Dosimetric case study of 3-D FiF vs. VMAT techniques in the treatment of H/N tumor

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Introduction

- VMAT approach demands even more sophisticated equipment and seamless teamwork, and consequently more resources, advanced training and more time for treatment planning and verification of dose delivery than 3-D CRT.[1]
- Some cancer centers worldwide are currently in the early stages of implementing radiotherapy and are only able to offer 2D and 3D radiotherapy plans due to issues such as the limitations of advanced imaging and physics QA, a lack of adequately trained dosimetrists, and health insurance clearance.[1]
- An essential issue that may have been frequently overlooked is how clinics with limited equipment can still provide high-quality patient care even if their linear accelerator only has MLC and no physical/dynamic wedges.

Methods and Materials

- This case was from the H/N VMAT lab of John Patrick University. PTV is big and irregular in shape, 238.25cm^3, and it overlaps with many critical structures which can limit radiation dose, like left parotid, larynx, mandible, maxilla, and Retropharyngeal and close to brainstem and spinal cord.
- The prescription was 70Gy/35F. The planning objective was to ensure that ≥95% of the target volume was covered by at least 95% of the prescribed dose while restricting doses to spinal cord (maximum dose <45Gy) and contralateral parotid gland (mean dose ≤26Gy).
- 3D-CRT was planned with a combination of 6 and 18 MV of energy, using 5 MLC-shaped beams with the FiF technique. Two steps: determination of treatment field apertures, then using subfields to give a homogeneous dose distribution. The beam weights need to be readjusted to increase homogeneity of PTV while decreasing the hotspot volumes, and this entire process is iterative.
- VMAT was done with 6MV photons with two partial arcs range selected to avoid as much of the contralateral organs as possible.

Figure 1: 3D-CRT Fields Properties.

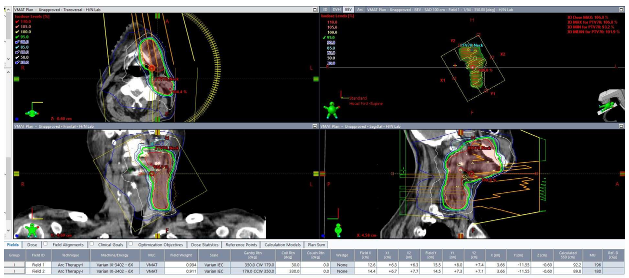
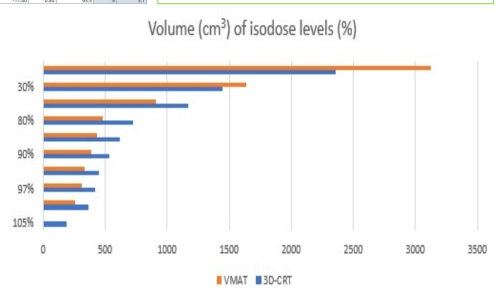


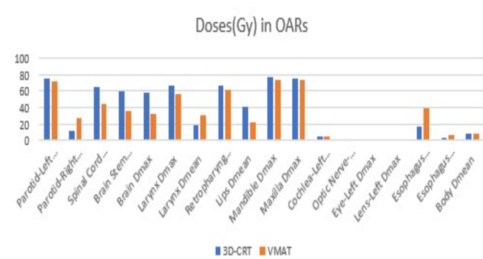
Figure 2: VMAT Fields Properties.

Figure 3: Dose distribution for two plans in same slide.

Results

- The target coverage was achieved 95% of prescribed dose to 100% of PTV in 3D CRT and VMAT methods.
- Comparing the max hot spot of 3D plan <110%, VMAT's hot spot <105%.
- CI & HI for VMAT showed better than 3D.
- This study report improved conformity with VMAT at the above 50% isodose levels; the volume of healthy tissue receiving low-dose radiation (10% and 30% isodose line coverages) was lower in 3D-CRT plans.
- The value of MU was statistically low for 3D at 39.6% less than VMAT which used more time.
- 3D improved sparing of the contralateral parotid gland, and it is significant to protect the right parotid gland when the left parotid is involved in the irradiation area. The mean dose of left parotid was 75.4 Gy and 72.6 Gy for 3D and VMAT plans. For right parotid gland, the mean dose was 11.6 Gy for 3D and 27.6 Gy for VMAT.
- The integral dose to the body was also lower in the 3D plans by 2% compared with the VMAT plan. A reason for this is that this VMAT plan was optimized by taking into consideration dose constraints to the spinal cord and brainstem.
- Compared to 3D, the absorbed doses of VMAT in the spinal cord and brainstem are reduced by 31% and 39%. The doses to the spinal cord and brainstem in this study were significantly lower in the VMAT plans, but at the cost of increased dose to the contralateral parotid gland.





Parameters	D2 (Gy)	D5 (Gy)	D50 (Gy)	D95 (Gy)	D98 (Gy)	Min Dose	Mean Dose	Max Dose	CI	HI	Total MU/Fx
3D-CRT	76.1	75.8	74.1	70.0	68.5	60.8	73.7	76.6	1.41	1.08	227
VMAT	72.6	72.3	71.4	70.0	69.5	65.2	71.3	74.2	1.89	1.03	376

Table 1: PTV dose parameters for two techniques.

Discussion

- 3D plan generated with a mix of 6 and 18 MV energy gave the best ratio of coverage and dose to OAR because the 6MV energy produces plans that are too hot to be used. As the energy increases, the dose to the OAR and the size of the hotspot decreases.[2]
- FIF technique can be added to a 3D forward-planning method to minimize hotspots and improve dose homogeneity in the target volume, producing high-quality clinical plans.[3]
- Compared with physical/dynamic wedges, FIF provides more nuanced hotspot reduction and can achieve a better dose distribution, and its ability to operate in two dimensions instead of one.[3]
- FiF is better than wedges in terms of maximum dose, D2, and V >107% for most of the sites, and its MU is 30% lower than in the wedge method. A reduction in MU minimizes the chance of developing secondary cancers in radiotherapy.[4]

Conclusion

- Both 3D-CRT and VMAT are dosimetrically feasible techniques in the treatments for H/N tumors.
- The use of 3D-CRT technique still be useful to improve the quality of treatments in various anatomical sites like H/N, and it is feasible to replace wedge filters with FiF.
- The advantages of VMAT are improved target volume conformity, particularly in volumes with complex concave shapes, and improved sparing of OARs; however, it cannot be considered the universal solution for all clinical scenarios. Each case must be evaluated on an individual basis to select the most appropriate radiation technique that will give optimal results.[5]
- As a time-intensive, labor-intensive process, IMRT/VMAT is not fully covered by the public health system in middle-and low-income countries, because it requires considerable investments in both software and hardware.[6] It also has a more stringent machine QA and quality control to check the performance of its delivery system. Achieving a widespread IMRT/VMAT technology in most cancer centers in the world will require a long time given the economic costs, quality, and safety problems.
- My future studies will increase the number of H/N cases tested to examine the robustness of the method in larger and different populations.

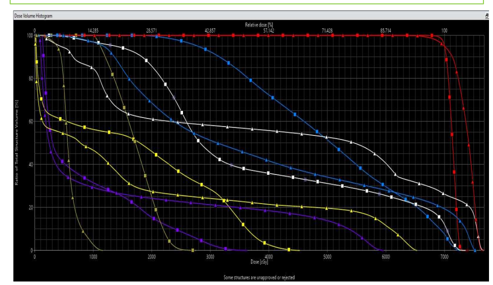


Figure 4: Comparison of DVH. Triangle = 3D-CRT; Square = VMAT.

References

1. Transition from 2-D Radiotherapy to 3-D Conformal and Intensity Modulated Radiotherapy. IAEA. May 2008. https://www-pub.iaea.org/MTCD/publications/PDF/TE_1588_web.pdf

2. Zhu J. Generation of wedge-shaped dose distributions through dynamic multileaf collimator dose delivery. J Appl Clin Med Phys. 2005 Summer;6(3):37-45.

3. Prabhakar, R., Julka, P.K. & Rath, G.K. Can field-in-field technique replace wedge filter in radiotherapy treatment planning: a comparative analysis in various treatment sites. Australas. Phys. Eng. Sci. Med. 31, 317–324 (2008). https://doi.org/10.1007/BF03178601

4. Onal C, Sonmez A, Arslan G, et al. Dosimetric comparison of the field-in-field technique and tangential wedged beams for breast irradiation. Jpn J Radiol. 2012 Apr;30(3):218-26

5. Teoh M, Clark CH, Wood K, Whitaker S, Nisbet A. Volumetric modulated arc therapy: a review of current literature and clinical use in practice. Br J Radiol. 2011 Nov;84(1007):967-96.

6. Klein EE, Hanley J, Bayouth J, et al. Task Group 142 report: quality assurance of medical accelerators. Med Phys. 2009; 36(9): 4197– 212.

Acknowledgments

- Special thank you to John Patrick University faculty and staff, especially Program Director David L. Phebus II and Clinical Coordinator Director Jennifer Phebus.
- Special thank you to Manager Dosimetry of Varian Medical Systems Thomas Costantino for training on 3D/IMRT/VMAT/SBRT treatment planning.
- Special thank you to the Preceptor, Clinical Supervisor, and Evaluators for my intern training.

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