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Comparison of patient-specific IMRT QA with the integral quality monitor (IQM) and the electronic portal imaging device (EPID)

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INTRODUCTION

Effective radiation therapy is contingent upon the correct delivery of plans sent to treatment machines by the treatment planning system. Complex treatment techniques, such as intensity modulated radiotherapy (IMRT), may be subject to differences between the planned and measured dose distributions due to a variety of factors. These include: machine output fluctuations, multi-leaf collimator (MLC) position errors, and jaw position errors. Thus, patient-specific IMRT quality assurance (QA) is a vital part of the treatment process. In this study, we compare IMRT QA results and error sensitivity for a large-area ionization chamber and an electronic portal imaging device (EPID).

AIM

To compare patient-specific IMRT QA and MLC error sensitivity of the integral quality monitor (iRT systems IQM) and EPID (Varian TrueBeam aS1000).

METHOD

- **Comparison of pre-treatment quality assurance:**
  - Performed on a Varian TrueBeam linear accelerator using the IQM and on-board EPID.
  - Twenty retrospective VMAT plans (53 fields) were used, some of which were highly modulated or contained small fields.
- **IQM evaluation:**
  - Deviation of the measured cumulative signal from the calculated reference cumulative signal per field
- **EPID evaluation**:
  - Gamma analysis with 3%/3mm, 2%/2mm, 1%/1mm, 3%/1mm dose difference (DD) and distance to agreement (DTA) criteria was performed to provide a reference for traditional pre-treatment QA results.
  - Deviation of the cumulative signal, defined as the relative difference of the sum of pixel values from the predicted and measured portal dose images, to provide a direct comparison to IQM results.
- **Investigation of MLC error sensitivity:**
  - Ten retrospective VMAT plans (24 fields) were used: three head and neck plans, two lung stereotactic body radiation therapy (SBRT) plans, three prostate plans, and two spine (SBRT) plans.
  - Eight MLC error plans created for each original VMAT plan: systematic open (0.25mm, 0.50mm, and 0.75mm) and close (-0.25mm, -0.50mm, -0.75mm), shifting every 4th leaf in bank A by 1mm, shifting leaves 1mm in groups of four in bank B.
  - MLC error sensitivity was evaluated using the cumulative signal difference between the baseline and error-induced measurements. Gamma analysis was also used as an evaluation tool for measurements performed with the EPID.

RESULTS

VMAT Pre-Treatment Quality Assurance

IQM

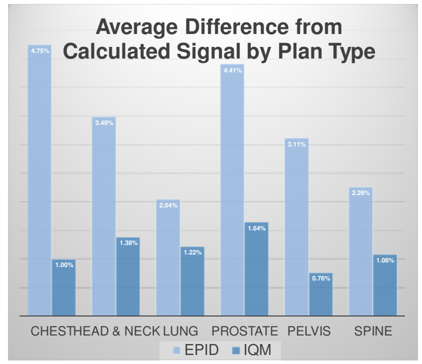
Measured vs. Calculated Reference Signal	
Average percent difference:	1.27 ± 0.90

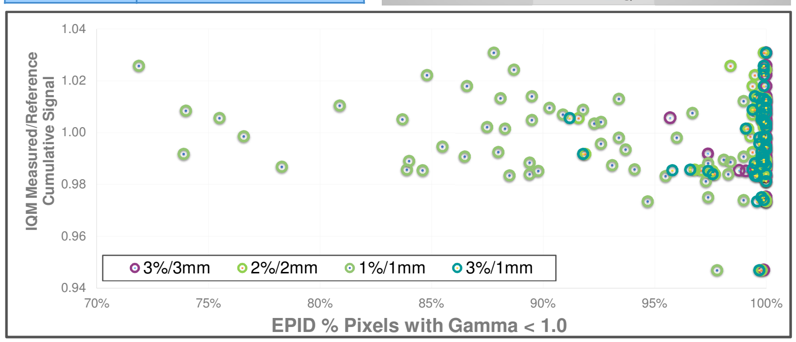
EPID

Measured vs. Calculated Reference Signal	
Average percent difference:	3.40 ± 1.55

Gamma Analysis

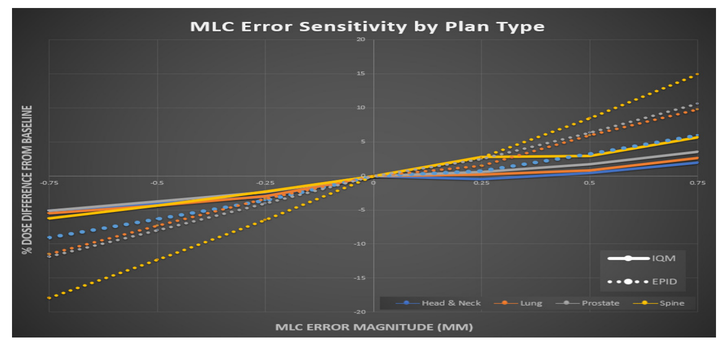
Criteria (DD/DTA)	Pixels with Gamma < 1.0 (mean, %)
3%/3mm	99.81 ± 0.70
2%/2mm	99.29 ± 1.66
1%/1mm	89.77 ± 7.11
3%/1mm	99.28 ± 1.75





MLC Error Sensitivity

Plan Error Type		IQM: Average Difference from Baseline	EPID: Average Difference from Baseline	EPID: % Pixels with Average Gamma <1.0: 3%/3mm	2%/2mm	1%/1mm	3%/1mm
Every 4th leaf 1mm		-0.28%	1.08%	99.95%	99.63%	93.30%	99.70%
Groups of 4 leaves1mm		0.90%	3.32%	99.78%	97.66%	79.83%	97.08%
Systematic Close	-0.25mm	-2.68%	-4.31%	99.85%	99.38%	94.11%	98.88%
	-0.50mm	-4.07%	-8.24%	99.15%	94.19%	67.67%	90.54%
	-0.75mm	-5.40%	-12.11%	99.39%	98.20%	89.32%	95.97%
Systematic Open	0.75mm	3.28%	9.80%	97.79%	88.98%	51.67%	79.65%
	0.50mm	1.39%	5.67%	99.90%	98.98%	89.14%	98.66%
	0.25mm	0.63%	1.77%	99.84%	98.96%	89.78%	98.29%



CONCLUSIONS

- On average, the difference between the measured and calculated signal was less for the IQM than the EPID. This may be due to higher accuracy of the IQM calculation algorithm.
- No correlation was observed between EPID gamma analysis and the difference between the IQM measured and calculated signal.
- Prostate plans showed the greatest deviation from the calculated signal for both measurement devices.
- IQM is more sensitive to small dose differences and provides more information regarding machine output than EPID gamma analysis.
- Unlike the EPID, the IQM does not provide information regarding the spatial dose distribution. Although, dissection of the IQM signal may provide spatial information.
- Signal differences for all MLC induced-error plans were measurable with both devices.
- Gamma analysis with the EPID proved to be an ineffective method for MLC error detection
- Cumulative signal difference from baseline was an effective parameter for MLC error detection for both detectors.

ONGOING WORK

- Evaluating the differences in response between the two detectors based on plan characteristics such as, small field size, and modulation index
- Expanding error sensitivity measurements to include other types of plan errors such as jaw positions and collimator angle.

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