PhD Thesis Title: Innovative applications of kilovoltage imaging in image-guided lung cancer radiotherapy

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ABSTRACT:

Radiotherapy is one of the most efficient and cost-effective treatments of cancer. To ensure accurate radiation delivery, there is a need for image guidance technologies to monitor tumor motion during radiotherapy treatment. This need is especially compelling in the case of lung cancer, where respiratory motion challenges accurate treatment delivery. This thesis presents the development of frontier technologies for image-guided lung cancer radiotherapy using kilovoltage imaging. Specifically, this thesis focuses on:

1. Improving 4-dimensional cone-beam CT (4D CBCT) image quality for more effective pre-treatment imaging.
2. Developing a non-invasive and widely applicable in-treatment imaging method.

This thesis consists of three main studies. The first study investigated the impacts of several factors on the image quality of 4D CBCT, which is currently suboptimal for clinical applications. It was found that improving 4D CBCT reconstruction algorithms is the most effective strategy.

The second study developed a novel 4D CBCT reconstruction method that significantly improves image quality compared to the current standard and existing noise reduction algorithms. The proposed method could leverage the usability of 4D CBCT in current clinical practice.

The third study developed an innovative markerless tumor tracking algorithm that could make more patients eligible for non-invasive in-treatment motion monitoring. The method is able to track tumors that are otherwise challenging to identify on kilovoltage images, and also achieves better localization accuracy than the current clinical standard.

The body of work presented in this thesis lays the technological foundation for widely applicable next-generation image guidance techniques. Retrospective patient studies have demonstrated the benefits of the presented methods in current lung radiotherapy treatments. Future development includes the prospective and clinical implementation of these technologies.

References to author publications that relate specifically to the dissertation:

1. **Shieh C C**, Kipritidis J, O0Brien R T, Kuncic Z and Keall P J 2014 Image quality in thoracic 4D cone-beam CT: A sensitivity analysis of respiratory signal, binning method, reconstruction algorithm, and projection angular spacing Med. Phys. 41(4), 041912.
2. **Shieh C C**, Kipritidis J, O0Brien R T, Cooper B J, Kuncic Z and Keall P J 2015 Improving thoracic four-dimensional cone-beam CT reconstruction with anatomical-adaptive image regularization (AAIR) Phys. Med. Biol. 60(2), 841.
3. **Shieh C C**, Keall P J, Kuncic Z, Huang C Y and Feain I 2015 Markerless tumor tracking using short kilovoltage imaging arcs for lung image-guided radiotherapy Phys. Med. Biol. 60(24), 9437–9454.