

In Vivo Dosimetry of Stereotactic Radiation Therapy Using Integral Quality Monitor (IQM) System



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Introduction

Real-time dosimetry is a challenging problem for high-dose and highly precise stereotactic radiosurgery (SRS) or stereotactic body radiation therapy (SBRT). Integral quality monitor (IQM) is a new in vivo dose monitoring and interlocking system using on-line comparison of checksums calculated from geometric and dosimetric parameters of fields, jaws, MLC and ion chamber.

Purpose

- To investigate the feasibility of using IQM for *in vivo* dosimetry of stereotactic radiation treatment with step-and-shoot intensity modulated radiation therapy (IMRT) or rotational volumetric modulated arc therapy (VMAT)

Materials/Methods

- A beta-version IQM system was commissioned initially on an Elekta Infinity Linac equipped with 160-MLCs Agility head, and later on an Elekta Versa HD Linac with Agility head and high dose-rate flattening-filter-free (FFF) energies.
- Prostate and head-and-neck IMRT and VMAT plans were used to assess IQM constancy in stationary and rotational delivering modes, respectively
- The IQM sensitivity of detecting dosimetric deviations caused by leaf errors in SBRT were evaluated with different plans. Two scenarios of plans were assessed: relatively small and large targets. Single leaf offsets of 2 mm and 5 mm into fields were introduced into the plans. Sensitivity of IQM detecting dosimetric errors in these scenarios were compared with TPS plans and MapCheck2 measurements.

Plan	Picket Fence (PF)	Lung SBRT	Lung SBRT	Prostate SBRT	Prostate SBRT
Modality	Stationary/Rotational	7-field IMRT	2-arc VMAT	7-field IMRT	2-arc VMAT
Energy	6 MV	6 MV	6 MV FFF	6 MV	6 MV
Dose Rate (MU/min)	600	600	1400	600	600
Total MUs/fx	2000	2776	5800	2322	2090
Prescription	-	12 Gy x 4	12 Gy x 4	7.25 Gy x 5	7.25 Gy x 5
Target Size (cc)	-	15	28	135	135

Table 1. Summary of original plans for IQM sensitivity assessment. Each plan was delivered three times.

Results

IQM constancy measurements across several days showed 0.1-0.2% average standard deviation for cumulative checksum comparison in prostate and H&N IMRT deliveries and 0.7-1.0% (excluding first three control points) in VMAT case.

Plan	Stationary PF		Rotational PF	
Single Leaf Offset	2 mm	5 mm	2 mm	5 mm
Checksum Deviation	1.1-2.0%	3.1-5.3%	1.2-2.6%	3.8-6.1%
p-value	0.0005	0.0005	0.0005	0.0005

Table 2. IQM checksum deviation caused by single leaf offset in picket fence tests

Results

Lung SBRT – Relatively Small Target

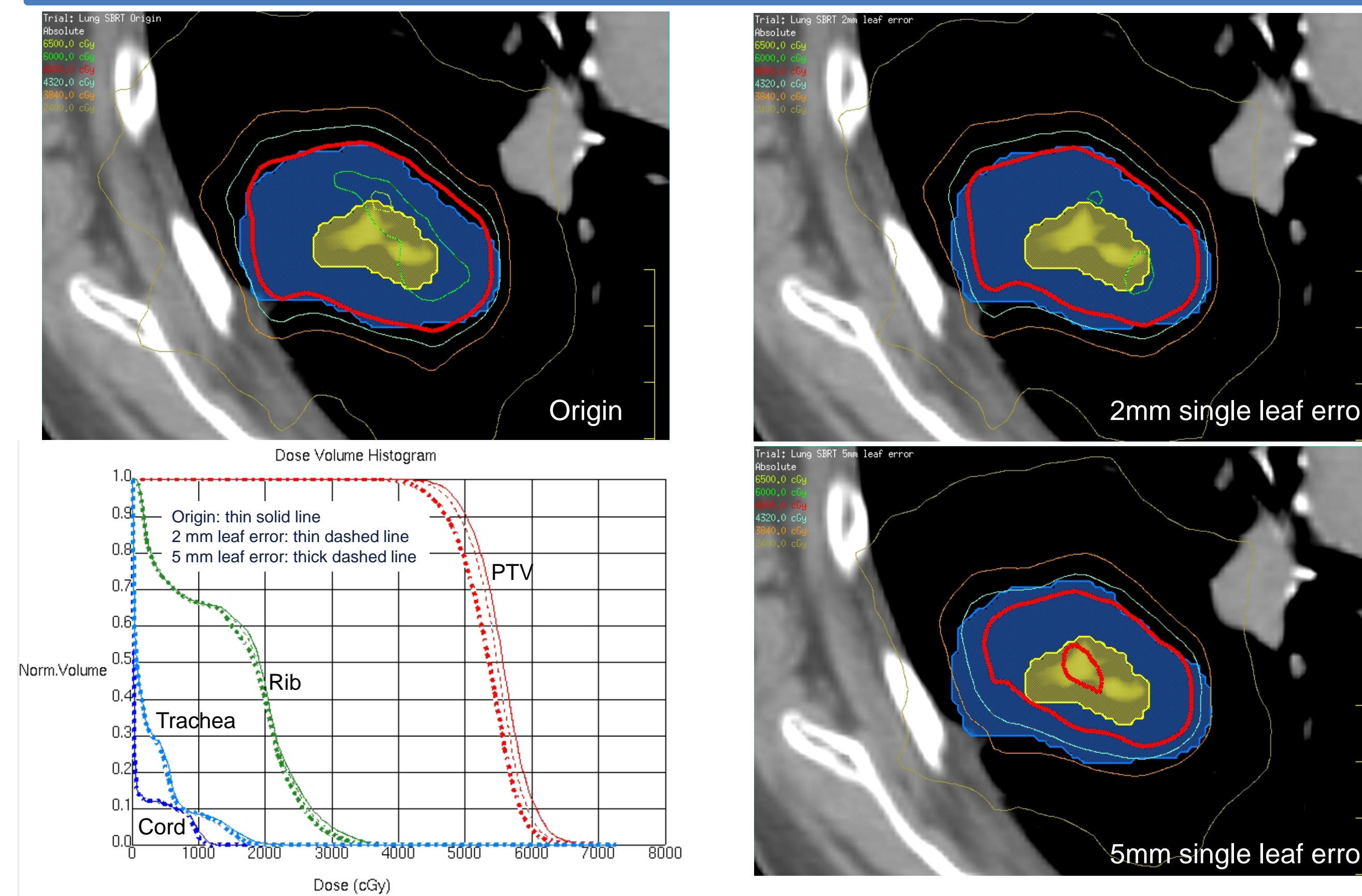


Figure 1. Dosimetric effects assessed by TPS of single leaf offsets of 2 mm and 5 mm in lung SBRT VMAT

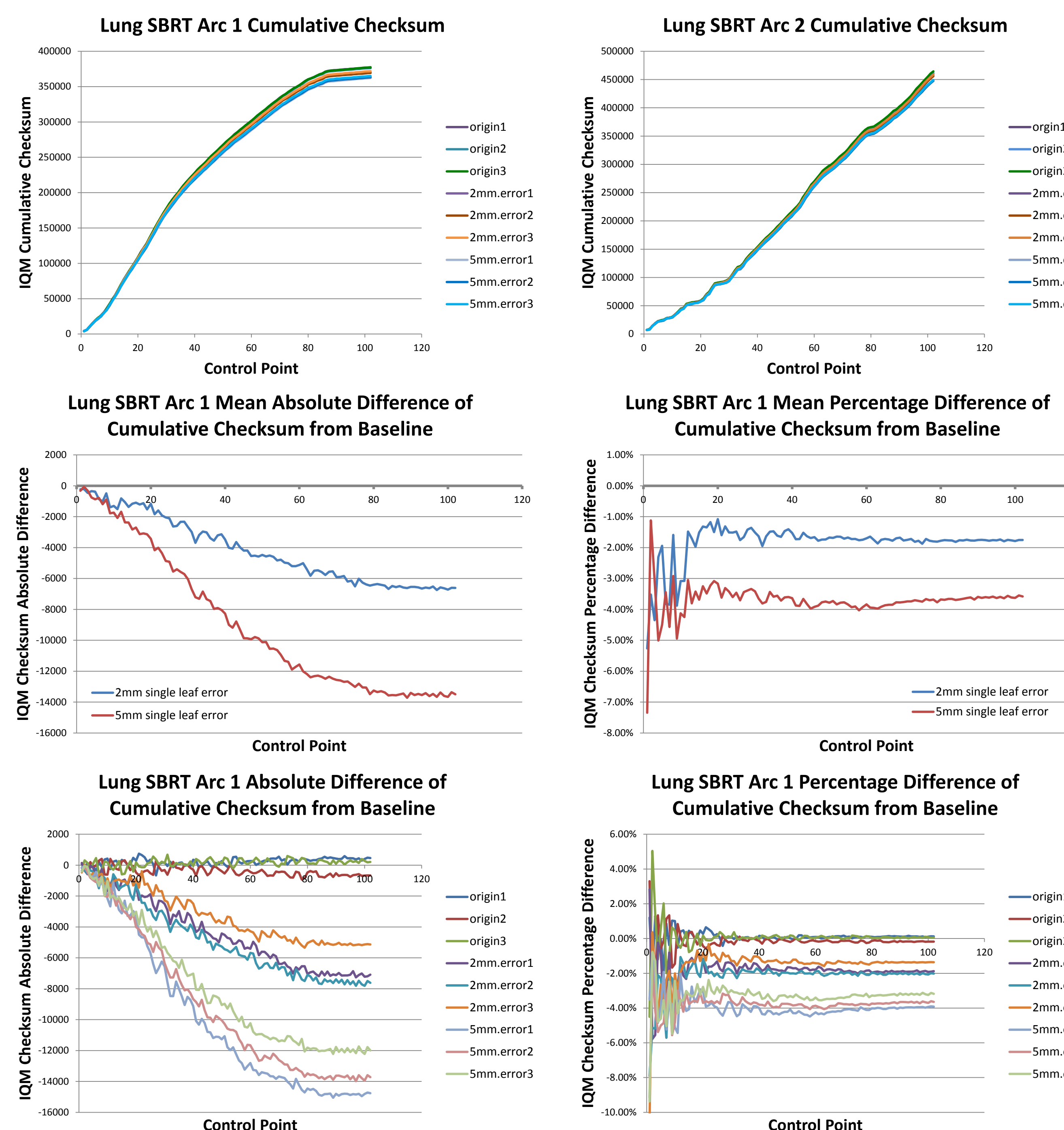


Figure 2. Dosimetric deviations from leaf errors detected by IQM in lung SBRT. Baseline was averaged cumulative checksum of three leaf-error-free measurements.

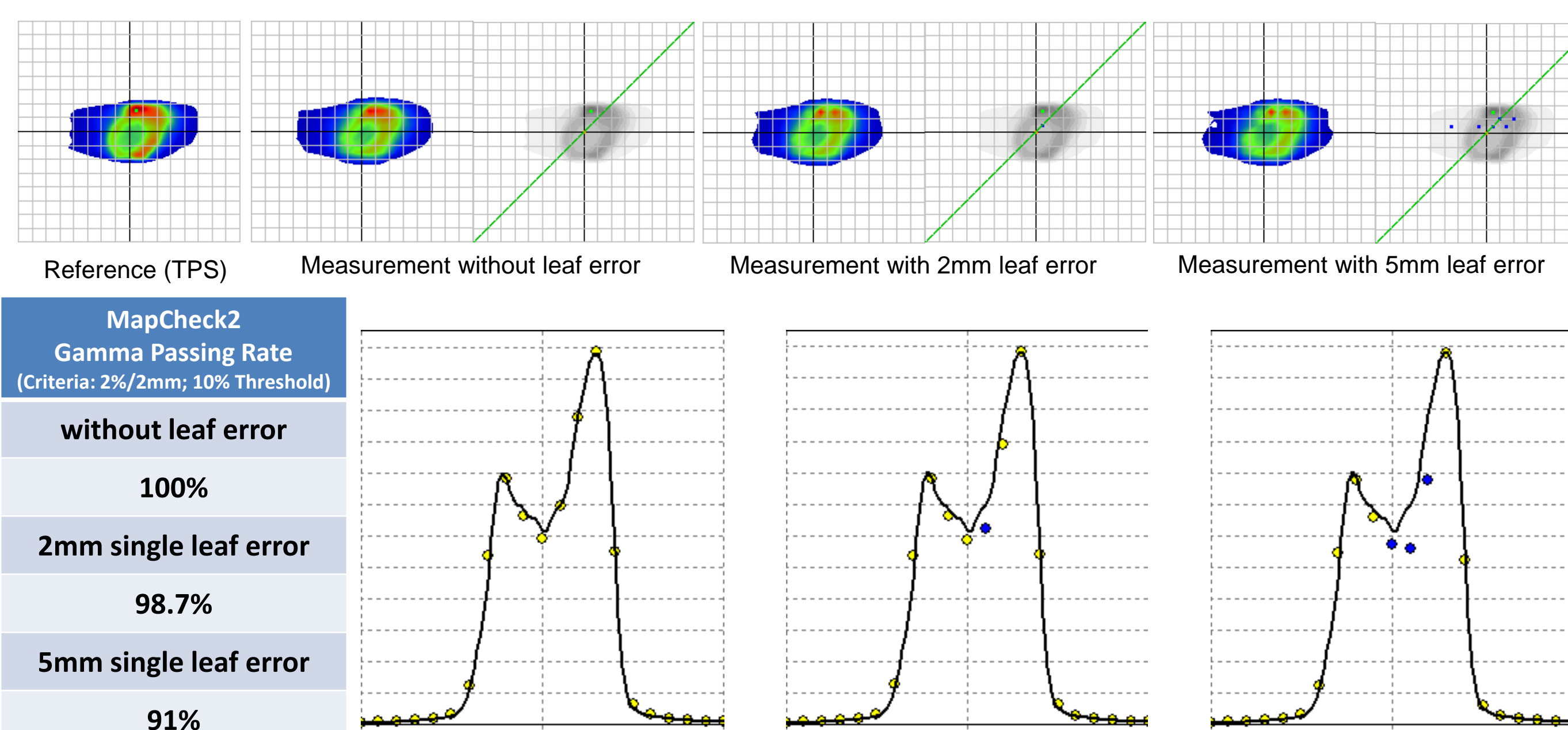


Figure 3. Dosimetric deviations from leaf errors detected by Mapcheck2 in lung SBRT.

Prostate SBRT – Relatively Large Target

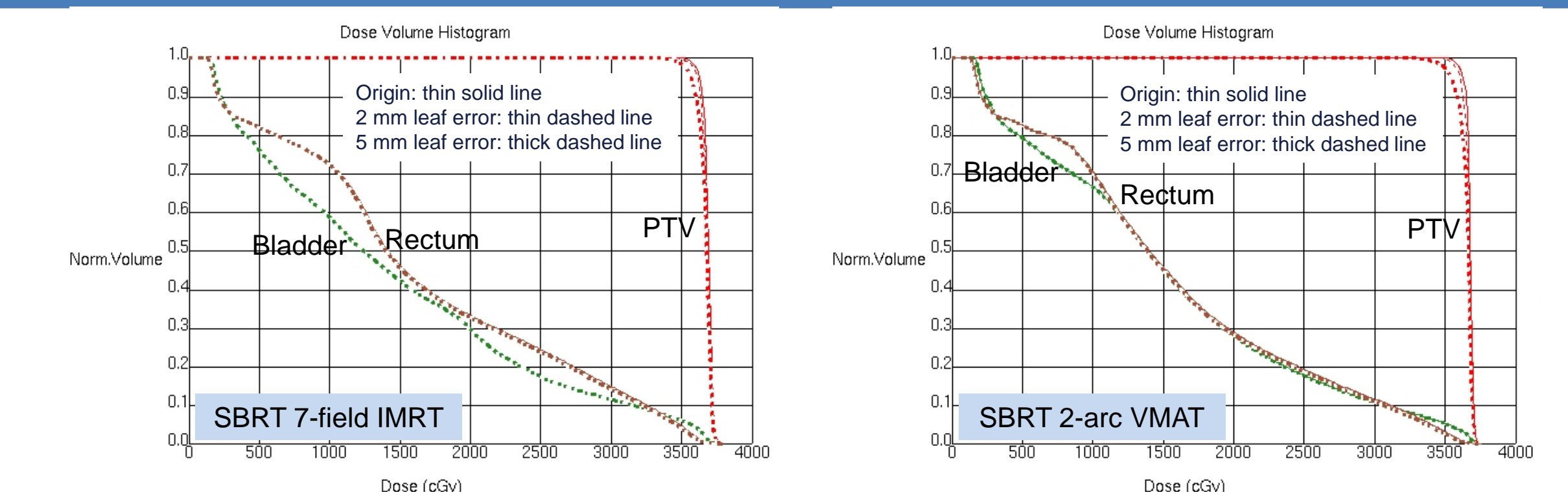


Figure 4. Dosimetric effects assessed by TPS of single leaf offsets in prostate SBRT IMRT and VMAT

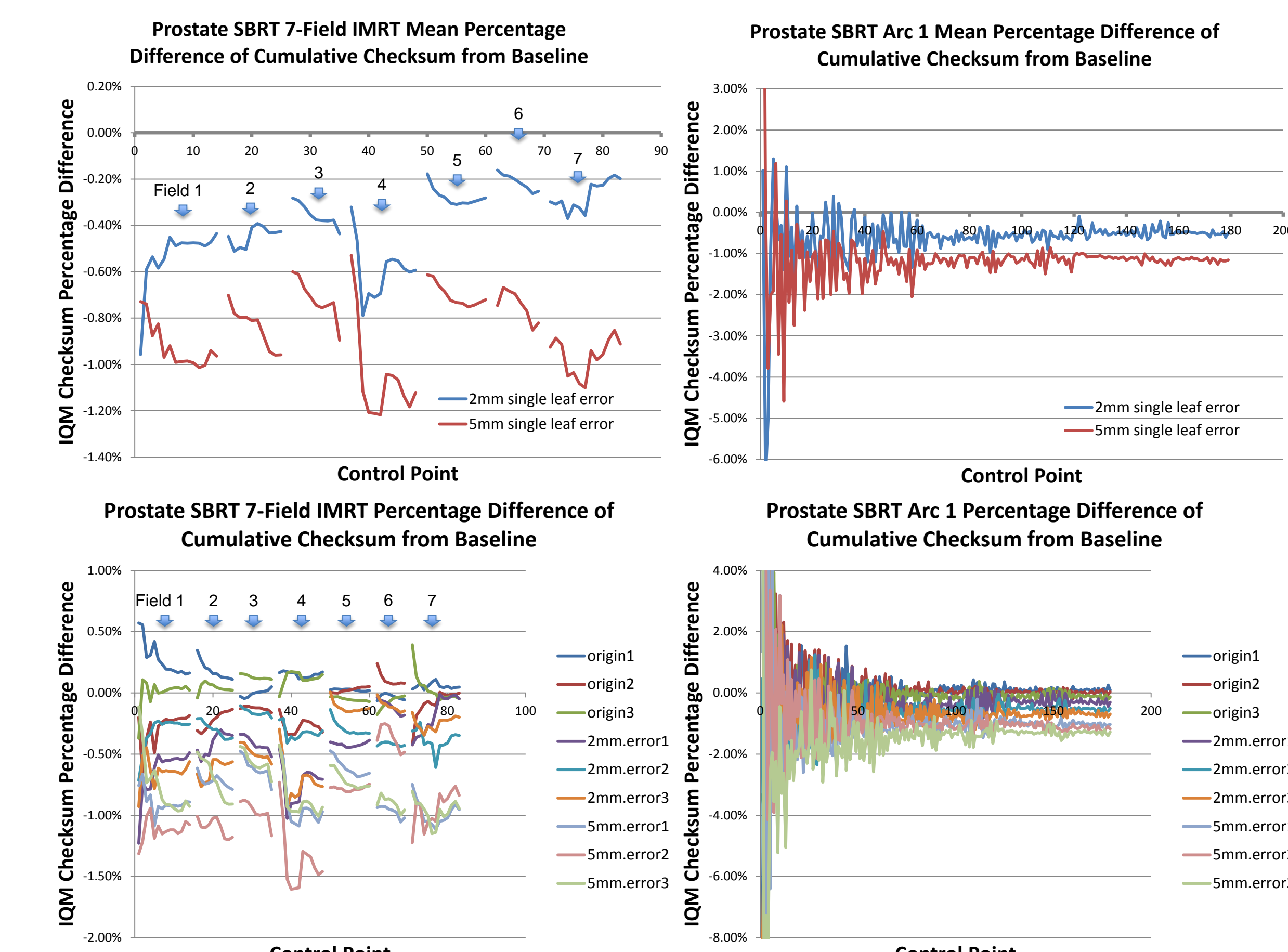


Figure 5. Dosimetric deviations from leaf errors detected by IQM in prostate SBRT IMRT and VMAT, respectively. Baseline was averaged cumulative checksum of three leaf-error-free measurements.

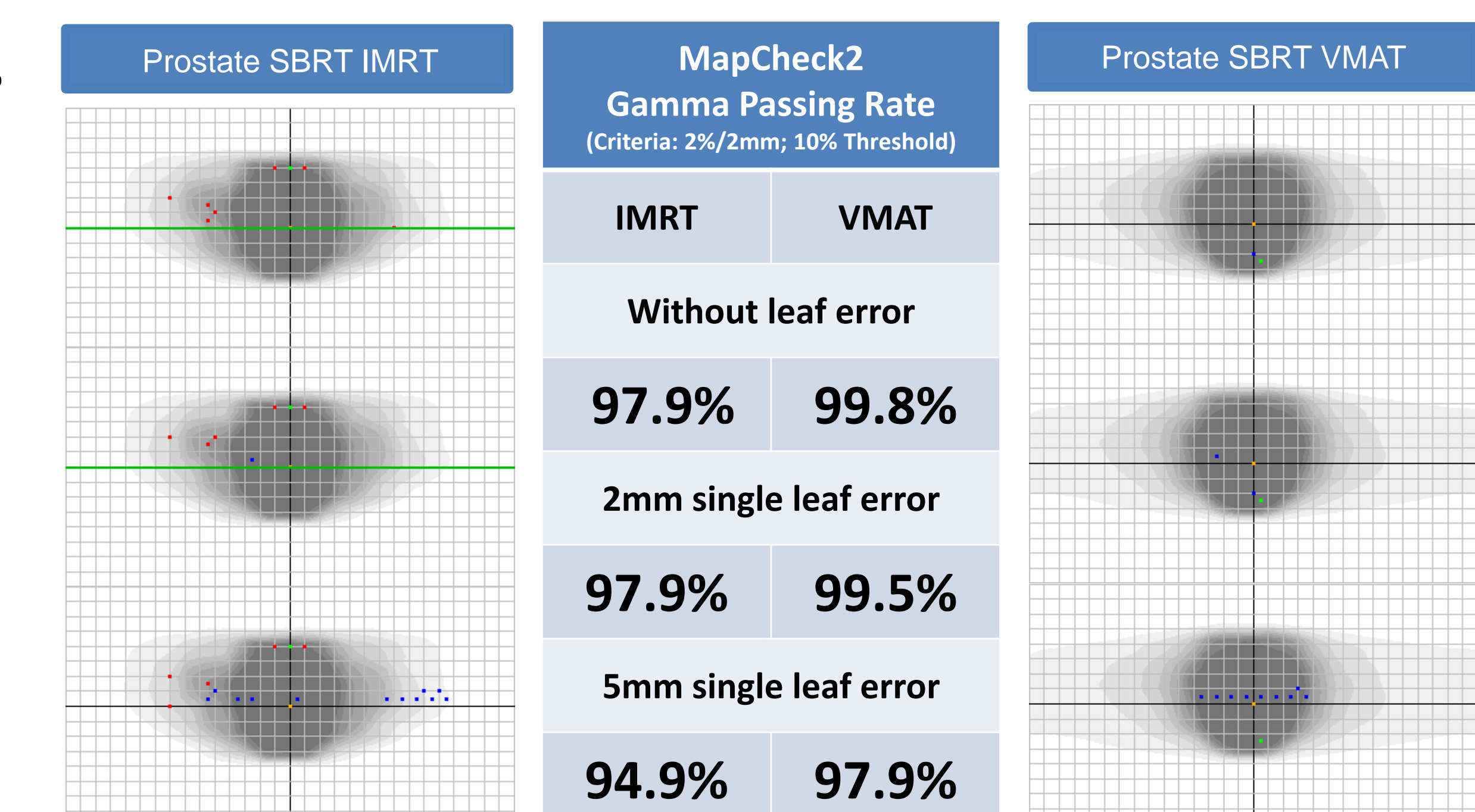


Figure 6. Dose discrepancy from leaf errors in Mapcheck2 measurements

Premature Conclusions

- IQM is a stable dosimetric system and can detect dosimetric deviations caused by small leaf errors in stereotactic radiation therapy.
- IQM sensitivity to leaf errors is more pronounced for relatively small fields (i.e., small targets) in SBRT.
- IQM appears to be more sensitive than Mapcheck2 to small leaf errors in SBRT of small targets while showing similar sensitivity in SBRT of relatively large targets.
- Given relatively small checksum deviations in response to small or moderate leaf errors, appropriate criteria need to be established for proper pass/fail assessment of a SBRT delivery using IQM.