Jennifer Croft, B.S., RT(T)
Grand Valley State University
Croftje@mail.gvsu.edu

Impact of anatomical changes on treatment plan robustness: A comparative study of intensity modulated proton therapy and volumetric modulated arc therapy in HN cancer

Introduction

Head and Neck cancers require precise radiotherapy due to complex anatomy and ongoing anatomical changes during treatment. Typical regimes deliver 36-70 Gy over several weeks, demanding accurate tumor coverage while sparing nearby organs at risk. Modern techniques such as VMAT and IMPT improve dose conformity and reduce toxicity.

IMPT uses the Bragg peak to minimize dose beyond the target, potentially improving sparing of critical structures. However, it is more sensitive to setup errors and anatomical variations. VMAT offers more forgiveness with anatomical changes throughout the course of treatment.

This study evaluates the robustness of IMPT and VMAT by analyzing dose accumulation, target coverage, and organ dose variability to inform adaptive planning strategies for head and neck cancer treatments.

Methods

This retrospective, quantitative paired-planned study was conducted to compare the robustness of Intensity Modulated Proton Therapy (IMPT) and Volumetric Modulated Arc Therapy (VMAT) for head and neck cancer in the setting of anatomical changes throughout the treatment course.

Ten patients previously treated with IMPT and possessing daily CBCT imaging were selected. The planning CT served as the reference dataset for creation of both IMPT & VMAT plans. Daily CBCT images were converted to synthetic CT datasets using an AI-based platform, enabling accurate dose recalculation under day-to-day anatomical variations.

Target volumes were contoured by physicians, while organs at risk were auto-segmented and reviewed for accuracy. Both IMPT and VMAT plans were generated in RayStation using clinically relevant robust parameters and high-resolution dose calculation grids.

Daily doses distributions were recalculated on each synthetic CTs and accumulated using deformable image registration. DVHs evaluated with CTV98% , V100, and OAR doses metrics. Paired statistical tests compared robustness between the two modalities.

Results

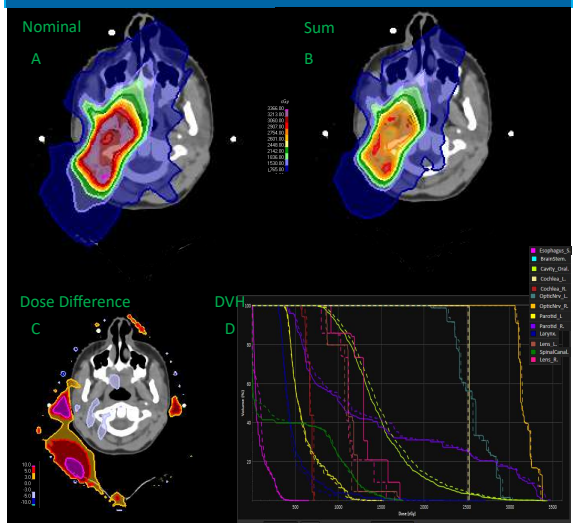
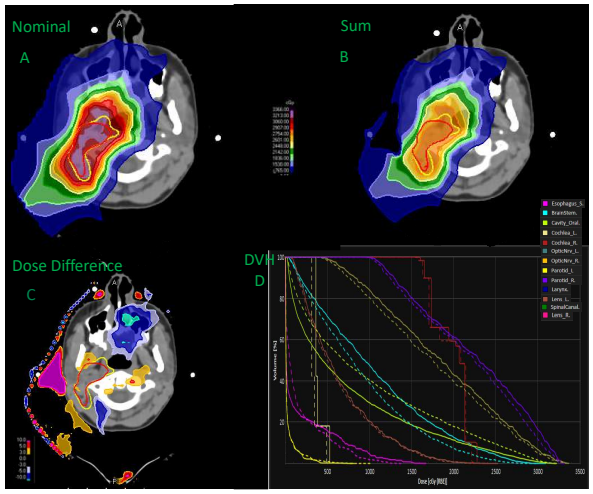


Fig. 1 & 2. The VMAT (top) & IMPT (Bottom) dosimetric quality & DVH comparison between Nominal plan & Sum plan. (A) Nominal (B) Sum (C) Dosimetric difference (D) DVH show dosimetric difference in OAR between the two modalities.
Nominal —— Sum - - - - - -



Conclusion

This research demonstrates that both IMPT and VMAT can achieve clinically acceptable head and neck treatment plans, yet their differences highlight meaningful considerations for patient-specific planning. Evaluating plan robustness requires assessment beyond initial planning metrics and must account for anatomical changes throughout the treatment course. While both modalities achieved excellent target coverage in the D98, accumulated dose analysis revealed meaningful differences in how VMAT and IMPT respond the V100. VMAT preserved better coverage while IMPT was more sensitive. Ultimately, this research strengthened understanding of comparative planning strategies and underscored the need for continued research that integrates clinical outcomes, patient quality of life, and evolving technology to guide optimal treatment decision in radiation oncology.

Limitations

The research analysis was challenging due to the integrating complex analysis with dynamic anatomical changes throughout the treatment course. Accurately comparing robustness between VMAT and IMPT was not limited to plan quality at simulation but demanded recalculation and summation of delivered dose across all data sets. Additional challenges include aligning datasets between two fundamentally different modalities, accounting for uncertainties unique to proton therapy and performing meaningful statistical comparison on a small patient cohort.

References

Anderson G, Ebadi M, Vo K, Novak J, Govindarajan A, Amini A. An Updated Review on Head and Neck Cancer Treatment with Radiation Therapy. *Cancers*. 2021;13(19):4912. doi:10.3390/cancers13194912

van Dijk LV, Steenbakkers RJHM, Haken B ten, et al. Robust Intensity Modulated Proton Therapy (IMPT) Increases Estimated Clinical Benefit in Head and Neck Cancer Patients. *PLoS One*. 2016;11(3):e0152477. doi:10.1371/journal.pone.0152477

Behrends C, Haussmann J, Kramer PH, et al. Model-based comparison of organ at risk protection between VMAT and robustly optimized IMPT

Acknowledgements

Xuanfeng Ding Ph.D., Associate Professor and Lead Proton Physicist, Research Project Advisor
Xiaoda Cong M.S., Research Assistant
Congxiao Chen B.S., Research Assistant
GVSU Statistical Consulting Center
Dr. B. Sango Otieno, Associate Professor