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JOINT AAPM | COMP MEETING

Independent Quality Control to Improve Stability and Reduce Calibration Time In Elekta Linear Accelerators

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ABSTRACT

Purpose: To reduce the frequency of calibration and adjustment of Elekta linear accelerator components, including MLCs, jaws, mechanical isocenter, beam spot position, symmetry, and flatness.

Methods: Independent quality control (QC) procedures were developed to assess Elekta linear accelerator performance. These procedures were independent of, yet aligned with, manufacturer calibration methodologies to minimize false-positive action levels and unnecessary recalibrations. In-house scripts were developed for data analysis, and all procedures and scripts will be publicly available.

Results: Twelve beam matched Elekta linear accelerators were evaluated over a five-year period. Tolerance and action levels were established to meet published guidelines while maximizing machine performance and limiting calibration and adjustment time to ≤1 h/month. MLC and jaw field size and field center stability were within 0.3 mm and 0.5 mm, respectively. Beam spot position remained within 0.5 mm at gantry 0 and 1.0 mm at non-zero gantry angles. Beam symmetry and flatness were stable within 0.5% at gantry 0 and 1.0% at non-zero gantry angles. mechanical sag, CBCT flexmap and isocenter deviations from month to month were ≤0.5 mm. End-to-end testing was done on 3 units with hexapod couch and demonstrated stability within 0.6 mm for two units and 1.3 mm for the other unit.

Conclusion: This framework allows Elekta linear accelerator users to independently verify machine performance at no cost, exceed manufacturer specifications, and maintain calibration and adjustment time below one hour per month per machine.

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INTRODUCTION

The objective of this project was to reduce the frequency of calibration and adjustment of Elekta linear accelerator components, including MLCs, jaws, mechanical isocenter, beam spot position, symmetry, and flatness. The objective was achieved in 3 steps.

First step was to build in-house quality control (QC) procedures that are reproducible, precise and matching the procedures used by Elekta field service engineer (e.g. 0.5 mm error on leaf #20 positioned at –10 cm gives the same error in our in-house procedure as in the Elekta self-calibration procedure).

Second step was achieved by monitoring changes in accelerator performance over 5 years (e.g. how leaf positioning is changing if you don't recalibrate periodically).

Third step was choosing specific calibration frequency and tolerance/action windows for each accelerator components. Accelerators were then monitored for 5 years to document the results.

METHODS AND MATERIALS

The mlc and jaws in-house QC procedures are similar to the Elekta self calibration process except that it covers the full range of leaf motion (instead of half). It also checks speed and orthogonality. Figure 1 shows one quadrant of results (upper left).

The mechanical in-house QC procedures (gantry, collimator, couch, isocenter for accelerator and imaging) are similar to the Elekta installation procedures except that the flexmap are done with collimator 0-180 instead of 90-270 degrees to allow checking the mlc brakes at gantry 90 and 270. Figures 2 shows an example of results.

The beam in-house QC procedures (symmetry, output, flatness, beamspot) were based on the +- 12 cm position used by Elekta Field service engineer to set flatness and symmetry. Figure 3 shoes an example of results

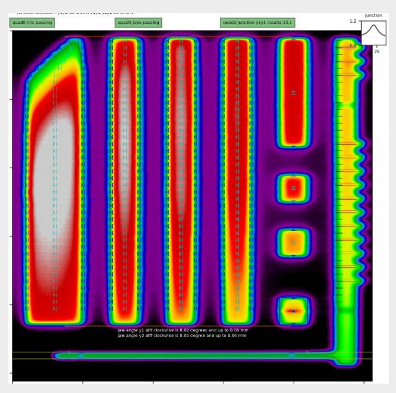

Figure 1. Example of MLC results

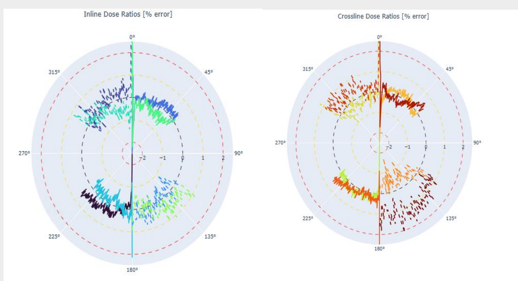

Figure 2. Example of beam results

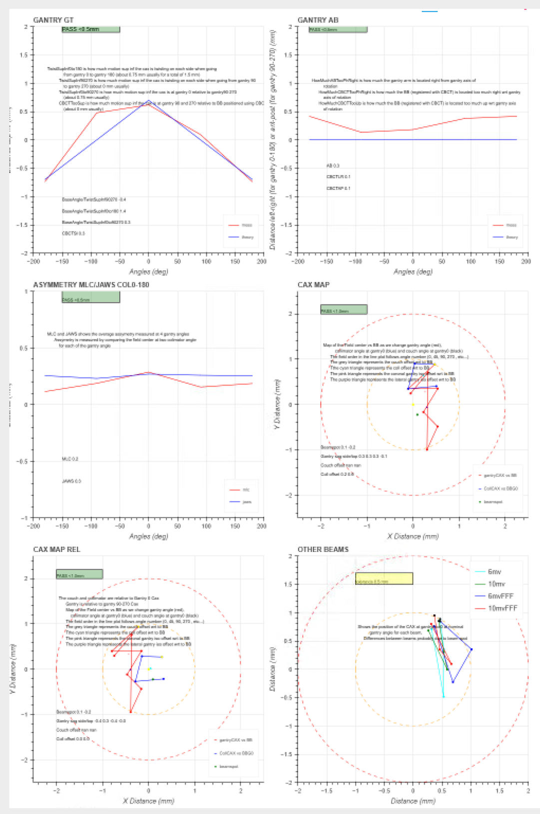

Figure 3. Example of mechanical results

RESULTS

Table 1 shows the tolerance used for in-house monthly QC. Those tolerances were found to be optimal after monitoring 5 years the reproducibility of accelerator components, long term stability, clinical needs and change-induced risks associated with any accelerator modification.

Parameter	Tolerance
Flatness, Symmetry, BeamSpot, Output, Steering Tables	0.5 %, 0.5 mm 6MV, 6MVFFF 0.7 %, 0.7 mm 10MV, 10MVFFF
Flexmap, Isocenter, Couch	0.5 mm sup inf iso 0.75 mm
MLC, jaws	0.5 mm (within 12 cm) 0.75 mm (> 15 cm)
Collimator, Gantry Angle	0.3 degrees
Total Accuracy (End-To-End)	1 mm, 2%

MLC findings: MLC gap size error for a 2 cm opening was 0.3 mm. Gain overtravel and undertravel errors were 0.25 and 0.35 mm per 150 mm travel. Y1 jaws offset was 0.4 mm and needs manual correction in accelerator to avoid Y1Y2 junctions error of 12%. After initial calibration, MLC leaf width may be used to derive an iView panel calibration parameter mm/pixel that is stable within 0.012 % over 10 years. MLC/Jaws calibration are only performed after parts change unless gain error is more than 0.5 mm per 150 mm travel.

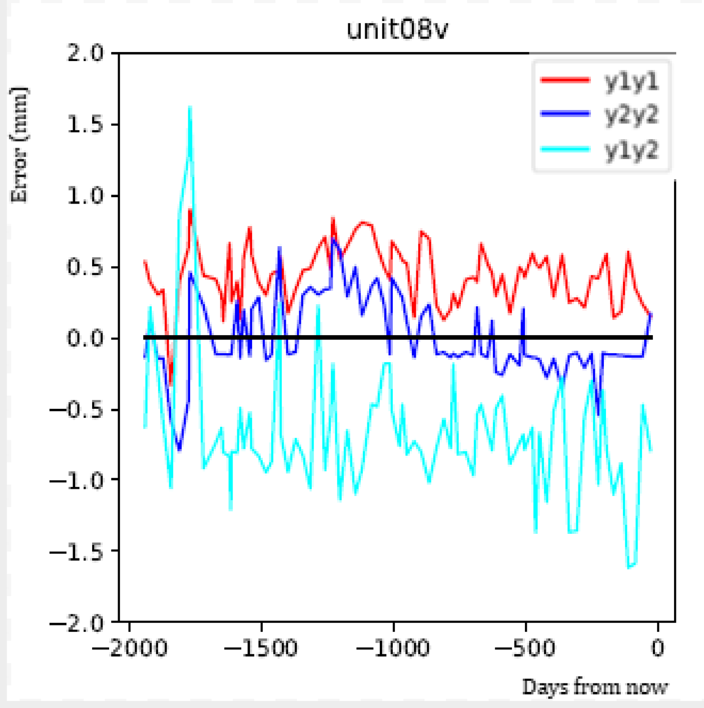

Figure 4. Typical jaw junction error

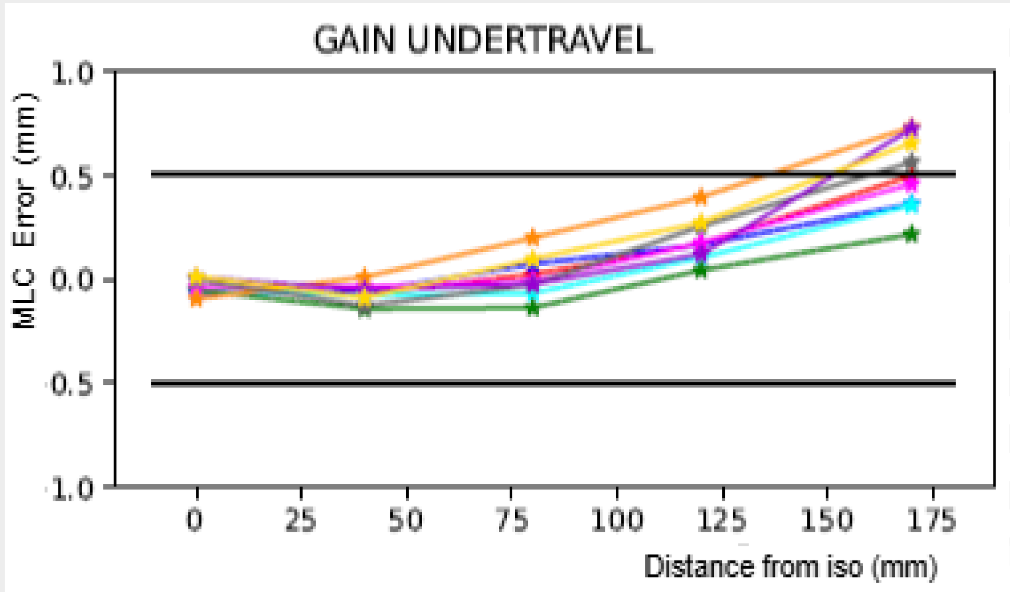

Figure 5. Average MLC error for 9 units over 6 years.
Gain undertravel error is about 0.35 mm per 160 mm of travel.

Mechanical findings: Sup-Inf isocenter radius (0.5 mm) is stable over time but flexmap sup inf error may degrade 0.2 mm per year on some units. Collimator error at angle 0 wrt to gantry axis of rotation has variability of 0.3 degrees from month to month. Reproducibility of other collimator angles relative to angle 0 is within 0.1 degrees from month to month.

Couch isocenter is 0.4 mm off in both direction (LR, SI) from acccelerator isocenter.

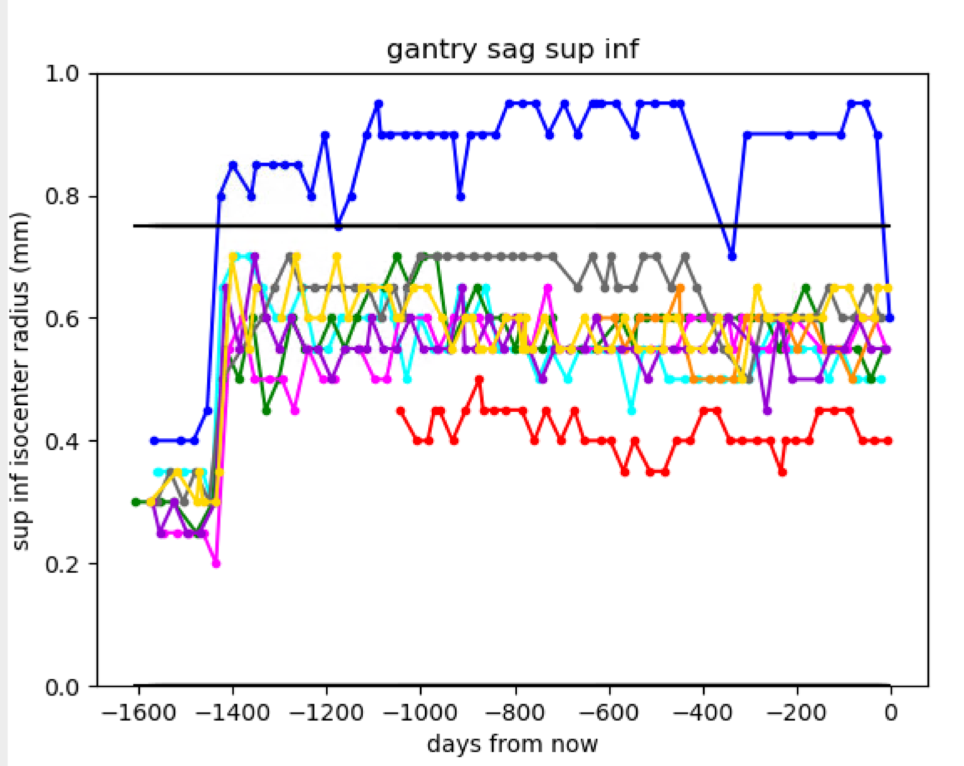

Figure 6. Sup Inf isocenter radius tolerance 7.5 mm

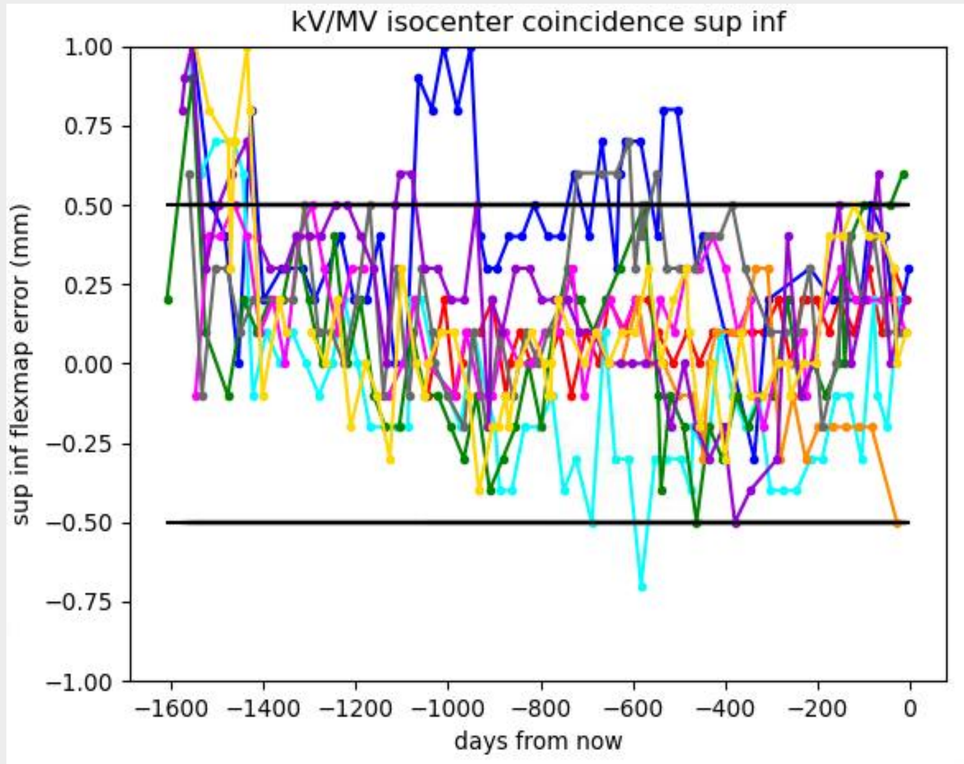

Figure 7. kV/MV isocenter coincidence tolerance 0.5 mm

Beam findings: Beamspot measured with epid (2nd order effect between jaws and mlc) did not correlate with standard beamspot measurements done with a detector on a corotating platform. Monthly beam tuning (peaking dose rate) is required. Adjustments of flatness, symmetry and beamspot is needed every year for each beam energy but it is difficult to predict when (check every months). Flatness can drift about 1% every year if left unchecked even if dose rate is peaked avery month.

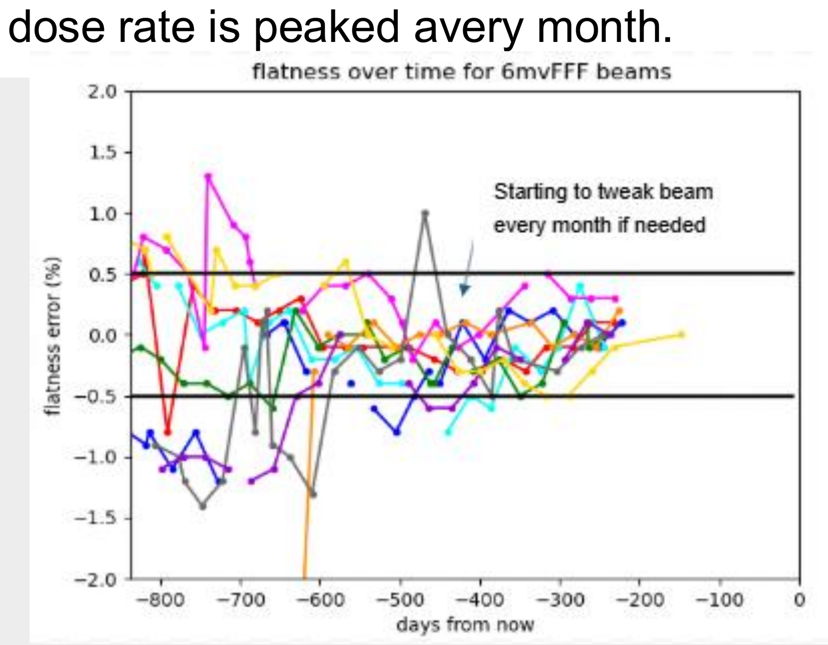

Figure 7. Flatness error for 9 units.

DISCUSSION AND CONCLUSIONS

This information allows Elekta linear accelerator users to independently verify machine performance at no cost using in-house codes, exceed manufacturer specifications, and maintain calibration and adjustment time requirements below one hour per month per machine. Codes will be freely accessible in Jan 2027 for interested users.