Hippocampal Sparing Whole Brain: RapidPlan Model Validation Process

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Background

Knowledge Based Planning (KBP) is a solution that can expedite the treatment planning process while improving dosimetric standardization across treatment plans. RapidPlan™ is a commercial implementation of KBP (Varian Medical Systems, Palo Alto, CA). In 2016, a Hippocampal Sparing Whole Brain Model Version 1.0 (HSWBv1) was made publicly available.[2] From this model, we developed a new HSWB KBP model (HSWBv2).[1] This new model placed further emphasis on improving hippocampal sparing, homogeneity, and conformity. A scorecard was used to quantify and compare the relative dosimetric performance (score) for each method between HSWBv1 and HSWBv2.[3]

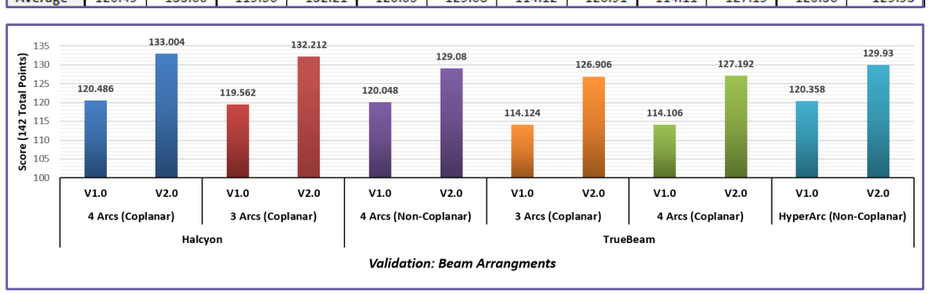
Figure 1: Example Version 2.0 scorecard; validation case score 131.4/142

Methods

Upon completion, HSWBv2 was then validated for use with various arc geometries, treatment machines, beam energies, calculation, and optimization methods. HSWBv2 utilized a training set of 42 cases. Five additional validation cases, not included in the original model training set, were used for further evaluating the plan quality between HSWBv1 and HWBv2. Different treatment delivery systems (Halcyon, Truebem, and C-series), beam arrangements (coplanar/non-coplanar, HyperArc™ , and 3-arc/4-arc VMAT), optimization settings (convergence modes), and calculations algorithms (AcurosXB/AAA) to validate that the HSWBv2.

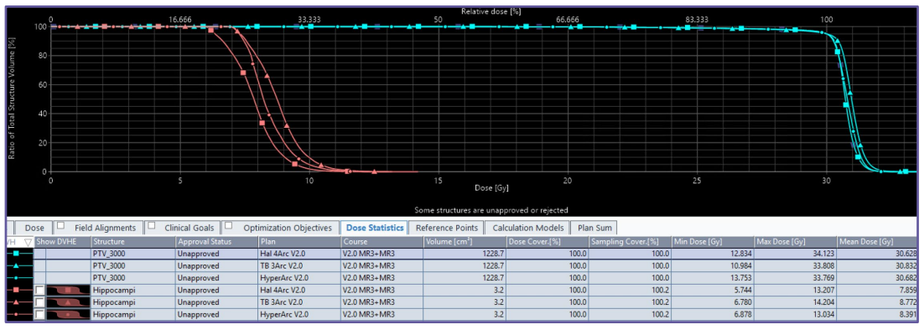
Table 1: Validation results for different beam arrangements (6X-FFF, AcurosXB v17, extended convergence mode, MR3 return, 2x Intermediate dose)

Validation Cases HSWB MR3+MR3												
	Halcyon				TrueBeam							
	4 Arcs (Coplanar)		3 Arcs (Coplanar)		4 Arcs (Non-Coplanar)		3 Arcs (Coplanar)		4 Arcs (Coplanar)		HyperArc (Non-Coplanar)	
Patient	V1.0	V2.0	V1.0	V2.0	V1.0	V2.0	V1.0	V2.0	V1.0	V2.0	V1.0	V2.0
36	120.38	132.64	118.46	131.55	121.41	128.72	112.73	126.39	113.35	127.36	118.23	129.4
37	122.87	132.91	119.37	131.92	123.41	129.42	116.91	128.69	117.4	129.46	120	130.1
39	120.57	132.97	119.24	132.89	122.69	129.36	114.17	126.79	113.98	126.3	121.45	130.4
40	119.8	133.56	120.33	132.72	118.08	129.89	112.89	125.9	112.85	126.65	119.54	130.31
41	118.81	132.94	120.41	131.98	114.65	128.01	113.92	126.76	112.95	126.19	122.57	129.44
Average	120.49	133.00	119.56	132.21	120.05	129.08	114.12	126.91	114.11	127.19	120.36	129.93



Different beam arrangements were tested on both Halcyon (SX2MLC) and TrueBeam (M120 MLC). Both the three and four arc Halcyon cases utilized collimator of 315°, (0°), 45°, and 90°. The four arcs non-coplanar Truebeam consisted of two full arcs (0° couch) and two vertex arcs (90° couch) rotating from 180° (PA) -> 5° (from AP) with all arcs utilized a 315°/45° collimator. The 3 arc coplanar plan utilized 315°, 45°, and 90° collimator. The 4 arc plans utilized the same collimator as the 3 arcs except 90° split X jaw superior/inferior to the hippocampus. HyperArc utilized the full 4 arc arrangement. This beam arrangement validation resulted in higher scores across all variations for HSWBv2 against HSWBv1.

Figure 2: Example DVH showing dose difference in hippocampi sparing and PTV coverage between Halcyon (4 arcs), Truebeam (3 arcs), and HyperArc plans.



Results

Convergence mode testing showed that longer optimization time and earlier/multiple returns correlated to higher plan scores. The use of AcurosXB resulted in improved scoring against AAA as well.

Figure 3: Dose calculation and beam energy (Eclipse v17 algorithms, extended convergence mode, MR3 return for intermediate dose)

Validation Cases HSWB V2.0 MR3					
	Halcyon 4 Arcs		Truebeam 4 Arcs Non-Coplanar		
Patient	AXB	AAA	6X-FFF AAA	6X AAA	6X AAA Non-Jaw Tracking
36	131.18	127.04	120.16	119.27	117.79
37	132.68	129.95	123.1	121.89	121.7
39	132.16	127.58	121.23	121.53	120.24
40	132.27	128.11	122.21	121.78	120.81
41	131.72	127.79	122.21	121.36	119.2
Average	132.002	128.094	121.782	121.166	119.948

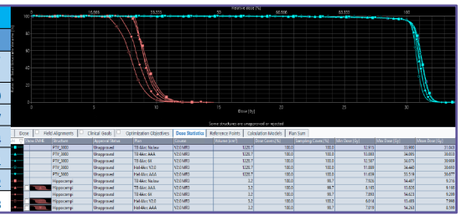
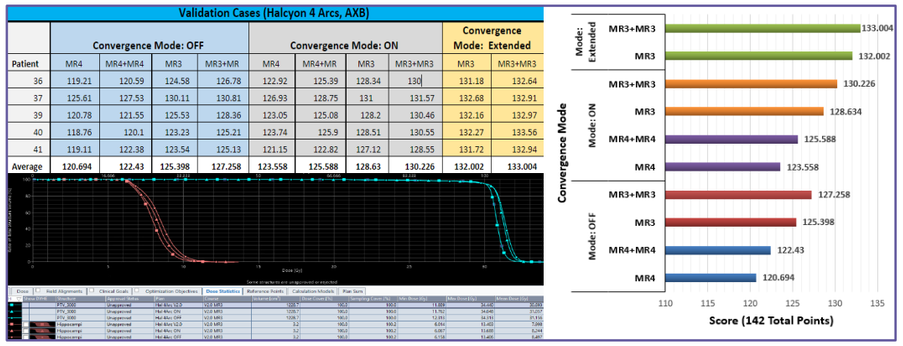


Figure 4: Convergence Mode: Off, On, Extended (Halcyon 4 arc, 6X-FFF, AcurosXB v17)

Validation Cases (Halcyon 4 Arcs, AXB)									
	Convergence Mode: OFF				Convergence Mode: ON				Convergence Mode: Extended
Patient	MR4	MR4+MR4	MR3	MR3+MR	MR4	MR4+MR	MR3	MR3+MR3	MR3	MR3+MR3
36	119.21	120.59	124.58	126.78	122.92	125.39	128.34	130	131.18	132.64
37	125.61	127.53	130.11	130.81	126.93	128.75	131	131.57	132.68	132.91
39	120.78	121.55	125.53	128.36	123.05	125.08	128.2	130.46	132.16	132.97
40	118.76	120.1	123.23	125.21	123.74	125.9	128.51	130.55	132.27	133.56
41	119.11	122.38	123.54	125.13	121.15	122.82	127.12	128.55	131.72	132.94
Average	120.694	122.43	125.398	127.258	123.558	125.588	128.63	130.226	132.002	133.004



Conclusions

The HSWBv2 model validation data shows improved results over HSWBv1. The refined scorecard metrics aided in better quantifying desired improvements according to community feedback from using HSWBv1. Testing HSWBv2 across multiple delivery systems, beam geometries, beam energies, optimization processing, and algorithms provides additional confidence in model quality and future use expectations. This KBP model is available for public use along with further information on how to implement the model in a clinical description document.[4]

Reference

(1) Liu, Hefei et al. "RapidPlan hippocampal sparing whole brain model version 2-how far can we reduce the dose?." *Medical dosimetry : official journal of the American Association of Medical Dosimetrists*, S0958-3947(22)00039-5. 2 May. 2022, doi:10.1016/j.meddos.2022.04.003.

(2) Magliari, Vanessa et al. "Hippocampal sparing whole brain: Rapid Plan Model Following the NRG-CC001 Protocol". AAMD conf poster present. 2017; (Published online available at:) https://medicalaffairs.varian.com/download/PosterPresentationAAMD2017RapidplanHCSWB.pdf

(3) https://github.com/Varian-Innovation-Center

(4) https://medicalaffairs.varian.com/wholebrain-hippocampalsparing-vmat2