

Evaluation of the cumulative signal response with the electronic portal imaging device (EPID) and the integral quality monitor (IQM) for patient-specific SBRT QA

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INTRODUCTION

A key reason for performing patient-specific quality assurance (QA) is to ensure safe and proper delivery of treatment plans. Differences between the planned and measured dose distributions can arise due to a variety of factors such as multi-leaf collimator (MLC) position errors. The electronic portal imaging device (EPID), a widely used tool for QA, has limitations including reproducibility, small fields, and high modulation. This becomes especially critical for Stereotactic Body Radiotherapy (SBRT) plans, which utilize small fields, high modulation, and large dose gradients outside the treatment volume. In this study, we compare SBRT QA results and error sensitivity for an EPID and a large-area ionization chamber.

AIM

To compare the results of the cumulative signal for patient-specific SBRT quality assurance performed with an electronic portal imaging device (Varian TrueBeam aS1200) and an integral quality monitor (IRT Systems IQM).

METHOD

- Cumulative signal evaluation for quality assurance:**
 - Performed on a Varian TrueBeam linear accelerator using the on-board EPID and the IQM.
 - Eight retrospective SBRT plans (16 arcs) were used.
 - Selected plans featured small field segments and relatively high modulation (i.e. MU / dose delivered).
- EPID:**
 - The cumulative signal for the EPID was evaluated using the ratio of the measured to predicted portal dose. A threshold of 1% was utilized to account for EPID noise.
- IQM:**
 - The cumulative signal for the IQM was evaluated using the ratio of the measured to calculated reference signal.
- Investigation of cumulative signal with MLC errors:**
 - Five retrospective SBRT plans (10 arcs) were used: one lung plan, one prostate plan, one spine plan, one kidney plan, and one pelvis plan.
 - Six MLC error plans were created for each original SBRT plan: systematic close (-0.25mm, -0.50mm, -0.75mm) and open (0.25mm, 0.50mm, and 0.75mm).
 - MLC error sensitivity was evaluated using the cumulative signal difference between the baseline and error-induced measurements.
 - Gamma analysis with 3%/1mm, 3%/0.5mm, and 1%/1mm dose difference (DD) and distance to agreement (DTA) criteria was evaluated for the EPID measurements as a reference.

RESULTS

Cumulative Signal		
	EPID	IQM
Mean	1.026	0.984
Standard Deviation	0.005	0.012
Range	0.014	0.035

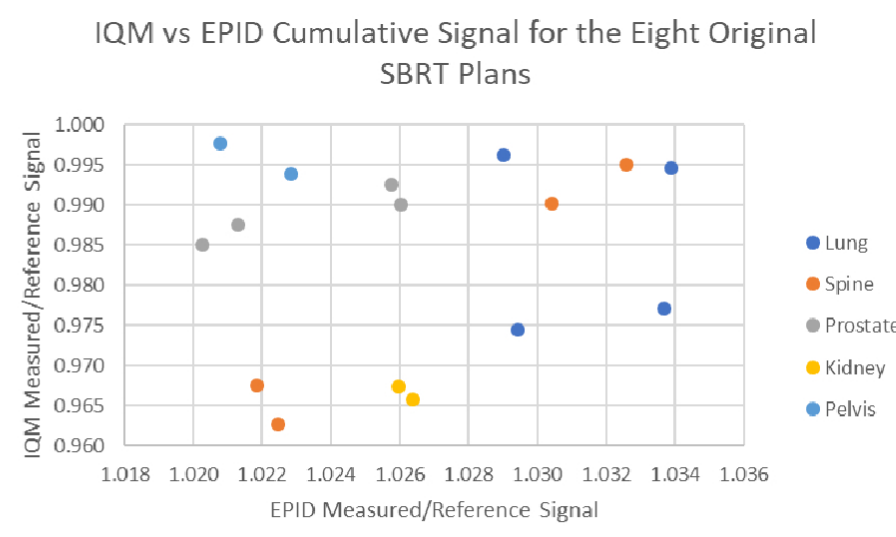


Figure 1: Cumulative signal for the eight retrospective SBRT plans. Table I (left) shows the overall mean, standard deviation, and range of the cumulative signal for these plans.

Plan Error Type		EPID				IQM
		Average Difference from Baseline	% Pixels with Average Gamma < 1.0			Average Difference from Baseline
			3%/1mm	3%/0.5mm	1%/1mm	
Systematic Close	-0.75mm	-7.50 ± 1.54%	93.32 ± 4.61%	73.63 ± 10.53%	84.45 ± 5.04%	-6.55 ± 1.23%
	-0.50mm	-5.14 ± 1.12%	98.85 ± 1.11%	86.85 ± 3.63%	95.34 ± 2.21%	-4.39 ± 0.78%
	-0.25mm	-2.70 ± 0.62%	99.84 ± 0.15%	96.68 ± 0.99%	98.56 ± 0.99%	-2.28 ± 0.47%
Systematic Open	0.25mm	1.44 ± 0.37%	97.02 ± 3.58%	81.50 ± 8.90%	84.81 ± 3.79%	1.37 ± 0.28%
	0.50mm	4.00 ± 0.99%	85.45 ± 11.38%	57.51 ± 18.16%	69.37 ± 5.81%	3.37 ± 0.85%
	0.75mm	6.96 ± 1.72%	65.56 ± 15.22%	51.23 ± 15.31%	49.53 ± 6.60%	6.62 ± 1.56%

Table II: Average cumulative signal difference from baseline for the EPID and IQM and gamma analysis for MLC error-induced SBRT plans.

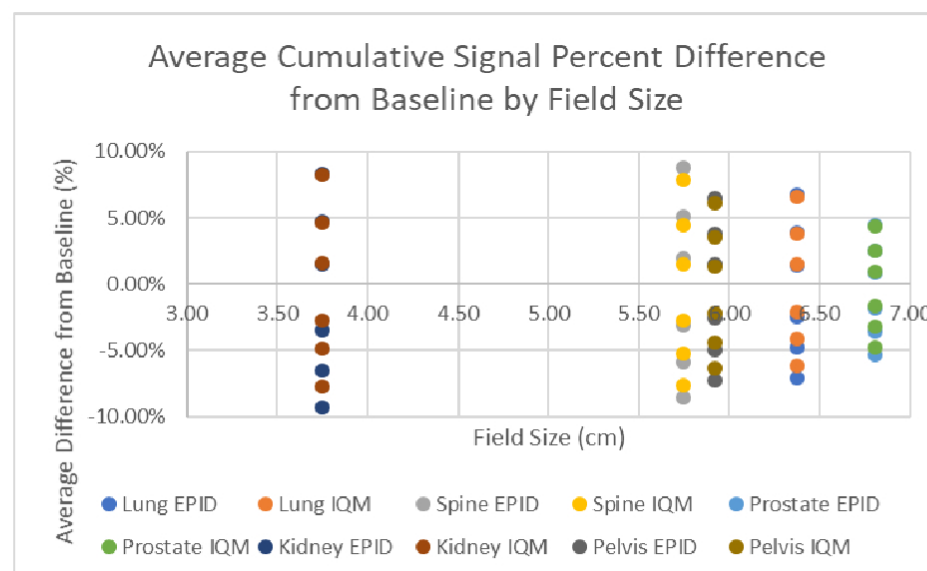
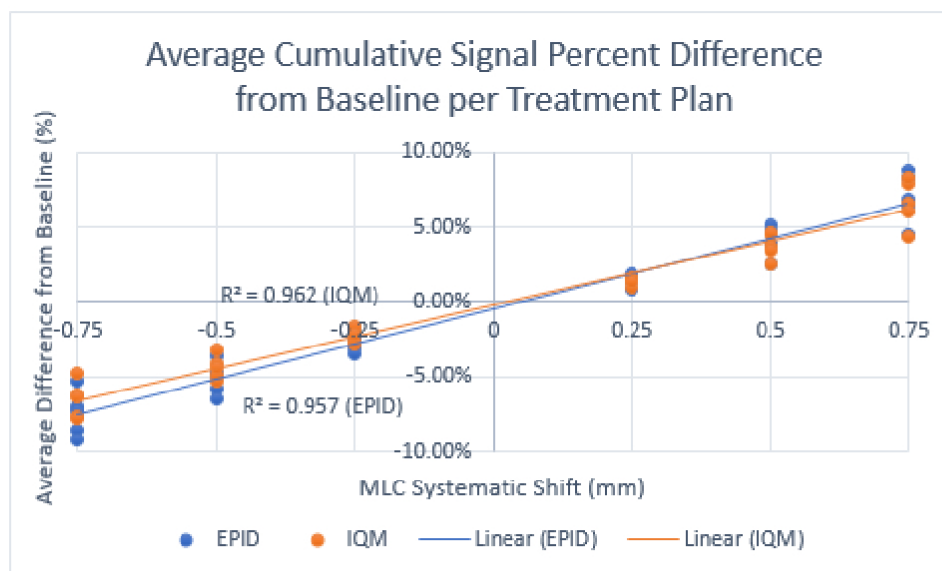


Figure 2 (left): Average percent difference of the cumulative signal from MLC error-induced plans to the original SBRT treatment plan.

Figure 3 (right): Average cumulative signal difference from baseline, per plan and device, as a function of field size.

CONCLUSIONS

- In the eight original SBRT plans, the greater range and larger standard deviation of the IQM's cumulative signal reinforces that the IQM is more sensitive to dose differences than the EPID.
- No correlation was observed between the cumulative signal for both devices and the type of SBRT plan.
- The average cumulative signal percent difference correlates (IQM Pearson correlation of 0.962 and EPID Pearson correlation of 0.957) between the detectors with each type of MLC error plan type and with gamma analysis.
- The difference in cumulative signal between the two detectors is not significant. This can be attributed to the chosen EPID threshold of 1%.
- The cumulative signal shows larger differences from baseline for smaller fields compared to larger field sizes.
- Deviations from the measured reference signal can be observed along each arc's control points with the IQM. This presents an avenue in determining the position in an arc where a treatment field is failing.
- Further studies include:
 - Determining if a correlation exists between the cumulative signal difference from the MLC error-induced plans and differences in the DVH compared to the original treatment plan.
 - Determining an appropriate threshold percentage for the EPID to account for noise.
 - Determining appropriate cumulative signal thresholds for patient-specific QA passing criteria.

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REFERENCES

Saito, M., Sano, N., Shibata, Y., Kuriyama, K., Komiyama, T., Marino, K., . . . Onishi, H. (2018). Comparison of MLC error sensitivity of various commercial devices for VMAT pre-treatment quality assurance. Journal of Applied Clinical Medical Physics, 19(3), 87-93. doi:10.1002/acm2.12288

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