PhD Dissertation Title: Development of a Robust Treatment Delivery Framework for Stereotactic Body Radiotherapy (SBRT) of Synchronous Multiple Lung Lesions

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Graduation Date: 11/11/2020
Available Link: https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1000&context=radmed_etds

ABSTRACT:

Stereotactic body radiation therapy (SBRT) of lung tumors uses high doses of radiation to deliver high biological effective doses (BED) in very few fractions (1-5). With the use of highly conformal fields to cover the tumor without depositing large doses to non-cancerous structures, this technique has proven time and again to be successful at achieving high local control. However, frequently patients receiving SBRT are elderly with multiple medical comorbidities who may not tolerate long treatment times. Furthermore, many patients are present with oligometastatic or multiple primary lung tumors. The success of SBRT on oligometastatic lung disease relies on the physician experience with precise patient positioning and immobilization, which may not be available in all clinics. Likewise, there is no standard framework to guide the radiation oncology clinics experienced in SBRT with planning and treating multiple lung tumors synchronously. This dissertation explores the treatment planning methods available for the SBRT of multiple lung lesions and presents innovative solutions to the challenges in the current practice. To begin, two treatment planning methods for multiple lesion SBRT are compared: treating each lesion individually with separate isocenters and treating all lesions at the same time with a single isocenter. Treating multiple lesions with multiple isocenters will increase the patient's imaging and treatment time and the number of instances a radiation therapist must enter the treatment room, thus increasing the chances a patient will move from the setup position. Using an individual isocenter placed between the tumors and volumetric arc therapy (VMAT) to treat all tumors at the same time can reduce the treatment time, increasing the patient's comfort and decreasing the chance of movement from the treatment position. However, with this technique, there is a chance of decreased target coverage and reduced BED due to small setup errors.. The dissertation continues by quantifying this loss in target coverage using a novel simulation method. Simulations yielded average deviations of 27.4% (up to 72% loss) ($p < 0.001$) from the planned target coverage. The largest deviations from the planned coverage and the desired BED were seen for the smallest targets (< 10 cc), some of which received < 100 Gy BED, which is suboptimal for the SBRT. The patient misalignment resulted in a substantial decrease in conformity and an increase in the gradient index, thus violating the major characteristics of the SBRT. To minimize coverage loss due to the small setup errors, a novel Restricted Single-Isocenter Stereotactic Body Radiotherapy (RESIST) treatment method was developed to provide efficient and effective treatments without substantially increasing the treatment time. Lastly, RESIST was automated in the treatment planning system to allow for efficient and accurate treatment planning for the two lung lesion SBRT. Automation includes beam geometry, algorithm selection, and an in-house trained dose volume histogram (DVH) estimation model to improve the plan quality. Automated planning significantly improves the treatment planning time and decreases the chance of planning errors.. Further development of RESIST for > 2 lesions and multi-site SBRT merits further investigation.

Keywords: Lung SBRT, VMAT, Synchronous Multiple Lesions, Setup Errors, RESIST, Automation

References to author publications that relate specifically to the dissertation:

1. **Lana Sanford**, Janelle Molloy, Sameera Kumar, Marcus Randall, Ronald McGarry and Damodar Pokhrel, "Evaluation of Plan Quality and Treatment Efficiency for Single-Isocenter/Two-Lesion Lung Stereotactic Body." Radiation Therapy. J Appl Clin Med Phys 2019; 20(1):118–127. DOI: 10.1002/acm2.12500

2. **Lana Sanford Critchfield**, Mark E Bernard, Marcus Randall, Ronald C McGarry and Damodar Pokhrel, "Risk of Target Coverage Loss for Stereotactic Body Radiotherapy Treatment of Synchronous Lung Lesions via Single-Isocenter Volumetric Modulated Arc Therapy." J Appl Clin Med Phys 2021; 22(1); 251-269. DOI: 10.1002/acm2.13145

3. **Lana Sanford Critchfield**, Justin Visak, Mark E Bernard, Marcus Randall, Ronald C McGarry and Damodar Pokhrel, PhD., "Automation and Integration of a Novel Restricted Single-Isocenter Stereotactic Body Radiotherapy (a-RESIST) Method for Synchronous Two Lung Lesions." J Appl Clin Med Phys (Article in Press), May 25, 2021. DOI: 10.1002/acm2.13259