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Longitudinal assessment of Daily QA measurements in Elekta Harmony Linear Accelerator

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Abstract

In this project, we evaluated the longitudinal dosimetric and mechanical performance on first Elekta Harmony LINAC in the United States, during its first year of clinical use. Daily QA data were measured using the Sun Nuclear DailyQA ™ device; QA data were logged in TotalQA. We analyzed metrics such photon and electron output constancy, beam energy constancy, flatness, symmetry, jaw positioning, and field-size accuracy. Deviations from baseline were analyzed over time, and event dates were reviewed to support root-cause assessment.

Our results showed photon and electron output constancy remained less than 3%. Energy constancy averaged less than 2% for photon and electrons. Mechanical shifts and field-size deviations were <0.3 cm, and flatness deviations were <3%. The Elekta Harmony LINAC demonstrated stable dosimetric and mechanical performance during its first year of clinical operation, with results remaining within TG-142 and institutional QA tolerances.

Introduction

Mary Bird Perkins Cancer Center was the first clinic to install the Elekta Harmony in the United States. The AAPM TG-142 requires daily quality assurance on linac to ensure machine performance such as dosimetry, mechanical and safety hasn't been compromised since last patient treatment the previous day. One of the mandatory daily QA test is the machine output. This test are essential for verifying that linear accelerator performance remains consistent with commissioning baselines and institutional tolerances. We conducted this project to provide an early longitudinal assessment of daily QA performance during the system's first year of clinical use.

We reviewed and analyzed the Daily QA trends over first one year of clinical use of the newly installed Elekta Harmony Linac, to evaluate the dosimetric and mechanical stability of photon and electron beams over time. Overall, the Elekta Harmony LINAC demonstrated stable performance, with measured deviations remaining within TG-142 and institutional action levels. These results establish preliminary benchmark data for routine QA trending in our clinic. In the future the trending value will provide longitudinal monitoring to prevent machine downtime for maintaining reliable clinical operation.

Methods and Materials

- Daily QA data were acquired using the Sun Nuclear Daily QA™ (DQA3) system. Measurements were performed using a 20 × 20 cm² field at a nominal dose rate of 600 MU/min; with photon measured at SSD = 100 cm, while electron were acquired at SSD = 95 cm. The DQA3 report records beam output constancy, flatness, symmetry, energy constancy, field-size deviation, and positional shifts relative to baseline. All data were automatically corrected for Temperature and pressure in the DQA3 device.
- All raw data were stored in our QA database (TotalQA). We exported data from December 2024 to December 2025 (1st year of clinical use) for longitudinal analysis on the Elekta Harmony LINAC.
- Evaluated parameters included photon and electron output constancy, beam energy constancy, flatness, symmetry, jaw positioning, and field-size accuracy. Each daily measurement was compared with its baseline value to quantify longitudinal deviation. Photon and electron beams were analyzed separately to evaluate energy-specific performance trends.
- Event dates were reviewed to help identify service-related changes or possible causes of observed deviations. Outlier data near 100% deviation and cells with empty values were excluded from the stability analysis to avoid skewing the longitudinal performance assessment.

Table 1. Summary of daily QA stability metrics. Values represent mean absolute deviation, standard deviation and 95th percentile across valid measurements. Field-size deviations were converted using the nominal 20 cm x 20 cm field size..

Metric	Energies	Absolute mean deviation	STD (max)	P95%
Output constancy	6X, 6X FFF, 6X Wedge, 10X, 10X FFF	0.71–1.24	0.46	1.18–1.93%
Energy check	6X, 6X FFF, 6X Wedge, 10X, 10X FFF	1.52–1.77	1.26	3.41–4.12%
Flatness	6X, 6X FFF, 6X Wedge, 10X, 10X FFF	0.14–0.30	0.33	0.35–0.82%
Field size	6X, 6X FFF, 6X Wedge, 10X, 10X FFF	0.04–0.06	0.04	0.06–0.19 cm
Output constancy	6e, 9e, 12e, 15e	0.56–0.91	0.95	1.10–1.34%
Energy check	6e, 9e, 12e, 15e	0.42–1.39	0.29	1.08–2.93%
Flatness	6e, 9e, 12e, 15e	0.08–0.21	0.25	0.24–0.56%
Field size	6e, 9e, 12e, 15e	0.003–0.034	0.03	0.03–0.06 cm

Results

Photon output constancy remained stable across all energies, with maximum mean deviations 1.24% ± 0.4%. The maximum photon output deviation was −2.41% for 6X FFF, with the 95th percentile ~ 2%. Electron output constancy demonstrated slightly greater stability, with mean deviations <1% ± 0.3% and a 95th percentile of approximately 1.2%. The maximum electron output deviation was −1.63% for 6 MeV.

Beam energy constancy ranges from 1.52–1.77 % for photons and 0.42–1.39% for electrons. Absolute deviations for mechanical shifts and field-size accuracy were <0.3 cm across photon and electron beams. The maximum field size was 0.25 cm for 10X beam, while the maximum flatness reported was 2.4% for 6X.

Flatness and symmetry deviations in both radial and transverse directions were <2.5% for all evaluated energies. Overall, electron beams demonstrated smaller absolute mean output deviations than photon beams, with electron deviations ranging from 0.56%–0.91% compared with 0.71%–1.24% for photons.

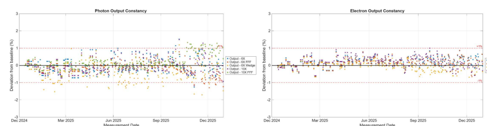

Fig 1. Output constancy deviation for photons (left) and electron (right). Plots were normalized using the first measurement as a baseline.

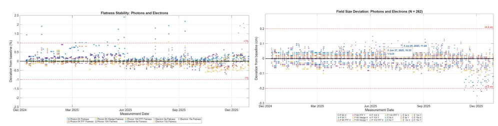

Fig 2. Flatness deviation (left) and field size deviation (right) for all photon and electron energies.

Discussion

Over the one-year evaluation period, electron beams demonstrated slightly greater output stability than photon beams. Daily electron output constancy showed mean absolute deviations ranging from 0.56% to 0.91%, compared with 0.71% to 1.24% for photon beams. All evaluated dosimetric and mechanical parameters remained within institutional tolerances: **3% dosimetric warning level and the 0.3 cm mechanical action level**.

A total of 262 measurement days were available for review. Days or entries with missing values were excluded from the analysis. In addition, outliers with values near 100% were excluded as it does not represent valid daily QA measurements. These entries were likely associated with beam interruptions, machine service events, or machine checkout procedures following repairs, rather than true beam-performance deviations. Overall, the results indicate stable LINAC performance over one year of clinical operation, aside from unrelated service events (e.g., imaging-system issues or other non-beam LINAC faults).

This study establishes the first quantitative, longitudinal benchmarks for its Daily QA performance. Our results serve as a practical reference for other centers regarding commissioning expectations and long-term operational stability. The findings validate that vendor-stated specifications are consistently met in a real-world clinical environment. Future work will focus on identifying longitudinal trends for monthly and daily to enhance QA efficiency, optimize service scheduling, and minimize system downtime.

Conclusions

The Elekta Harmony LINAC demonstrated dosimetric and mechanical stability during its initial year of clinical operation in our center. Overall performance remained stable, with maximum deviations consistently within TG-142 and our institutional clinical protocols.

Future study will be to extend the longitudinal tracking to improve QA efficiency, aid in proactive service scheduling, and minimize downtime while maintaining high-quality clinical delivery. Outliner data (near 100% deviation) was excluded from analysis to ensure accurate stability tracking.

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