PhD Thesis Title: An investigation of plan-class specific reference (pcsr) fields and other strategies for improved dosimetry in modulated clinical linear accelerator treatments

Author: Vimal K. Desai
Email: vkdesai@wisc.edu
Institution: The University of Wisconsin - Madison
Supervisor: Dr. Wesley Culberson
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ABSTRACT:

Over the past few decades, external beam radiotherapy has been used extensively to treat cancer. The use of intensity modulated radiation therapy (IMRT) has markedly improved the conformity of dose that can be delivered to a tumor target volume, while simultaneously minimizing dose delivered to nearby healthy tissues. Despite the advantages that IMRT has afforded, significant challenges remain regarding dosimetry in modulated clinical linear accelerator-based treatments. The absorbed dose to water, arguably one of the most important quantities to determine in any radiotherapy treatment, is difficult to determine in these modulated clinical treatments. This is because the radiation detectors used to determine the absorbed dose values precisely and accurately are currently calibrated under a well-defined set of reference field conditions which do not resemble most actual patient-specific treatments. Because of this disconnect, additional plan-specific correction factors are often required to convert a radiation detector's reading to an absorbed dose to water. Most institutions lack the time and resources necessary to account for these detector and plan-specific correction factors, and a blanket correction is sometimes used based on simplified calculations or ignored altogether. Because composite IMRT treatments are comprised of various MLC-defined fields, it cannot always be assumed that the dose to water calculated in a clinical field using a radiation detector is accurate based on its reference field calibration, or that a single correction factor could be applicable for every IMRT plan measured with a given detector. To maintain a high degree of dosimetric accuracy and precision, it is therefore important to investigate both the magnitude and variability of the correction factors across many different treatment plans to determine the accuracy of the detector-reported absorbed dose to water.

An existing methodology developed to help facilitate the calibration of radiation detectors for patient-specific deliveries is thoroughly investigated in this thesis work. The methodology itself lacks quantitative guidelines that would provide a path towards its universal implementation. This work helps to address that gap in knowledge through the analysis of many actual clinical plans. Strategies using quantitative plan complexity metrics and objective clustering algorithms are investigated as potential bases for standardizing dosimetry involving modulated clinical fields through the establishment of plan classes.

Large numbers of detector-specific corrections that could be used to convert various radiation detectors' readings into an accurate absorbed dose to water are also determined using rigorously benchmarked Monte Carlo simulations and measurements with cutting-edge small field detectors. The detectors are each assessed in terms of their suitability as potential reference-class dosimeters in modulated clinical fields and compared to the Monte Carlo simulations to ensure each model's accuracy. The validated models are then used to compute hundreds of individual detector-specific corrections for three different-sized ionization chambers.

Finally, the detector-specific corrections established using the Monte Carlo methods illustrate the difficulty in establishing potential plan classes. Various modelling strategies are developed and evaluated as an alternative

to the plan-class specific reference field concept which attempt to simplify the determination of beam and detector-specific corrections using readily available input parameters. Ultimately, a simplified volume averaging metric calculated using the treatment planning system determined dose grid shows the highest correlation with the full Monte Carlo determined factors and could lay the basis for improving dosimetry in modulated clinical fields without the need for extensive measurement and computing resources.

References to author publications that relate specifically to the dissertation:

1. **V. Desai,** Z. Labby, L. DeWerd, and W. Culberson, "On the implementation of the plan-class specific reference field using multidimensional clustering of plan features and alternative strategies for improved dosimetry in modulated clinical linear accelerator treatments," *Medical Physics* **47**(8): 3621-3635, 2020. **https://doi.org/10.1002/mp.14207**

2. **V. Desai,** Z. Labby, M. Hyun, L. DeWerd, and W. Culberson, "VMAT and IMRT plan-specific correction factors for linac-based ionization chamber dosimetry," *Medical Physics* **46**(2): 913-924, 2019. **https://doi.org/10.1002/mp.13293**