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Multi-institutional Experience in Varian Halcyon Commissioning

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Abstract

The Varian Halcyon linear accelerator uses a ring-gantry architecture and dual-layer MLC to support streamlined image-guided treatment delivery. Unlike conventional C-arm linacs, Halcyon commissioning primarily verifies vendor-provided Golden Beam data rather than building an independent beam model. To provide practical commissioning benchmarks, we retrospectively reviewed commissioning data from nine Halcyon systems across five institutions, including four version 2.0 and five version 3.0 systems. Reference dosimetry, PDDs, output factors, beam profiles, and delivery validation were compared with Golden Beam data and relevant AAPM/IROC references. Across institutions, measurements demonstrated strong agreement with reference data. IROC output ratios ranged from 0.991–1.013, measured %dd(10)x ranged from 62.9–63.72%, output factor deviations were <0.7%, and beam symmetry met vendor specifications. TG-119 and IROC lung phantom results further confirmed accurate VMAT delivery. These findings support reproducible Halcyon commissioning across diverse clinical settings.

Introduction

The Varian Halcyon linear accelerator, featuring a ring-gantry design and dual-layer multileaf collimator (MLC), has gained increasing clinical adoption due to its streamlined workflow and operational efficiency. Unlike conventional C-arm linacs, Halcyon commissioning is centered on verification of vendor-provided Golden Beam data rather than independent beam modeling. However, published guidance on acceptable commissioning methodologies remains limited. This study presents a multi-institutional comparison of Halcyon commissioning practices and results.

Methods and Materials

Commissioning reports from nine Varian Halcyon systems across five medical centers (three community institutions and two academic institutions) were retrospectively reviewed, including four version 2.0 systems and five version 3.0 systems. Evaluations focused on dosimetric parameters that remain consistent across Halcyon versions, including reference dosimetry, percent depth dose (PDD), output factors, beam profiles, and delivery validation. A range of detectors, phantoms, and measurement workflows were employed across institutions. All measured data were compared against Varian Golden Beam data and relevant task group references.

Results

Across all institutions, commissioning measurements demonstrated excellent agreement with Varian Golden Beam data. For reference dosimetry, calibration accuracy was evaluated using available independent IROC validations, which showed a mean deviation of 0.93% and confirmed accurate output calibration. Percent depth doses (PDDs), output factors, and beam profiles exhibited minimal inter-institutional variability and closely agreed with reference values within established tolerances. Available VMAT delivery validation results, including TG-119 tests and IROC lung phantom irradiations, further confirmed stable geometric and dosimetric performance of the systems.

Reference Dosimetry: All institutions used a 100 cm SSD calibration geometry. Four institutions performed independent IROC validation, with dose ratios ranging from 0.991–1.013 cGy/MU (mean absolute deviation 0.925%), confirming accurate delivery. Measured %dd(10)x ranged from 62.9% to 63.72%, in agreement with the 63% vendor reference. An average initial output adjustment of 4.3% was reported.

Percent Depth Dose (PDD): Eight institutions measured PDDs at 90 cm SSD, and one at 100 cm SSD, using ion chambers or MicroDiamond detectors. Quantitative analyses from five institutions demonstrated consistent agreement with Golden Beam reference data across all field sizes.

Output Factors: Seven institutions measured output factors using 90 cm SSD at 10 cm depth, while two reported total scatter factors (Scp) using 95 cm SSD at 5 cm depth. All institutions used ion chambers for large fields and diode or MicroDiamond for small-fields (≤1 cm in any axis) with daisy-chaining. Measured output factors showed excellent agreement with Varian Golden Beam data, with a maximum deviation <0.7% and a mean absolute difference of 0.148%.

Beam Profiles: Most institutions used IC profiler arrays, with three also performing water-tank scans using ion chambers or MicroDiamond detectors. Quantitative comparisons were based on the 28 × 28 cm² field at 90 cm SSD and 10 cm depth, with off-axis evaluation at 10 cm. All institutions met the 2% vendor specification, with a mean absolute symmetry of 0.56%.

Delivery and End-to-End Validation: One institution performed TG-119 end-to-end testing, achieving gamma pass rates of approximately 100% for EPID (2%/2 mm, 10% LDT) and 99.2% for ArcCHECK (3%/3 mm, 10% LDT). Another institution completed IROC lung phantom validation, with superior and inferior TLD measured vs. institution ratios of 0.99 and 1.03 (within the 0.92–1.05 acceptance range) and an average film gamma pass rate of 95% (7%/5 mm), exceeding the 85% criterion.

Field Size X*Y	R100 [mm]			D50			D100			D200		
	Ref	Meas	Diff	Ref	Meas	Diff	Ref	Meas	Diff	Ref	Meas	Diff
2x2	11.7	11.83 ± 0.22	0.13	77.5	77.55 ± 0.07	0.05	53.8	53.59 ± 0.31	-0.21	26.8	26.58 ± 0.19	-0.22
4x4	12.0	12.10 ± 0.33	0.10	80.0	79.99 ± 0.19	-0.01	56.4	56.20 ± 0.26	-0.20	28.4	28.15 ± 0.18	-0.25
6x6	12.7	12.34 ± 0.41	-0.36	81.6	81.56 ± 0.14	-0.04	58.5	58.36 ± 0.20	-0.14	30.0	29.82 ± 0.18	-0.18
8x8	12.2	12.36 ± 0.45	0.15	82.7	82.46 ± 0.07	-0.24	60.2	59.95 ± 0.20	-0.25	31.4	31.14 ± 0.23	-0.26
10x10	12.7	12.33 ± 0.40	-0.37	83.3	83.12 ± 0.04	-0.18	61.5	61.25 ± 0.27	-0.25	32.7	32.41 ± 0.25	-0.29
20x20	11.8	11.74 ± 0.68	-0.06	84.6	84.52 ± 0.10	-0.08	64.7	64.30 ± 0.22	-0.40	36.5	35.93 ± 0.29	-0.57
28x28	11.4	11.38 ± 0.77	0.03	85.1	84.95 ± 0.18	-0.15	65.7	65.34 ± 0.18	-0.36	37.7	37.26 ± 0.34	-0.44

Table 1. Comparison of PDD (90cm SSD). Varian Golden beam data as reference.

Field Size X*Y	Output Factor		
	Ref	Meas	Diff
1x1	0.697	0.698 ± 0.004	0.132
2x2	0.804	0.803 ± 0.004	-0.053
4x4	0.880	0.882 ± 0.002	0.187
6x6	0.930	0.932 ± 0.002	0.171
8x8	0.969	0.970 ± 0.001	0.129
10x10	1.000	1.000	0.000
14x14	1.044	1.045 ± 0.002	0.140
20x20	1.086	1.087 ± 0.002	0.139
24x24	1.108	1.106 ± 0.002	-0.184
28x28	1.113	1.115 ± 0.002	0.150

Table 2. Comparison of output factors.
(90cm SSD at 10cm depth)

	In-plane	Cross-Plane
OAI Spec ±10cm (%)	75.5 ± 2	
Symmetry Spec	2%	
Actual OAI -10cm (%)	75.74 ± 0.72	75.30 ± 01.59
Actual OAI +10cm (%)	75.2 ± 0.98	75.44 ± 0.63
Actual Mean Abs Symmetry	0.50 %	0.62 %

Table 3. Comparison of beam symmetry and off axis intensity.
(90cm SSD at 10cm depth)

TG-119 Plan	Gamma Passing Rate		
	TG-119 Reference	Measured ArcCheck	Measured PEID
Multitarget	99.1 ± 0.9	99.4%	100.0%
Prostate	98.0 ± 2.2	99.1%	99.9%
Head & Neck	96.2 ± 3.0	99.0%	100.0%
C-Shape (Easy)	97.6 ± 3.9	98.8%	99.9%
C-Shape (Hard)	94.4 ± 7.2	99.7%	100.0%

Table 4. TG-119 VMAT delivery validation.

Discussion

This multi-institutional experience shows that Halcyon commissioning results are highly reproducible despite differences in institutional workflow, detector selection, phantom setup, and measurement strategy. The strong agreement between measured data and Varian Golden Beam data suggests that Halcyon commissioning can be effectively approached as a verification process when appropriate detectors, small-field measurement techniques, and independent validation tests are used.

Reference dosimetry results showed consistent output calibration, supported by independent IROC validation in four institutions. PDD, output factor, and profile measurements demonstrated minimal inter-institutional variability across clinically relevant field sizes. Small-field output measurements required careful detector selection and daisy-chaining but still showed excellent agreement with reference data. Beam-profile measurements also confirmed stable off-axis response and symmetry, meeting vendor specifications.

Delivery validation provided complementary confirmation of clinical performance. TG-119 VMAT testing demonstrated high gamma passing rates using both EPID and ArcCHECK measurements, while IROC lung phantom irradiation confirmed end-to-end geometric and dosimetric accuracy.

Together, these results suggest that a combined commissioning strategy—reference dosimetry, water-tank or array-based beam-data verification, small-field output validation, and independent end-to-end testing—provides a robust framework for Halcyon clinical implementation.

Limitations include the retrospective nature of the study, variation in available datasets across institutions, and incomplete quantitative reporting for some commissioning categories. However, the consistency of results across academic and community centers supports the use of these data as practical reference benchmarks for institutions commissioning Halcyon systems.

Conclusions

This multi-institutional study demonstrates that Halcyon commissioning results are highly reproducible across diverse clinical settings. Despite variations in commissioning methodologies, appropriate measurement strategies consistently verified agreement with Golden Beam data. These findings provide practical guidance and reference benchmarks for clinical medical physicists and may serve as a valuable resource for institutions undertaking Halcyon commissioning.

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