Evaluating the Feasibility and Accessibility of Hippocampal Sparing Whole Brain Radiotherapy with Simultaneous Integrated Boost (HSWB-SIB) RapidPlan Model for Multiple Brain Metastases on the Halcyon

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INTRODUCTION

- A common treatment course for brain metastases consists of whole brain or hippocampal sparing whole brain radiotherapy (HSWB) followed by stereotactic radiosurgery focused on the gross metastases
  - Two separate courses requiring the patient to spend multiple weeks receiving treatment
- Some have demonstrated combining these two separate courses into a single treatment with a Simultaneous Integrated Boost (SIB)[1,2]
  - Reduces patient's time in clinic and potentially improves clinical outcomes
- Using Varian's RapidPlan in conjunction with Eclipse Scripting API would allow for the generation of a standardized, automated approach for creating HSWB-SIB plans
  - Increase accessibility by demonstrating for multiple platforms

METHOD

- 12 patients with 2 – 14 brain metastases were retrospectively replanned for HSWB-SIB on three different modalities
  - Halcyon (HAL), TrueBeam Coplanar (TB-Co), and TrueBeam with HyperArc (TB-HA)
- Used a recently published HSWB RapidPlan model[3] with slight modifications to account for SIB
  - Adjusted and added optimization structures and objectives
  - Objectives were injected into optimizer after DVH estimation using Simultaneous Integrated Boost Injector (SIBI) for RapidPlan

Table 1: Custom optimization objectives injected after DVH Estimation to achieve the SIB distribution.

Structure	Add/Remove	Objectives			
		Type	Volume (%)	Dose (cGy)	Priority
Boost PTVs	Add	Lower	99.0	48.8	290
		Lower	100.0	44.5	270
		Upper	0.0	52.5	215
Boost GTVs	Add	Lower	100.0	51.5	200
		Upper	0.0	53.5	150
Hotspots	Add	Lower	100.0	52.5	250
		Upper	0.0	54.0	180
Rings	Add	Upper	0.0	52.5	180
PTV_WBopt07	Remove	Upper	0.1	31.5	300
		Upper	0.0	32.1	400
	Add	Upper	0.2	31.5	300
		Upper	0.1	32.1	400

- Plans were prescribed 30 Gy to the whole brain PTV and 50 Gy to the metastases in 10 fractions
- Used Eclipse Treatment Planning System v16.1 with Acuros XB
  - Photon Optimizer with convergence mode on
- Plans were evaluated using dose volume histograms, isodose distributions, dose metrics, and Varian's Dosimetric Scorecard
  - Developed a new dosimetric scorecard to fit physician's preferences for HSWB-SIB treatment

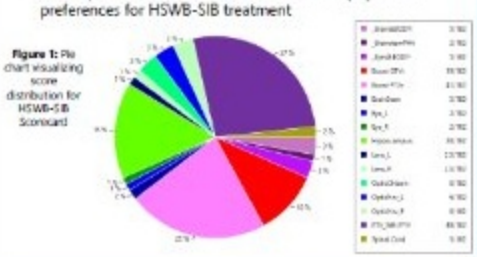

Figure 1: Pie chart visualizing score distribution for HSWB-SIB Scorecard

RESULTS

- Novel technique using post DVH estimation custom objective injection worked successfully for all three modalities
  - Generated plans in under 30 minutes
  - Developed simple UI for easy planning
- For plan comparisons, plans were normalized such that Whole Brain PTV D95% received 30 Gy
- Statistical analysis was done using Analysis of Variance followed by Tukey's test
- All OAR doses were clinically acceptable
- Dosimetric scorecard achieved average scores of 84.85 ± 5.65%, 86.45 ± 4.97%, and 87.39 ± 5.49% for Hal, TB-Co, and TB-HA, respectively
- Plan deliverability was found to be achievable for all modalities
  - Patient-Specific VMAT QA achieved passing gamma pass rates for all modalities
  - Independent Monte Carlo 2nd check agreed for all modalities
- Macroscopic lesions received an average BED D_{mean} of 85.0 Gy with an average max dose to the hippocampus of 11.48 Gy across all three modalities

Table 2: Evaluation of target coverage and hippocampus dose as well as planning feasibility, quality assurance, and deliverability metrics. Values are reported as mean ± standard deviation. A p-value < 0.05 was considered significant. Dose values for the Total Boost GTVs are reported in BED with α/β = 10 Gy for tumor. Patient-specific VMAT QA uses a γ criteria of 3%/2mm. Statistically significant p-values are highlighted in bold.

Structure	Metric	Modality			ANOVA P-Value	Significant Comparisons
		Hal	TB-Co	TB-HA		
Hippocampus	$D_{100\%}$ (Gy)	6.39 ± 0.32	7.26 ± 0.29	7.65 ± 0.32	**< 0.001**	TB-Co v TB-HA TB-Co v Hal TB-HA v Hal
	D_{mean} (Gy)	8.56 ± 0.49	8.78 ± 0.39	8.73 ± 0.30	0.429	-None-
	$D_{0.035cc}$ (Gy)	11.81 ± 0.96	11.51 ± 0.55	11.33 ± 0.61	0.105	-None-
Whole Brain PTV	$D_{98\%}$ (Gy)	27.90 ± 0.54	28.22 ± 0.46	28.57 ± 0.40	**0.008**	TB-HA v Hal
	$D_{2\%}$ (Gy)	37.84 ± 3.34	37.13 ± 3.14	36.87 ± 2.94	0.755	-None-
	V_{40Gy} (cc)	4.58 ± 2.63	3.98 ± 1.97	4.45 ± 2.21	0.806	-None-
Total Boost PTVs	$D_{98\%}$ (Gy)	50.60 ± 0.57	50.43 ± 0.41	51.13 ± 0.47	**0.005**	TB-Co v TB-HA TB-HA v Hal
	$D_{100\%}$ (Gy)	46.14 ± 1.61	45.76 ± 1.82	47.13 ± 1.35	0.132	-None-
Total Boost GTVs (BED)	D_{mean} (Gy)	85.47 ± 1.81	84.82 ± 1.10	84.73 ± 1.34	0.434	-None-
	$D_{0.03cc}$ (Gy)	88.65 ± 1.84	88.09 ± 1.29	87.34 ± 1.74	0.185	-None-
Total Calculation Time (min)		23.01 ± 1.81	29.70 ± 5.63	27.47 ± 3.14	**0.001**	TB-Co v Hal TB-HA v Hal
Total Monitor Units (MU)		1909 ± 187	2710 ± 370	1899 ± 188	**< 0.001**	TB-Co v TB-HA TB-Co v Hal
Patient-Specific VMAT QA γ Pass Rate (%)		99.99 ± 0.03	93.64 ± 2.52	97.51 ± 1.52	**< 0.001**	TB-Co v TB-HA TB-Co v Hal TB-HA v Hal
Monte Carlo 2nd Check Pass Rate (%)		98.92 ± 0.64	97.05 ± 1.17	99.17 ± 1.24	**< 0.001**	TB-Co v TB-HA TB-Co v Hal

- All three modalities achieved clinically acceptable plans
- Deliverability wise, TB-Co received the worst results, but still clinically acceptable
- Clinics should investigate which modalities best suits their needs

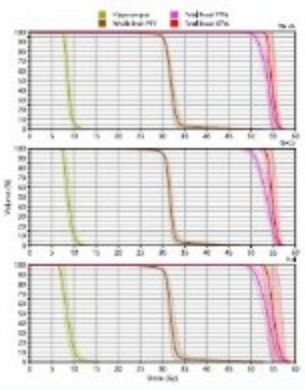

Figure 2: Composite DVHs for the three different modalities. The solid line is the mean value from all plans for that modality, the shadowed region spans from the minimum value to the maximum value from all plans for that modality. It is important to emphasize due to the context of this research, these are not DVH estimation bands.

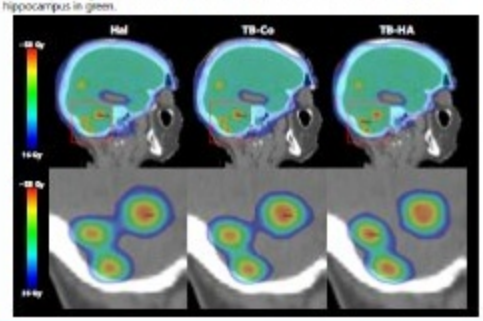

Figure 3: Isodose distributions for a case with 14 metastases. The top row shows a sagittal view of the isodose colorwash for all three modalities, with a lower limit of 16 Gy on the dose colorwash. The bottom row shows a zoomed in view of the region of interest indicated in the above image, now with a lower limit of 35 Gy on the dose colorwash to better demonstrate the differences in conformity among the three modalities. Contours shown are GTVs in red, PTVs in pink, and hippocampus in green.

CONCLUSIONS

- Easy and intuitive planning of fundamentally complex HSWB-SIB treatments in **under 30 minutes**
- This novel technique enables less skilled treatment planners to generate high-quality, clinically acceptable plans across three different modalities
  - Plans that achieve a therapeutic dose for the macroscopic disease while adequately covering the microscopic disease in the whole brain
  - OAR doses within tolerance of NRG CC001 protocol
- Implementing this technique would potentially enable busier clinics to use their time more effectively, while allowing smaller, more remote, clinics to provide the same quality of care to a commonly underserved patient cohort
- SIBI software planning to be released to community after further generalization

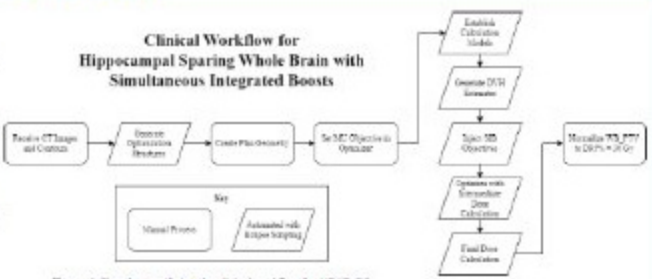

Figure 4: Flowchart outlining the clinical workflow for HSWB-SIB

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