sala**, Edward Castillo, Thomas Guerrero: American Association of Physicists in Medicine (AAPM): Annual Meeting, San Antonio, TX. *Predicting Post-SBRT Pulmonary Function using 4DCT Derived Ventilation Imaging*, July 2019

4) **Ina M. Sala,** Hazel Ramirez, David Solis, Jr., Mark Pankuch, Thomas Guerrero. American Association of Physicists in Medicine (AAPM): Annual Meeting, San Antonio, TX. *Retrospective phantom study for evaluating the dosimetric effects of high frequency percussive ventilation motion for photon radiotherapy,* July 2019.

5) **Ina M. Sala,** Hazel Ramirez, Mark Pankuch, Thomas Guerrero. Particle Therapy Co-Operative Group (PTCOG): Annual Meeting, Manchester, UK. *The effects of dose heterogeneity for normal and high frequency percussive ventilation motion mitigation technique using pencil beam scanning radiotherapy, June 2019.*

6) **Ina M. Sala**, Beverly Maurer, Nicholas Myziuk, Craig Stevens, Thomas Guerrero. American Society of Radiation Oncology (ASTRO): Annual Meeting, San Antonio, TX. *High Frequency Percussive Ventilation for Chest wall motion immobilization*, October 2018.

7) **Ina M. Sala**, Girish B. Nair, Beverly Maurer, Thomas M. Guerrero, *High frequency percussive ventilation for respiratory immobilization in radiotherapy*, Technical Innovations & Patient Support in Radiation Oncology, Volume 9, 2019, Pages 8-12, ISSN 2405-6324. https://doi.org/10.1016/j.tipsro.2018.11.001