PhD Thesis Title: Evaluation of Different Dosimetric Parameters in Volumetric Modulated Arc Therapy Treatment Planning and Delivery Systems for Various Clinical Sites

Author: P. Mohandass Ph.D.
Email: kpmds03@gmail.com
Institution: Karunya Institute of Technology and Sciences (Deemed-to-be-University), Coimbatore, India
Supervisor: Prof. (Dr.) D. Khanna Ph.D.
Graduation Date: 10th October 2020
Available Online: http://hdl.handle.net/10603/315910

ABSTRACT:

Volumetric Modulated Arc Therapy (VMAT) is a modern rotational type of Intensity Modulated Radiotherapy (IMRT) technique. The significant advantages of VMAT are as follows: highly conformal dose, reduced Monitor Units (MU) and treatment time than conventional techniques. There are many dosimetric parameters involved in the Treatment Planning Systems (TPS) to generate a VMAT plan. The quality of the plan is also based on these dosimetric parameters during plan generation. It is, therefore, necessary to evaluate the different dosimetric parameters in the treatment planning to ensure quality and accuracy of VMAT delivery. It is also recommended by the TPS vendor to validate each dosimetric parameter for different sites before clinical use. Cone Beam Computed Tomography (CBCT) has become a potential tool for evaluating the variations in the patient positioning changes during treatment delivery. The accuracy of the setup error is based on the algorithm, registration and matching methods used in the CBCT system. Hence, it is crucial to assess the impact of the different registration and matching methods to estimate the patient's geometrical uncertainty for different clinical sites. Therefore, the present study aims to evaluate the different dosimetric parameters in VMAT planning and delivery systems for various clinical sites.

Statistical Uncertainty (SU) is an important dosimetric parameter in Monte Carlo (MC) dose calculation to decide the accuracy and calculation time during the treatment planning. Hence, it is important to find out the optimal acceptance of SU for quality of the VMAT plan with reduced calculation time. The VMAT plans were generated using SU from 0.5% to 5.0% for comparing different clinical sites. The study findings concluded that the SU can be accepted from 1% to 3% per plan with reduced calculation time without compromising the plan's quality and deliverability by accepting variations in the point dose within the target. Similarly, the New Monaco™ TPS version 5.11 includes refactoring changes as compared to its previous versions V5.10.02 in the MC dose calculation code, which needs to be validated by the clinical physicist. The results revealed that in both versions, SU could be accepted up to 3% per plan with reduced calculation time (Ct) without compromising the plan's quality and deliverability. The plan's quality of Monaco™V5.10.02 was similar to Monaco™ TPS-V5.11, except for the dose calculation time. The Monaco™ TPS uses different optimization modes during the VMAT plan generation. Among all, Multi Criteria Optimization (MCO) mode is found to be efficient and can generate a better plan. Therefore, the study evaluated the effect of MCO on Cranio Spinal Irradiation (CSI) and compared it with the c-VMAT plan. The results found that the MCO-VMAT can be used without compromising the target coverage and reduced the Organs At Risk (OAR) dose by accepting a slight increase of MUs, delivery and calculation time as compared to c-VMAT.

CBCT imaging has a vital role in a modern radiotherapy technique to ensure patient positioning accuracy. Approved plans CT images were used as the reference image sets for registration with their corresponding CBCT image sets. The breast patient setup verification was performed using the Clip-Box Registration (CBR) method. Considering the CBR method as the reference, two more registrations were performed using the Mask Registration (MR) method and the dual registration (DR) (CBR + MR) method in the offline mode. In the overall analysis, all three registration methods show insignificant variation in the patient setup error for the breast VMAT delivery pointing out that one can use any one of these three registration methods for patient setup verification for the breast VMAT plan. Similarly, the study compared the influence of three different matching methods delivery of VMAT in CBCT on the patient setup error. Grey-scale Matching (GM), Manual-Matching (MM), and Bone-Matching (BM) between on-board CBCT and reference CT image, were used to assess the setup error. Using the GM approach as a reference,

two other matchings were rendered in the offline mode using BM and MM. The statistical results showed insignificant differences among the three matching methods, indicating that any one of these three matching methods can be used during CBCT to check the patient translation error for the head and neck VMAT delivery.

These findings concluded that dosimetric analysis of statistical uncertainty, multicritical optimisation, and the validation of the new TPS versions on the VMAT plan generation should be ensured before clinical use for quality and accuracy of the different sites**.** Similarly, the results from the different matching and registration methods showed an increased accuracy and a decreased uncertainty of the patient setup error during the VMAT delivery for various clinical sites.

References to author publications that relate specifically to the dissertation:

1. **Mohandass P.,** Khanna D., Manigandan D., Bhalla N. K., and Puri A. (2018), "Validation of a software upgrade in a Monte Carlo treatment planning system by comparison of plans in different versions." Journal of Medical Physics, 43(2), 93-99. DOI: 10.4103/jmp.JMP_7_18
2. **Mohandass P.,** Khanna D., Kumar T. M., Thiyagaraj T., Saravanan C., Bhalla N. K., and Puri A. (2018), "Study to compare the effect of different registration methods on patient setup uncertainties in cone-beam computed tomography during volumetric modulated arc therapy for breast cancer patients." Journal of Medical Physics, 43(4), 207-213. DOI: 10.4103/jmp.JMP_67_18
3. **Mohandas P.,** Khanna D., Durai M., Bhalla N. K., and Puri A. (2019), "Dosimetric impact of statistical uncertainty on Monte Carlo dose calculation algorithm in volumetric modulated arc therapy using Monaco TPS for three different clinical cases." Reports of Practical Oncology & Radiotherapy, 24(2), 188-199. https://doi.org/10.1016/j.rpor.2019.01.005
4. **Mohandass P**., Khanna D., Nishaanth B., Saravanan C., Bhalla N., Puri A., and Mohandas B. (2020), "Impact of Three Different Matching Methods on Patient Set-Up Error in X-Ray Volumetric Imaging for Head and Neck Cancer." Reports of Practical Oncology & Radiotherapy, 25(6), 906-912. DOI: 10.1016/j.rpor.2020.09.001
5. **Mohandass P.**, Khanna D., Selvaganapath A., Nishaanth B., Saravanan C., Thiyagaraj T., Bhalla N., Puri A., and Blessy M. (2020), "Impact of Multi-criteria Optimization on 6-MV Flattening Filter-Free Volumetric Modulated Arc Therapy for Craniospinal Irradiation." Iranian Journal of Medical Physics, 17(6): 386-393. DOI: 10.22038/IJMP.2019.43270.1655