

# Dosimetric comparison between volumetric modulated arc therapy and intensity modulated proton therapy for whole brain irradiation with hippocampal sparing

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## Background and Objective

Whole brain radiation therapy (WBRT) is a main treatment in cancer patients with brain metastasis, however, the standard treatment of right and left parallel opposing in 3D technique cannot spare hippocampus organ. Advanced technique, Volumetric Modulated Arc Therapy (VMAT) and Intensity Modulated Proton Therapy (IMPT), were introduced to reduce organs at risk (OARs) doses [1]. The purpose of this study was to compare the dosimetric effect between VMAT and IMPT techniques for WBRT with hippocampal sparing.

## Methods

Fifteen-patient plans previously treated WBRT with VMAT from TrueBEAM linear accelerator (Varian Medical System, Palo Alto, CA) were re-planned with IMPT technique in Eclipse treatment planning system version 15.6. The 6 MV VMAT plans consisted of two full arcs with coplanar plane and two to three half arcs with non-coplanar beams. IMPT plans were generated from three multi-field optimizations for 45, 130 and 180 degree gantry angle with 270 degree couch angle for all fields and the range shifter was also applied to all proton fields.

The prescribed dose to WB planning target volume (PTV) was 30 Gy in 10 fractions. The dose constraints were matched to RTOG 0933 planning requirements [2] as shown in Table 1. The percentage of normalization dose was selected to receive at least prescribed dose at D95%.

**Table 1.** Dose constraints of PTV and hippocampus according RTOG 0933.

Organs	Dose Constraints		
	Per Protocol	Variable Acceptable	Deviation Unacceptable
PTV	D2% ≤ 37.5 Gy	40 Gy ≥ D2% > 37.5 Gy	V30% < 90%
	D98% ≥ 25 Gy	D98% < 25 Gy	D2% > 40 Gy
Hippocampus	D100% ≤ 9 Gy	D100% ≤ 10 Gy	D100% > 10 Gy
	Max. dose ≤ 16 Gy	Max. dose ≤ 17 Gy	Max. dose > 17 Gy

The target coverage and homogeneity index (HI) was used to evaluate PTV and the maximum and mean doses were reported for organs at risk (OARs) of hippocampus, eyes and lens.

## Results and Discussion

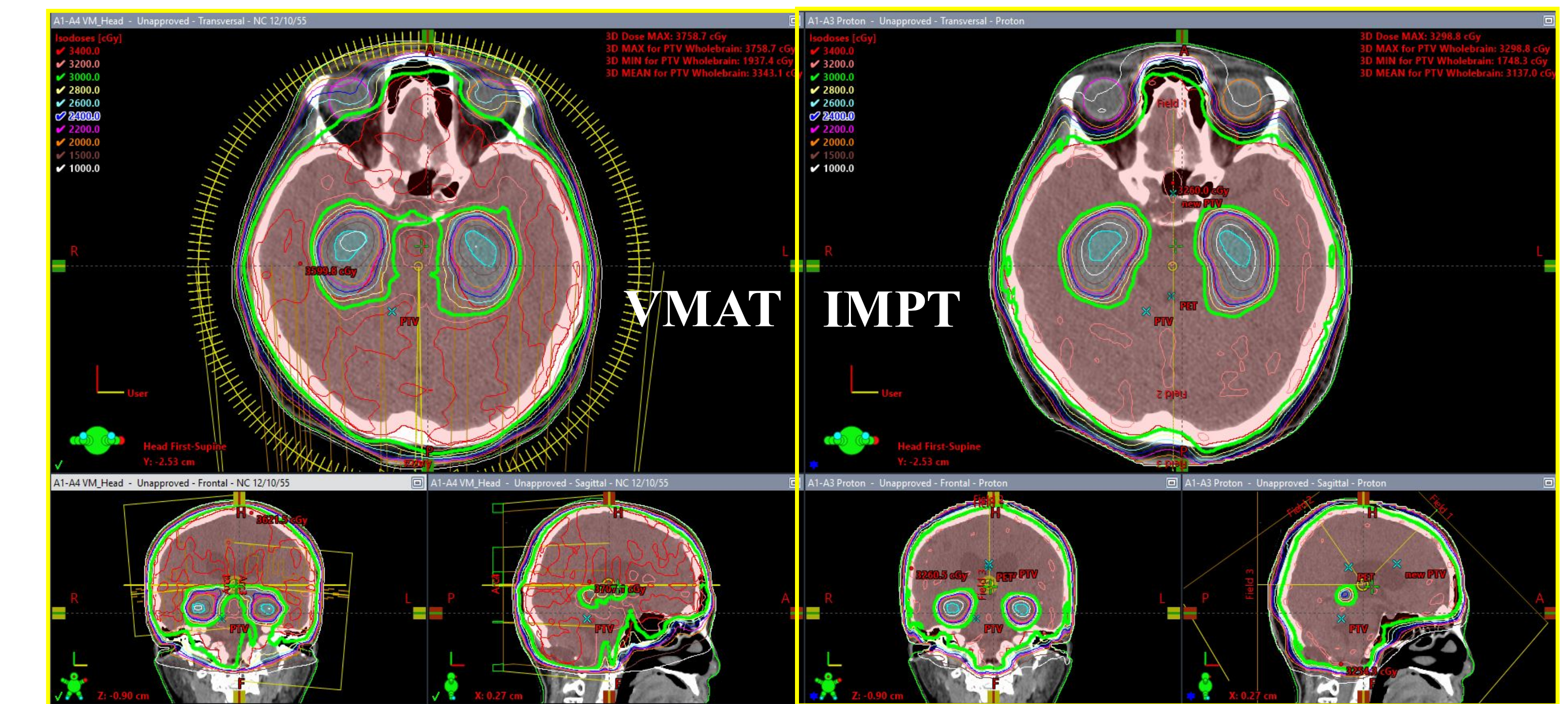
The PTV D<sub>95%</sub> was higher than the prescribed dose for all cases with no statistically significant using Wilcoxon match-pairs signed ranks test between VMAT and IMPT. The example of compared dose distribution between VMAT and IMPT is presented in Figure 1, while DVH comparison is shown in Figure 2. The PTV dose of VMAT was lesser homogeneous than IMPT. The average HI of VMAT and IMPT was 33.7 ± 13.0 and 17.6 ± 5.0, respectively as shown in Table 2. Moreover, IMPT technique presented significant lower doses to all OARs include hippocampus, eyes and lens than VMAT plans. The VMAT plans were not pass the dose criteria in several cases, especially D<sub>100</sub> (Hippocampus). The maximum dose of hippocampus of VMAT was reduced from 14.9 ± 2.1 Gy for VMAT to 9.1 ± 1.7 Gy for IMPT.

**Table 2.** Average doses of PTV and OARs.

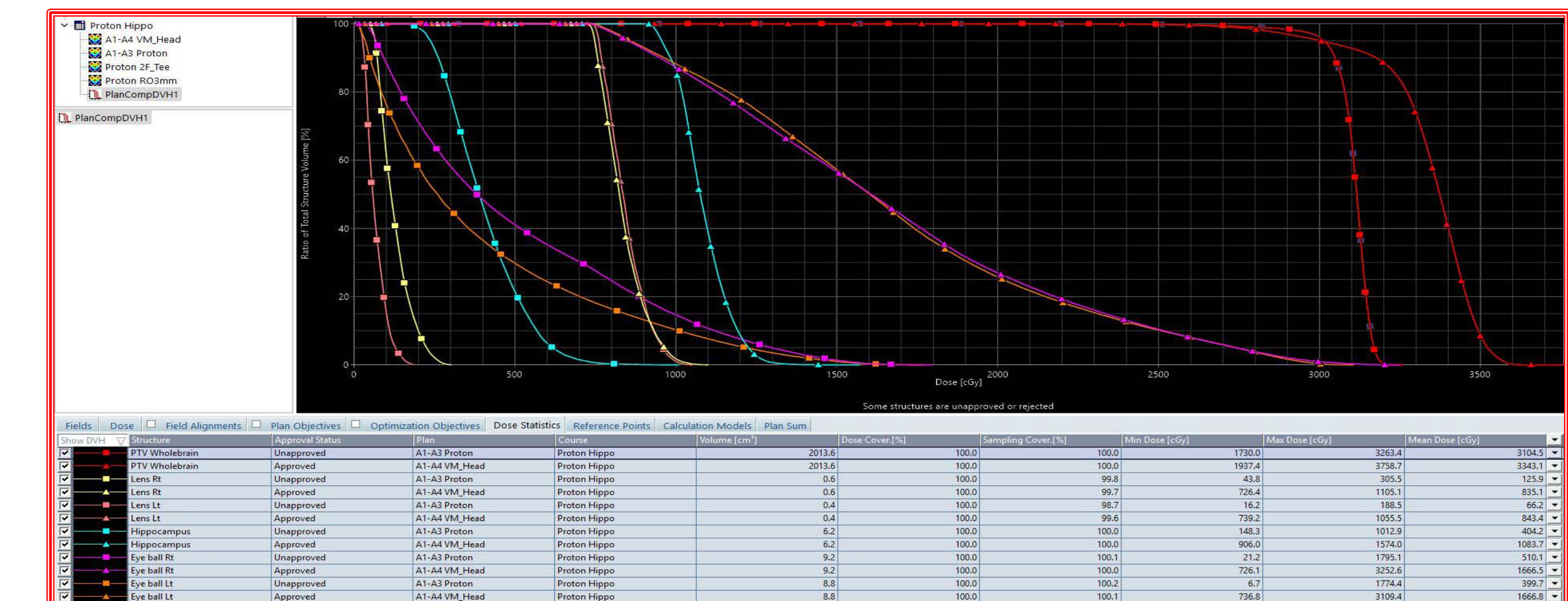
Parameters	Dose (Gy or GyE)		P-value	
	VMAT	IMPT		
PTV	D <sub>98</sub>	26.7 ± 2.9	27.1 ± 1.5	0.637
	D <sub>95</sub>	30.1 ± 0.1	30.0 ± 0.1	0.458
	D <sub>50</sub>	34.7 ± 2.4	31.4 ± 0.2	0.001
	D <sub>2</sub>	36.8 ± 3.2	32.3 ± 0.3	0.001
	HI	33.7 ± 13.0	17.6 ± 5.0	0.004
OARs	D <sub>max</sub> (Hippocampus)	14.9 ± 2.1	9.1 ± 1.7	0.001
	D <sub>mean</sub> (Hippocampus)	12.6 ± 1.7	5.9 ± 1.2	0.001
	D <sub>100</sub> (Hippocampus)	10.0 ± 1.0	3.7 ± 1.1	0.001
	D <sub>max</sub> (Rt len)	9.5 ± 3.5	2.9 ± 1.0	0.004
	D <sub>max</sub> (Lt len)	9.4 ± 3.3	2.6 ± 0.9	0.004
	D <sub>max</sub> (Rt eye)	22.9 ± 7.1	14.5 ± 2.4	0.011
	D <sub>max</sub> (Lt eye)	22.9 ± 7.3	14.0 ± 3.0	0.008

## Conclusion

IMPT offers significantly dosimetric advantages over VMAT in both PTV and OARs that expected to get more curative and less complications for patients whom treated from IMPT in clinic.



**Figure 1.** Dose distribution comparison between VMAT and IMRT for whole brain irradiation with hippocampal sparing.



**Figure 2.** Dose volume histogram comparison between VMAT and IMRT for whole brain irradiation with hippocampal sparing.

## References

- [1] Stoker J, Vora S, Patel A, Grosshans D, Brown PD, Gross TV, et al. Advantages of intensity modulated proton therapy during hippocampal avoidance whole brain radiation therapy. *Phys Img Rad Onc.* 2018;8:28-32.
- [2] Mehta PM, Kanner A, Gondi V, Tome W, Corn B, Rowley H, et al. A phase II of hippocampal avoidance during whole brain radiotherapy for brain metastases. *Radiation Therapy Oncology Group, RTOG 0922.* 2011.