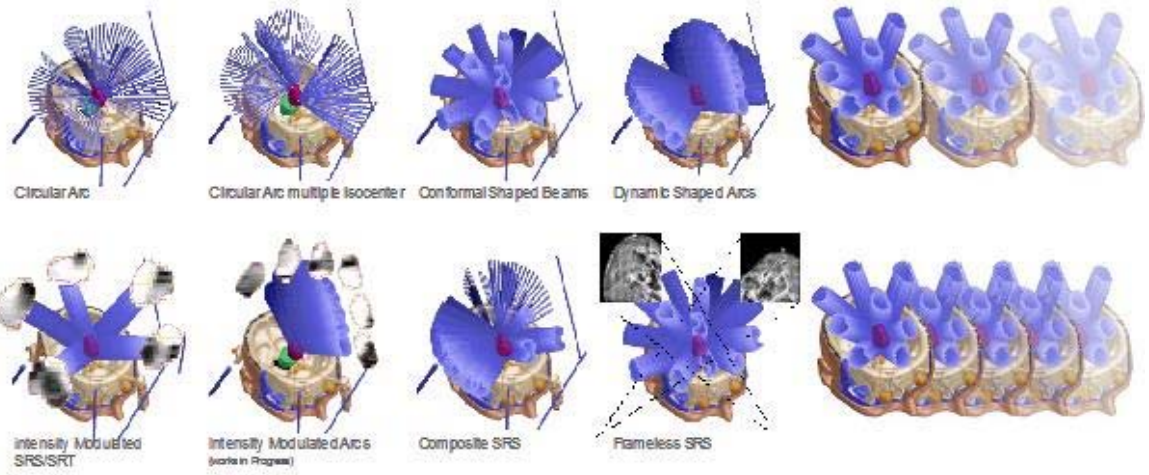
THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Knowledge that will change your world

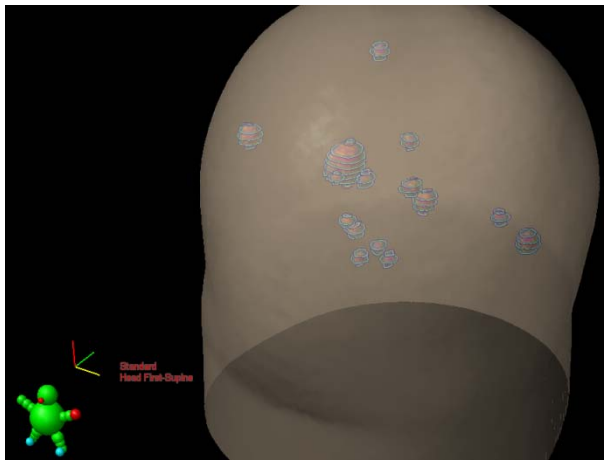
Clinical considerations for MLC based Linac SRS of small targets

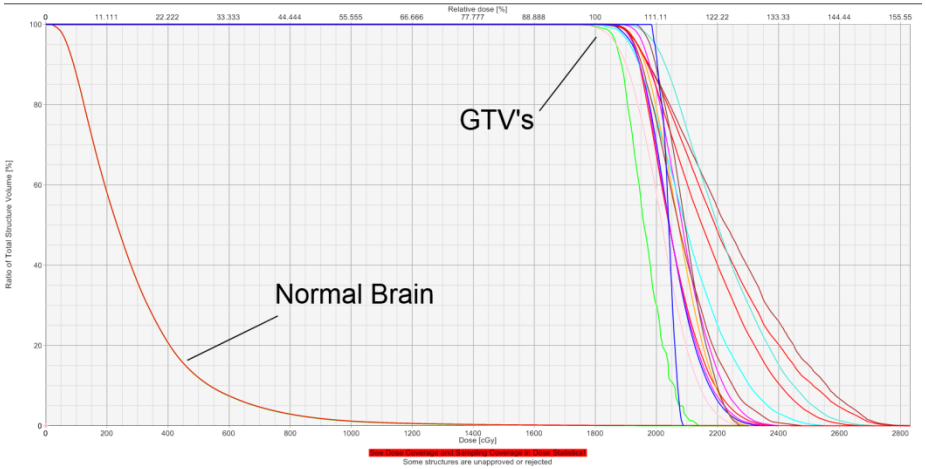
Richard Popple

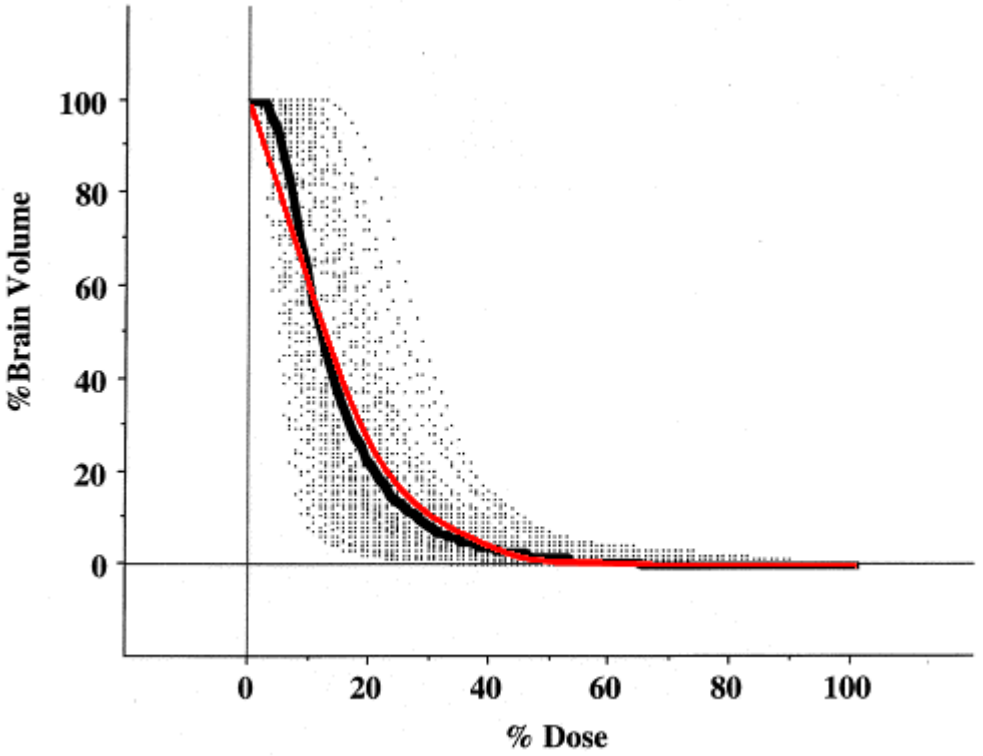
Radiosurgery tools



16 mets, Rx = 18 Gy, GTVtotal = 2cc

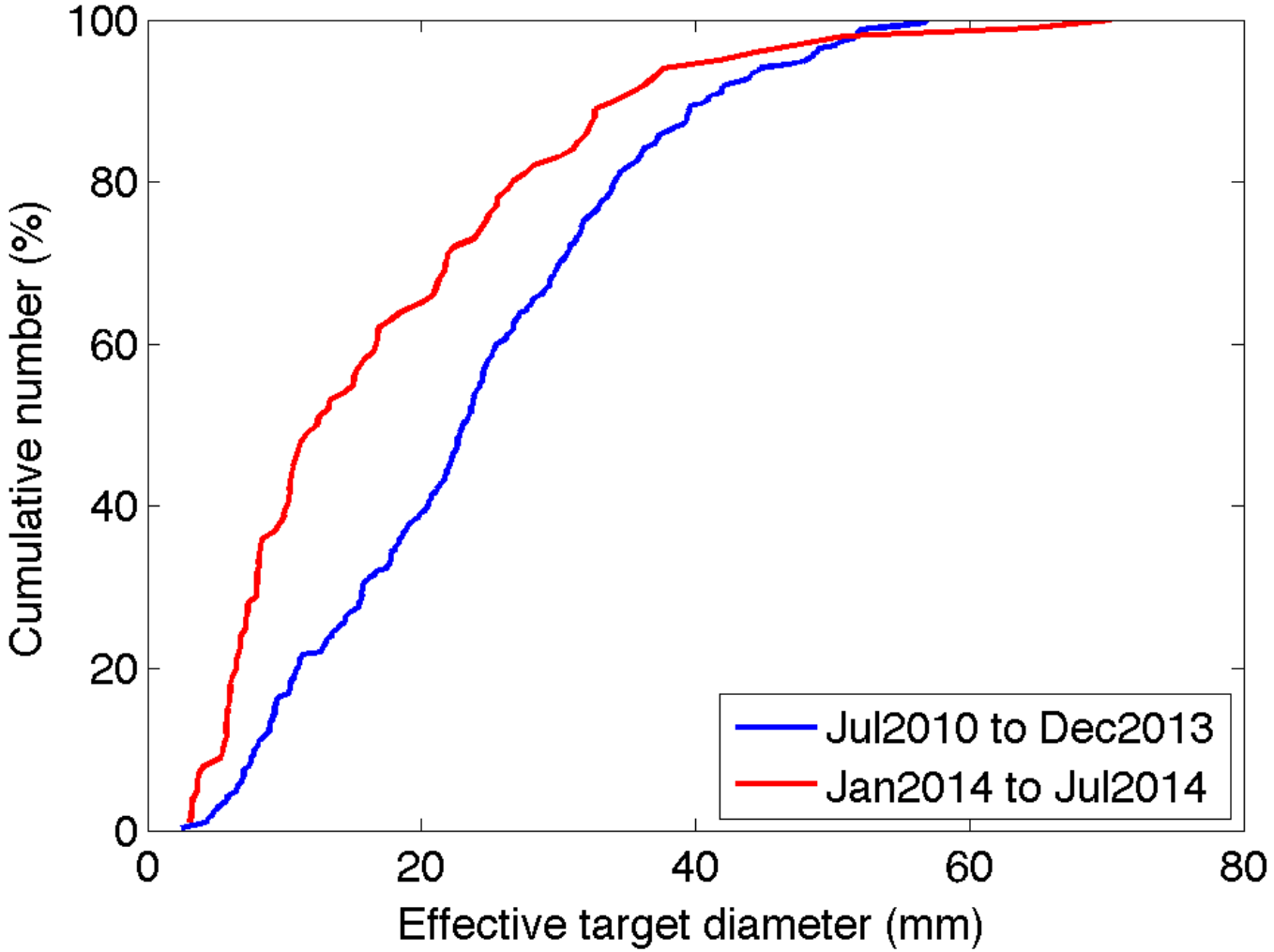




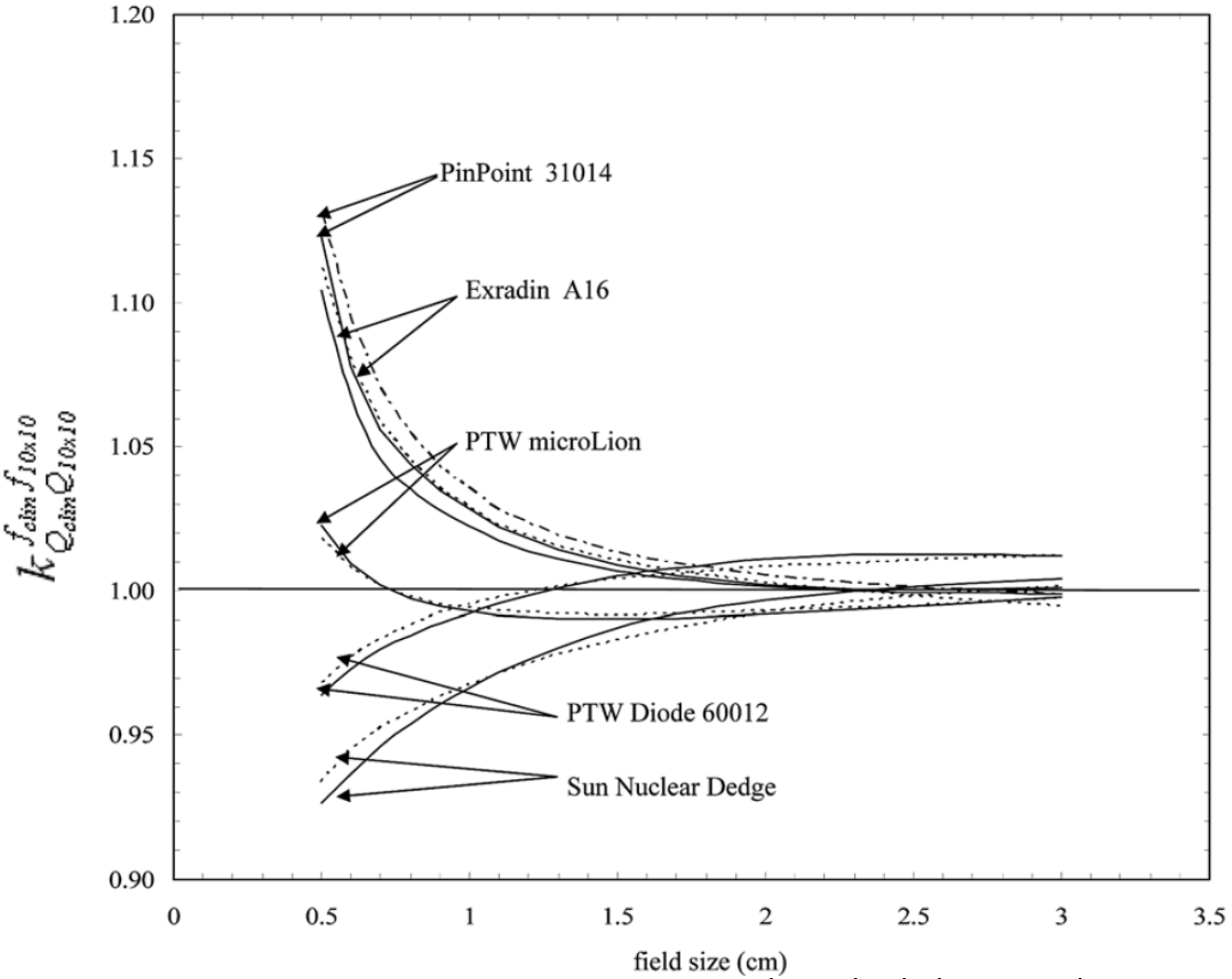


Yamamoto, Masaaki, et al. "Gamma Knife radiosurgery for numerous brain metastases: is this a safe treatment?." *International Journal of Radiation Oncology* Biology* Physics* 53.5 (2002): 1279-1283.

TrueBeam SRS - evolution of target size



Small field dosimetry



Francescon et al. Medical Physics, Vol. 38, No. 12, December 2011

Small field dosimetry

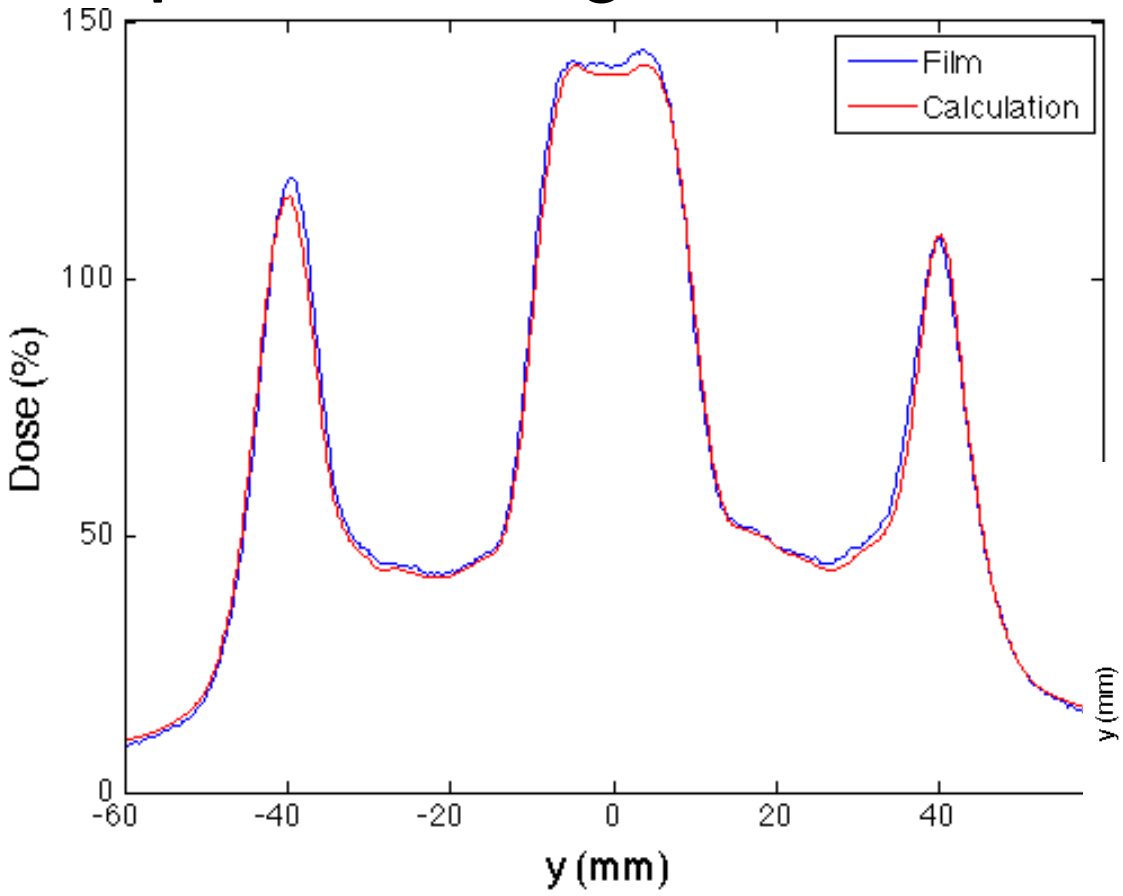
Output for square fields measured using EDR2 and calculated using AAA. Difference between calculation and measurement is given in parentheses.				
Field (cm)	6 MV FFF		10 MV FFF	
	EDR2	AAA	EDR2	AAA
3	0.629	0.623 (-0.9%)	0.718	0.721 (0.4%)
2	0.587	0.595 (1.4%)	0.670	0.679 (1.4%)
1	0.486	0.529 (8.9%)	0.519	0.562 (8.2%)
0.5	0.289	0.415 (43.7%)	0.305	0.398 (30.6%)

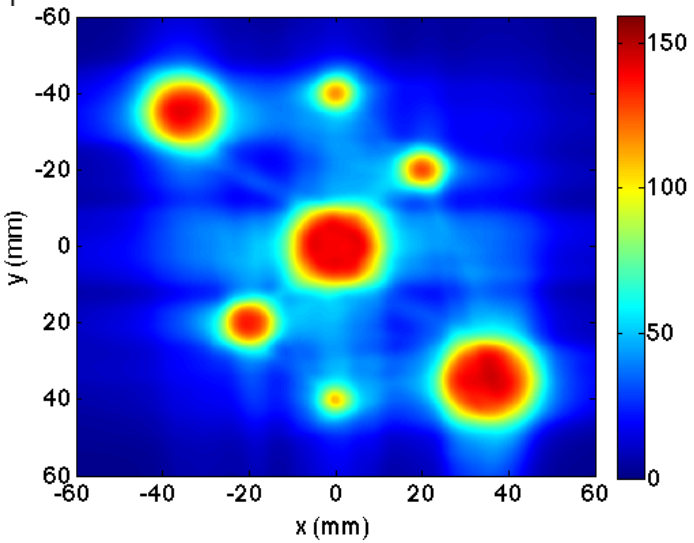
Small field dosimetry

Output for square MLC fields measured using EDR2 and calculated using AAA. Difference between calculation and measurement is given in parentheses.

MLC Field (cm)	Jaw field (cm)	6 MV FFF		10 MV FFF	
		EDR2	AAA	EDR2	AAA
1	10 x 10	0.523	0.535 (2.3%)	0.569	0.569 (-0.1%)
1	2.6 x 1.4	0.521	0.524 (0.6%)	0.560	0.560 (-0.0%)
0.5	10 x 10	0.385	0.379 (-1.6%)	0.403	0.374 (-7.3%)
0.5	2.1 x 0.9	0.377	0.370 (-2.0%)	0.390	0.366 (-6.0%)

Planning system calculation accuracy for multiple small targets

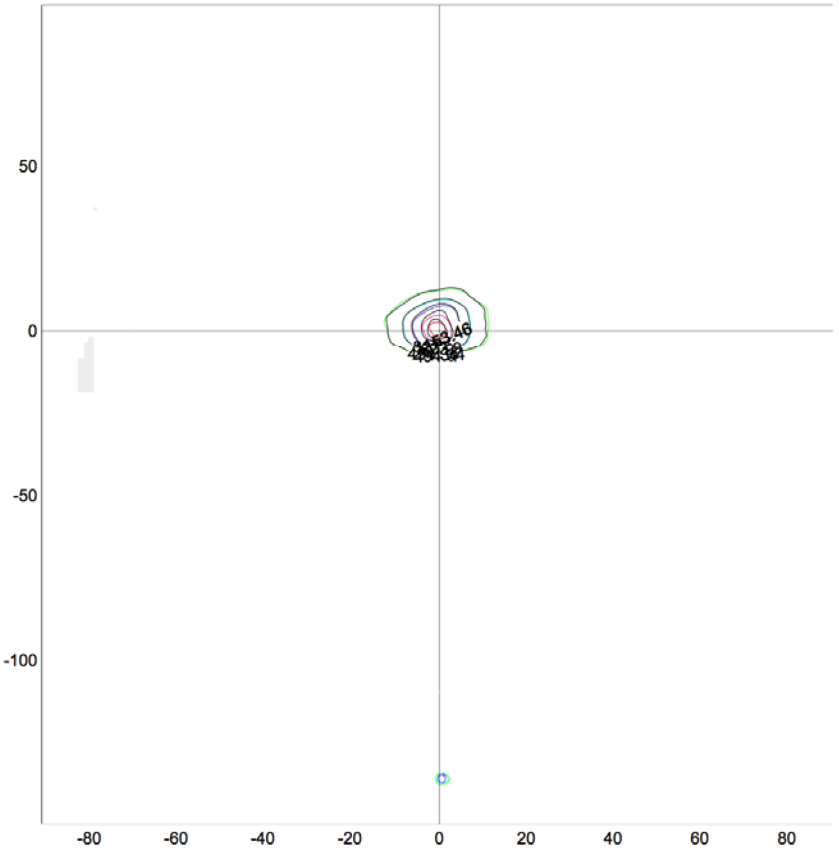




Multi-target single isocenter patient specific QA

Multi-target single isocenter patient specific QA

8 Target case – largest target (0.83 cm^3)

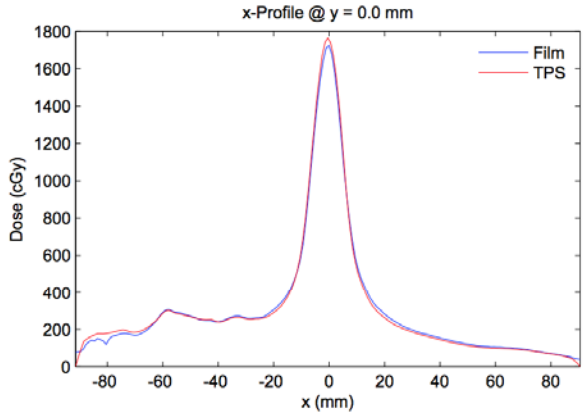


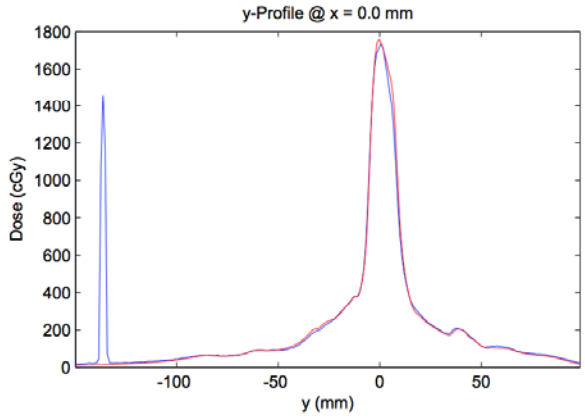
Analysis

Film data is normalized using a custom scaling factor. Film normalization factor: 6.000
TPS dose at (x,y) = (0.0,0.0): 1752.07 cGy
Film dose at (x,y) = (0.0,0.0): 1721.13 cGy

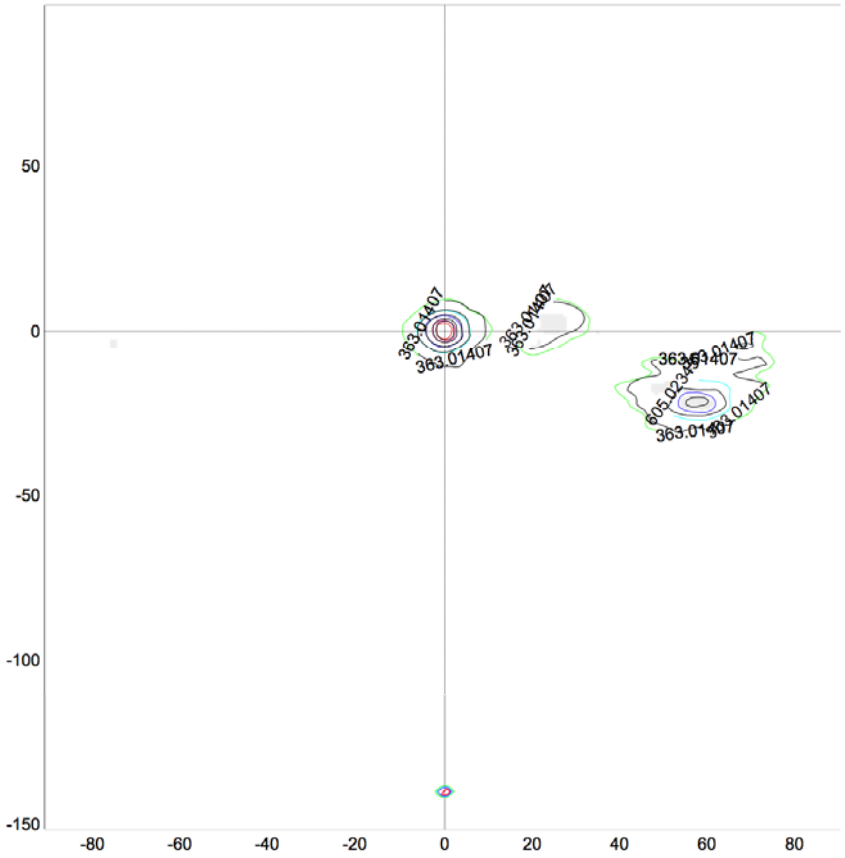
Fraction of calculation points in ROI exceeding gamma = 1 for 3% (49.4 cGy)/3 mm: 0.4% (42/11211)
ROI is defined as the region for which the TPS dose exceeds 5% (82.4 cGy).

Comment: Film not normalized. Film dose scaled by MU ratio only.





8 Target case – smallest target (0.02 cm^3)

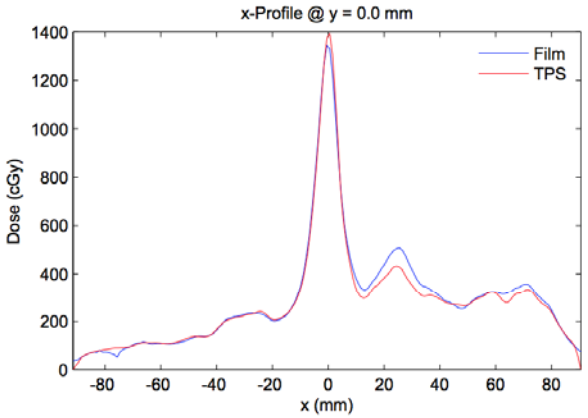


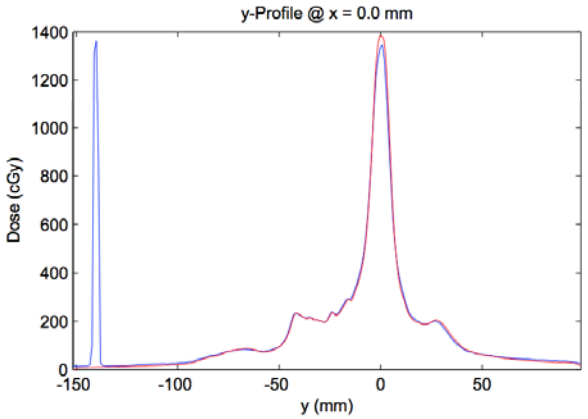
Analysis

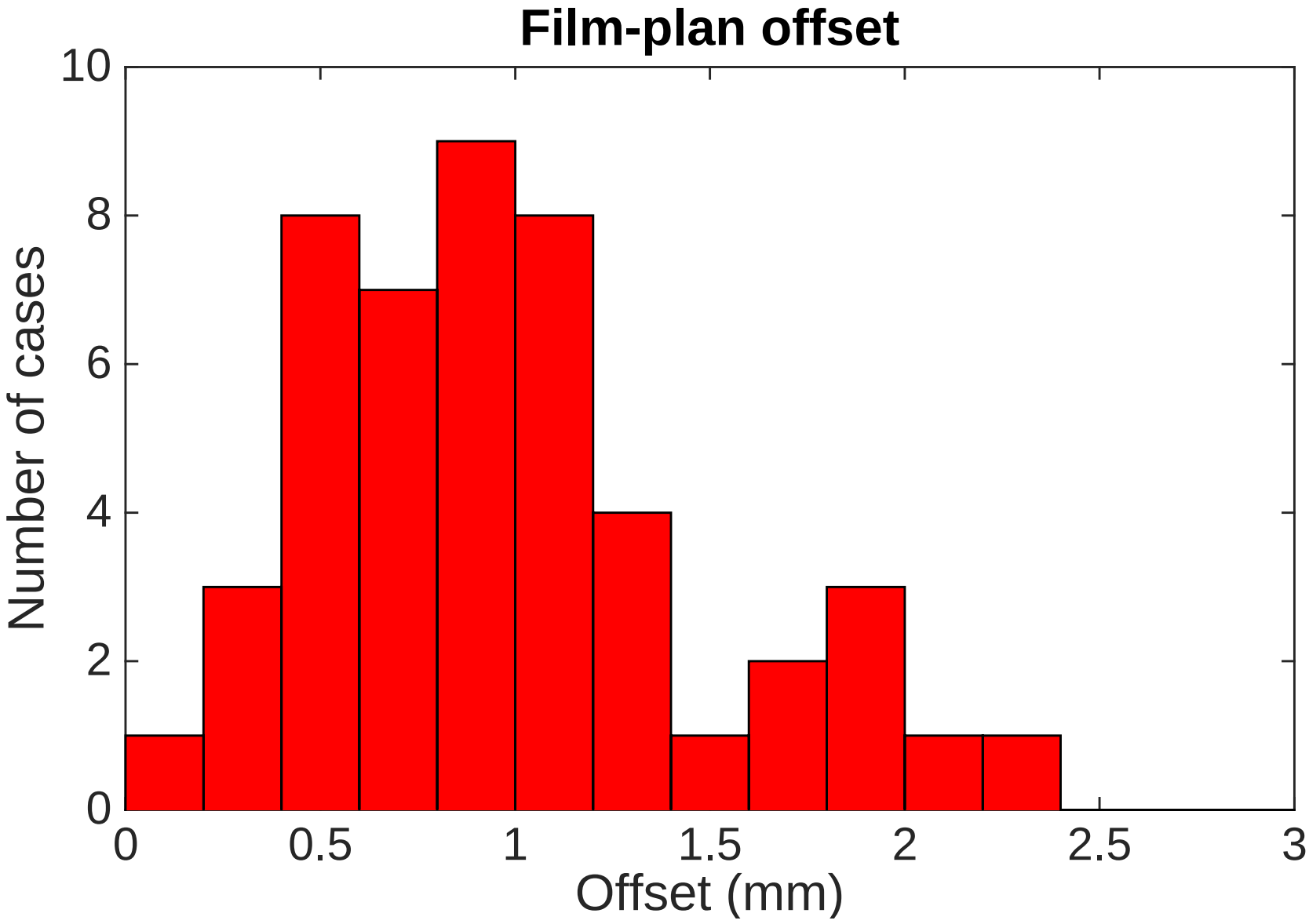
Film data is normalized using a custom scaling factor. Film normalization factor: 6.000
TPS dose at (x,y) = (0.0,0.0): 1384.43 cGy
Film dose at (x,y) = (0.0,0.0): 1337.50 cGy

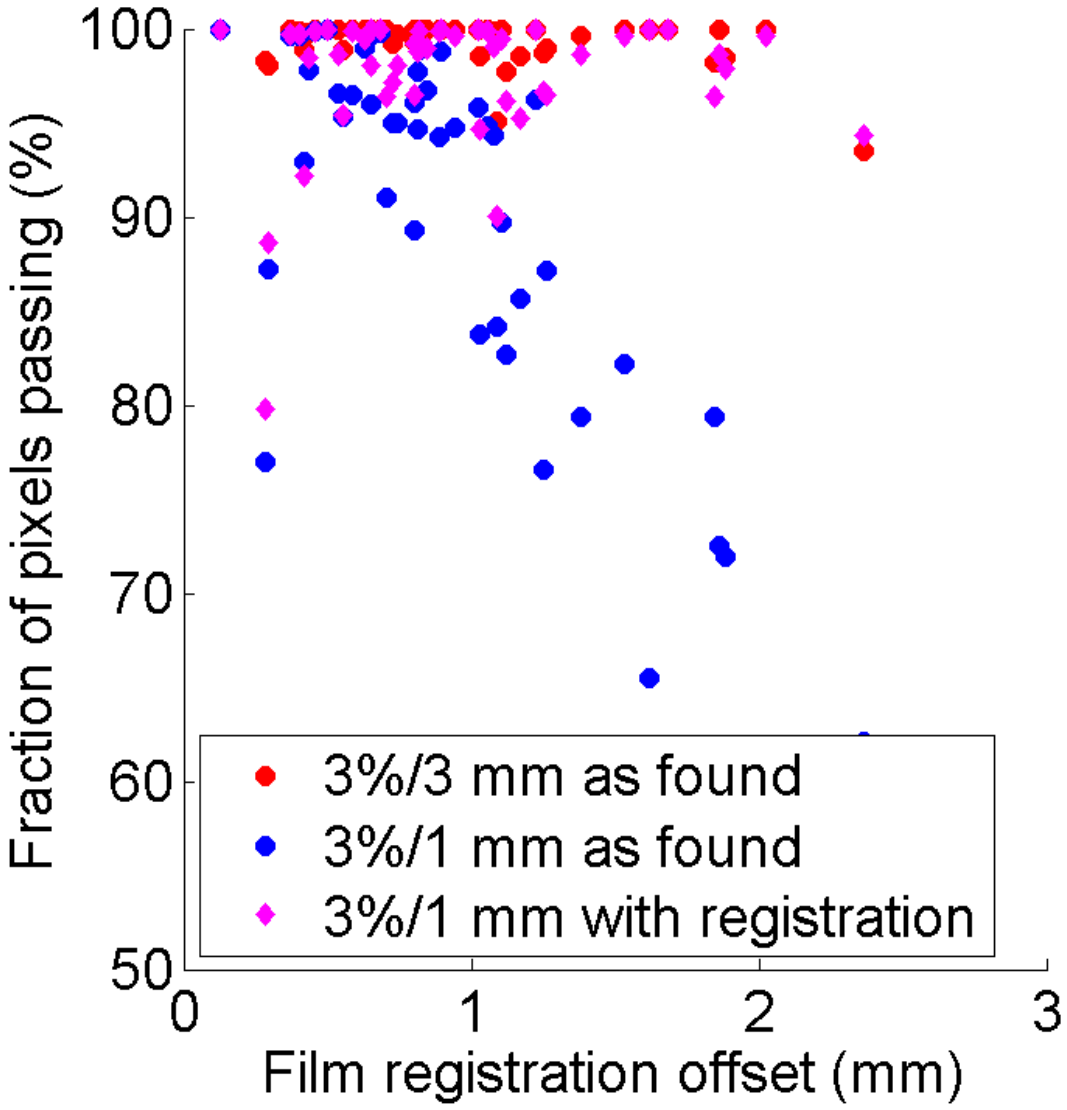
Fraction of calculation points in ROI exceeding gamma = 1 for 3% (36.3 cGy)/3 mm: 0.5% (79/14418)
ROI is defined as the region for which the TPS dose exceeds 5% (60.5 cGy).

Comment: Film dose scaled by MU scaling only.

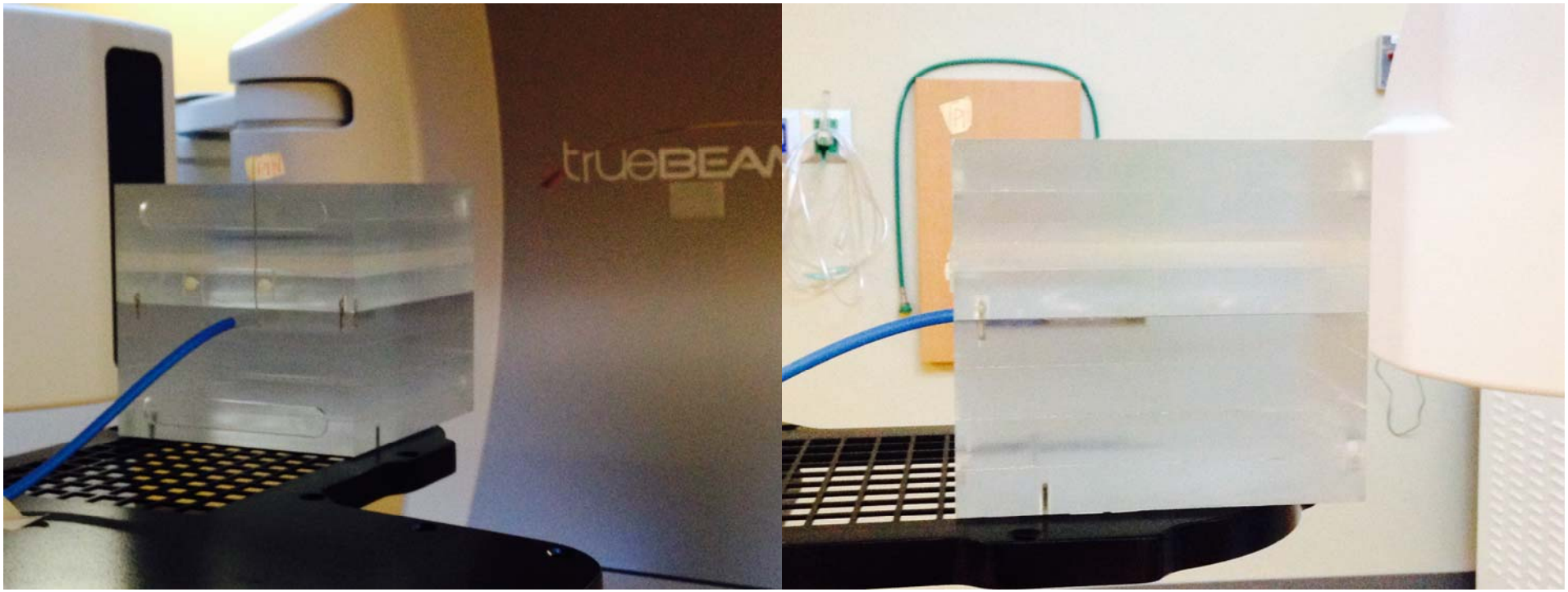


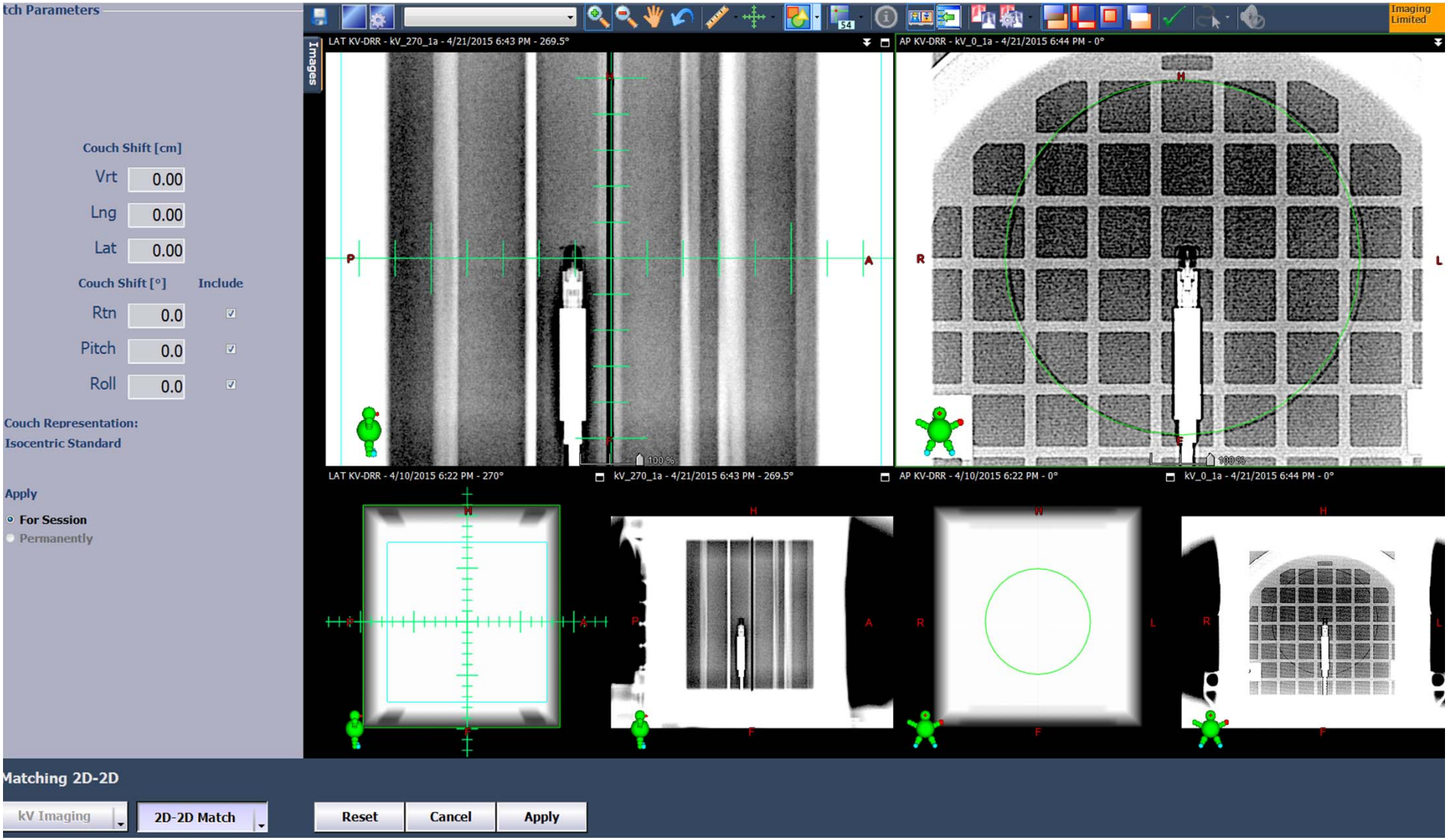


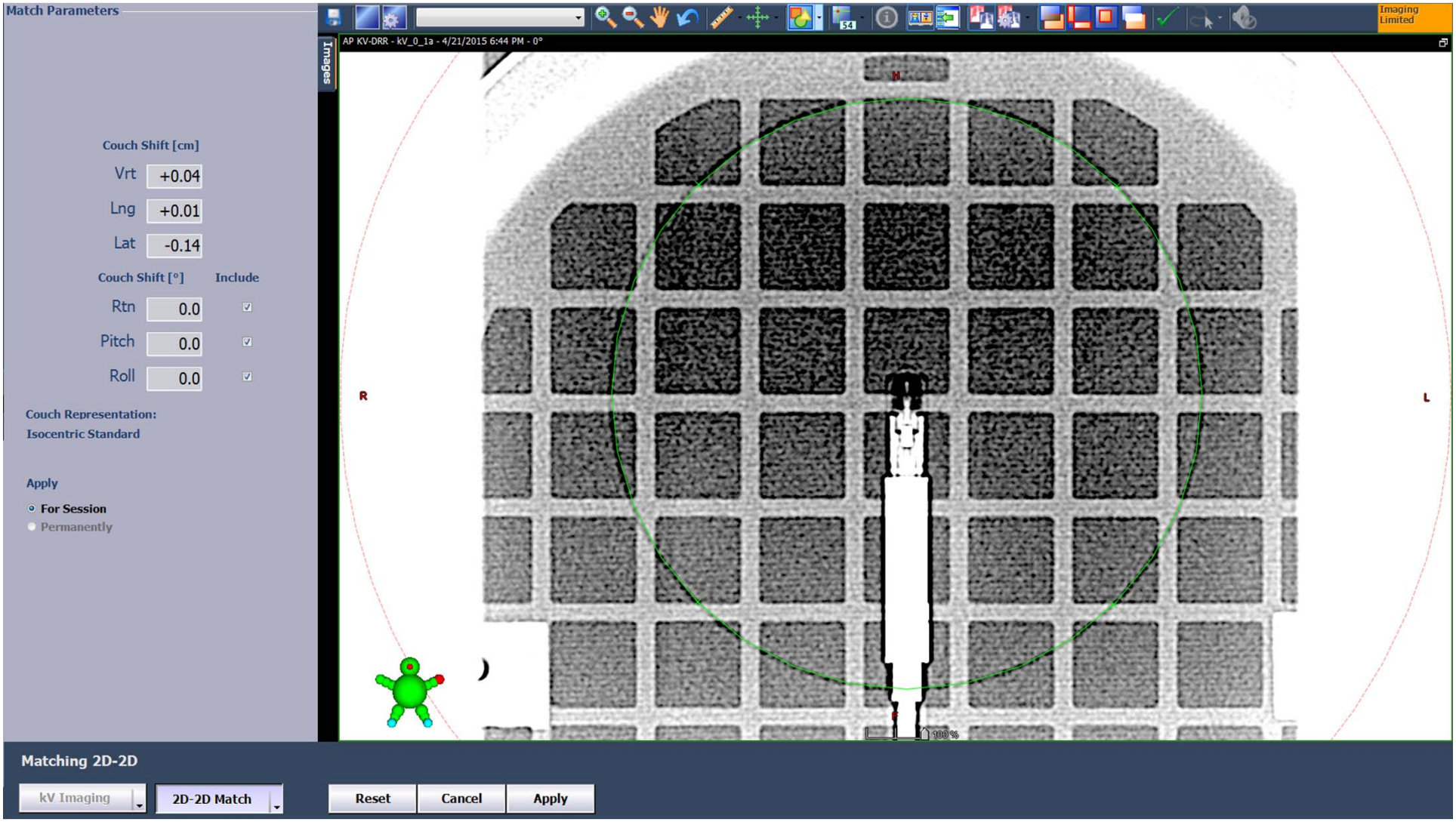



100
90
80
70
60
50
0
1
2
3
Fraction of pixels passing (%)
Film registration offset (mm)
3%/3 mm as found
3%/1 mm as found
3%/1 mm with registration

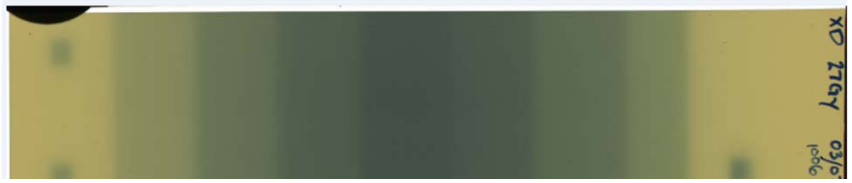
Solution: IGDQA

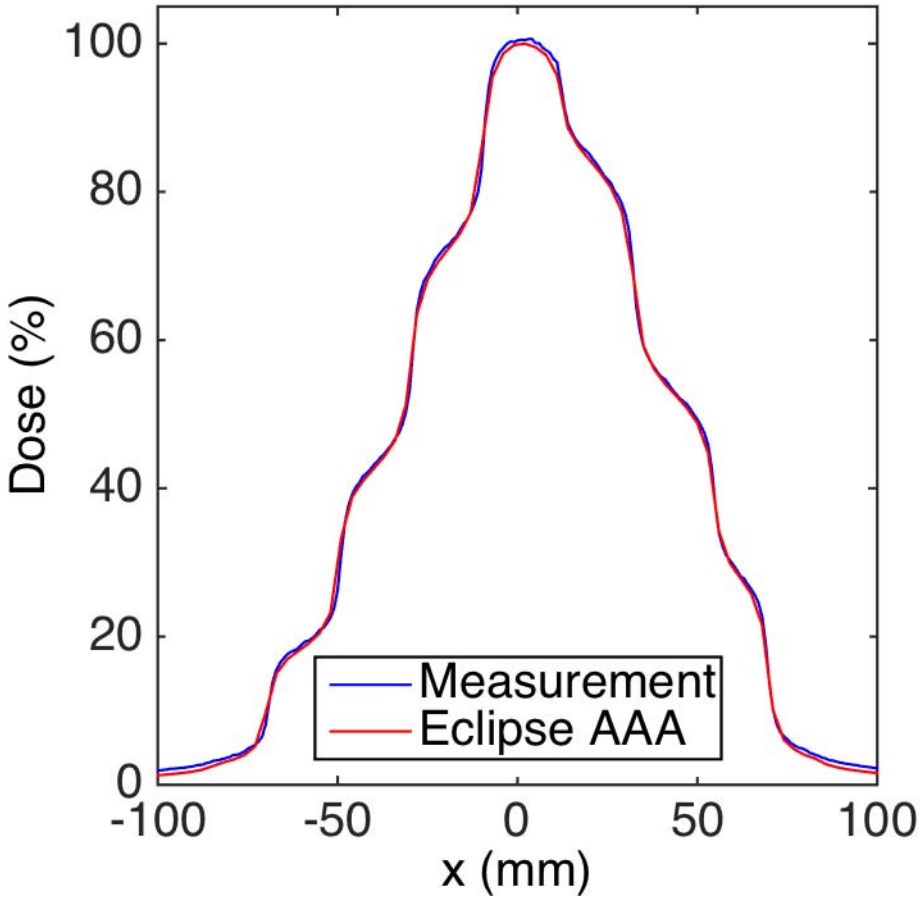


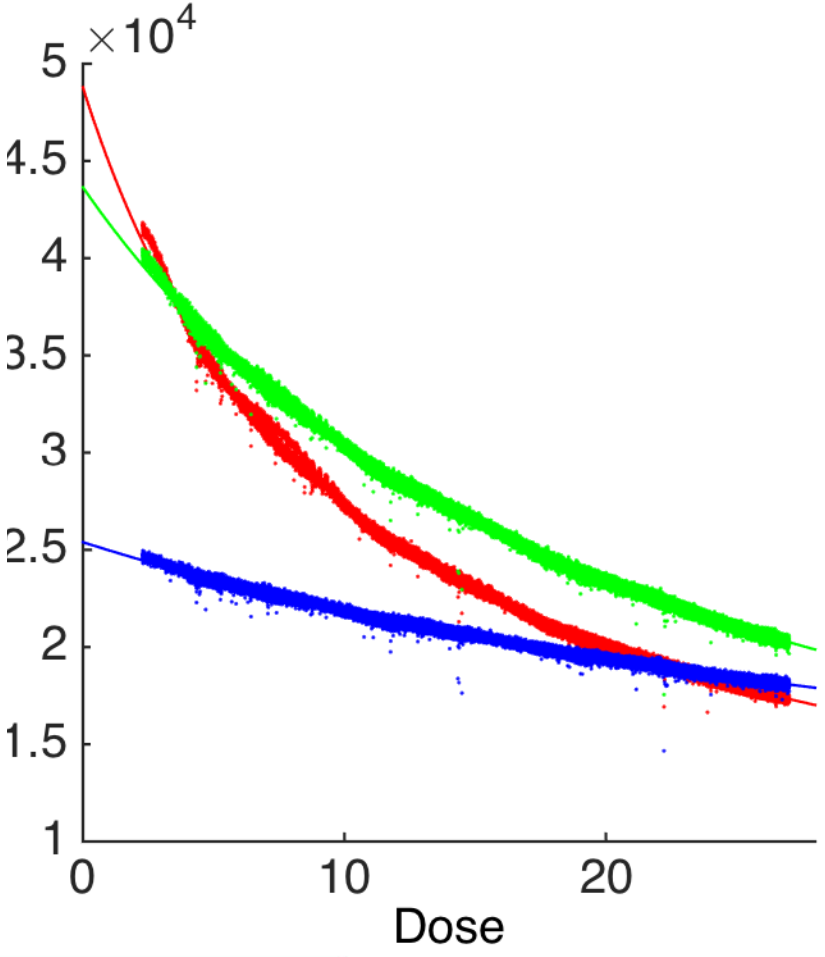



Match Parameters
Couch Shift [cm]
Vrt +0.04
Lng +0.01
Lat -0.14
Couch Shift [°]
Include
Rtn 0.0
Pitch 0.0
Roll 0.0
Couch Representation:
Isocentric Standard
Apply
For Session
Permanently
Images
AP KV-DRR - kV_0_1a - 4/21/2015 6:44 PM - 0°
Imaging Limited
H
R
L
100 %
Matching 2D-2D
kV Imaging
2D-2D Match
Reset
Cancel
Apply

Film calibration using step wedge



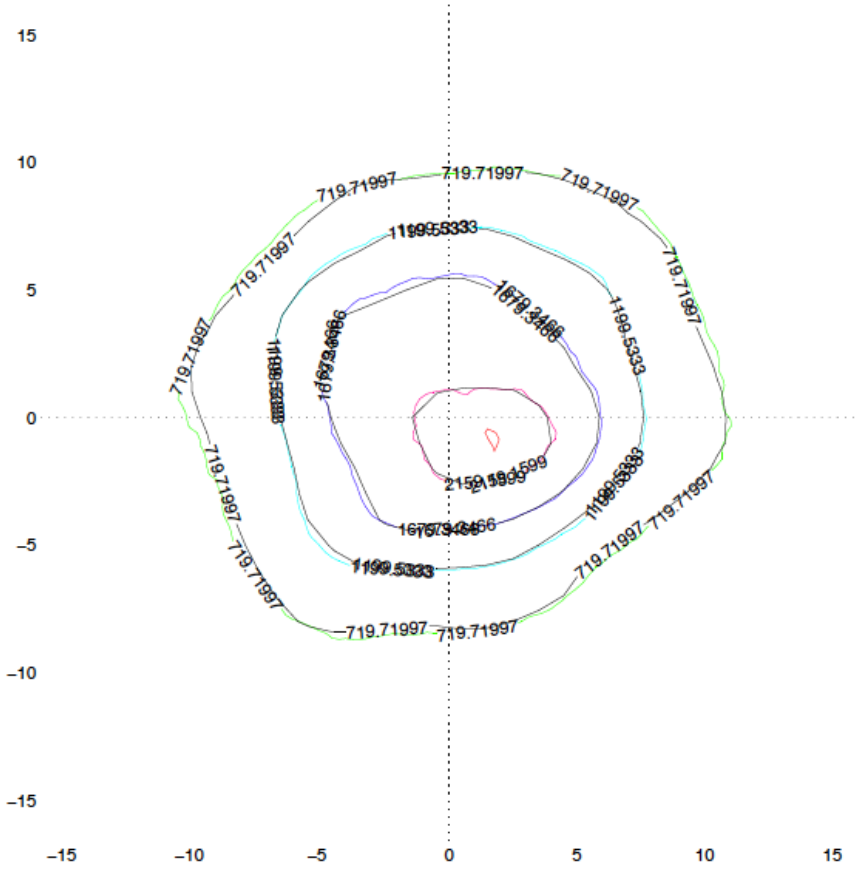

Dose (%)
x (mm)
Measurement
Eclipse AAA


×10^4
Dose

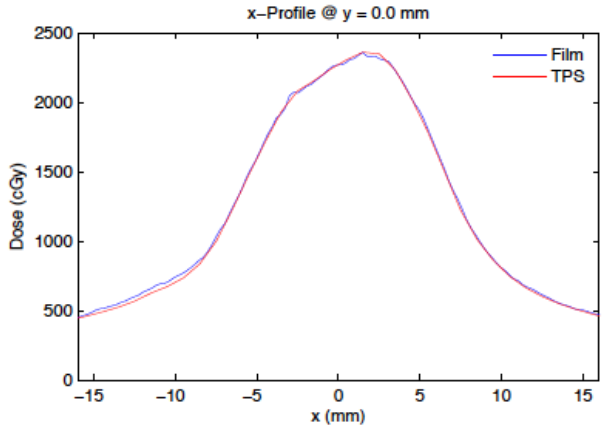
Does IGDQA improve alignment?

- IGDQA phantom: Mean offset magnitude = 0.43 mm (0.13 to 0.64)
- Previous experience: Mean offset magnitude = 0.96 mm (0.13 to 2.36)

Evaluation



Analysis
Using green color channel
Film data is normalized to the TPS mean dose in the region > 90% (2159.2 cGy).
Film normalization factor: 0.958
Additional registration shift: x = -0.32 mm, y = 0.16 mm (magnitude = 0.35 mm)
Dose at (0.0,0.0): TPS = 2271.54 cGy; Film = 2269.14 cGy
Fraction of calculation points in ROI exceeding gamma = 1 for 3% (72.0 cGy)/1 mm: 0.0% (0/6474)
ROI is defined as the region within 17.5 mm for which the TPS dose exceeds 20% (479.8 cGy).



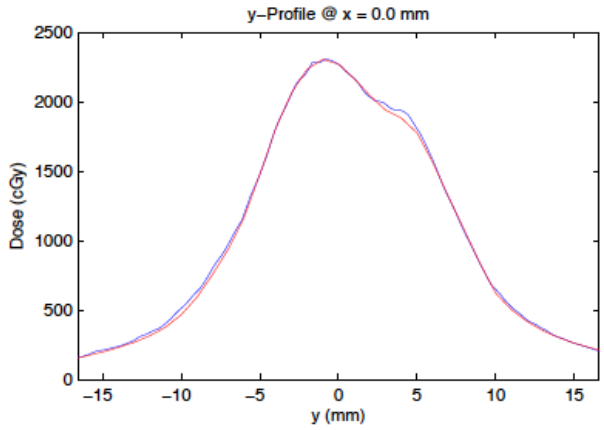


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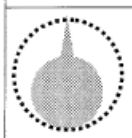
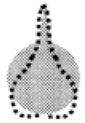
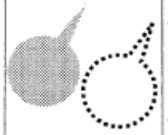
Table 2. Comparison of the various volume-based conformity indices in various clinical settings

Treatment plan	Parameters	$\frac{V_{RI}}{TV}$ RTOG (1)	$\frac{TV_{RI}}{TV}$ SALT-Lomax (28,32)	$\frac{TV_{RI}}{V_{RI}}$ Lomax (32)	$\frac{TV_{RI} \times TV_{RI}}{TV \times V_{RI}}$ Van't Riet (33)
	TV = 5 cm³* V_{RI} = 10 cm³ § TV_{RI} = 5 cm³ ¶	**2**	**1**	**0.50**	**0.50**
	TV = 5 cm³ V_{RI} = 3 cm³ TV_{RI} = 3 cm³	**0.60**	**0.60**	**1**	**0.60**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 4 cm³	**1**	**0.80**	**0.80**	**0.64**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 2.5 cm³	**1**	**0.50**	**0.50**	**0.25**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 0 cm³	**1**	**0**	**0**	**0**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 5 cm³	**1**	**1**	**1**	**1**

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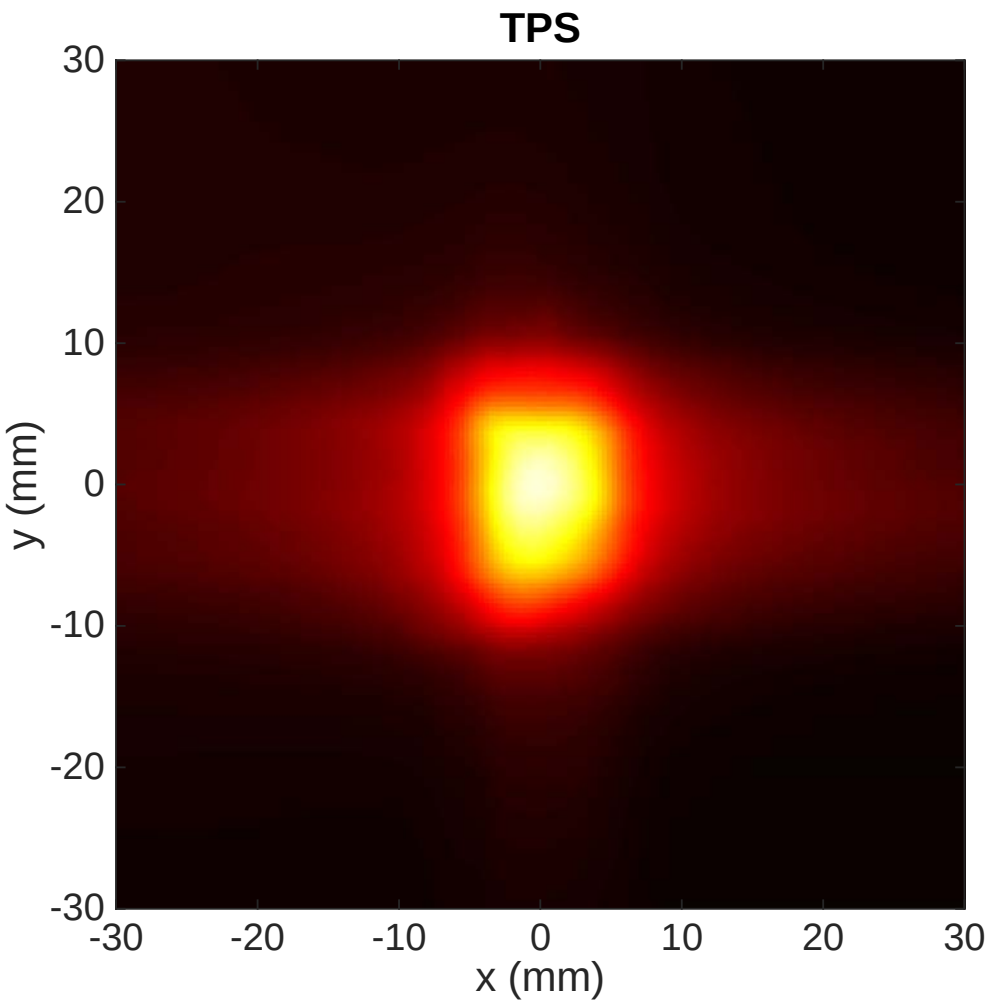

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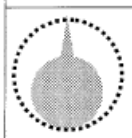	TV = 5 cm³* V_{RI} = 10 cm³ § TV_{RI} = 5 cm³ ¶	**2**	**1**	**0.50**	**0.50**
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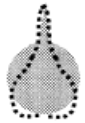	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 4 cm³	**1**	**0.80**	**0.80**	**0.64**
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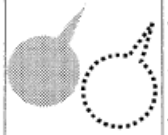	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 0 cm³	**1**	**0**	**0**	**0**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 5 cm³	**1**	**1**	**1**	**1**

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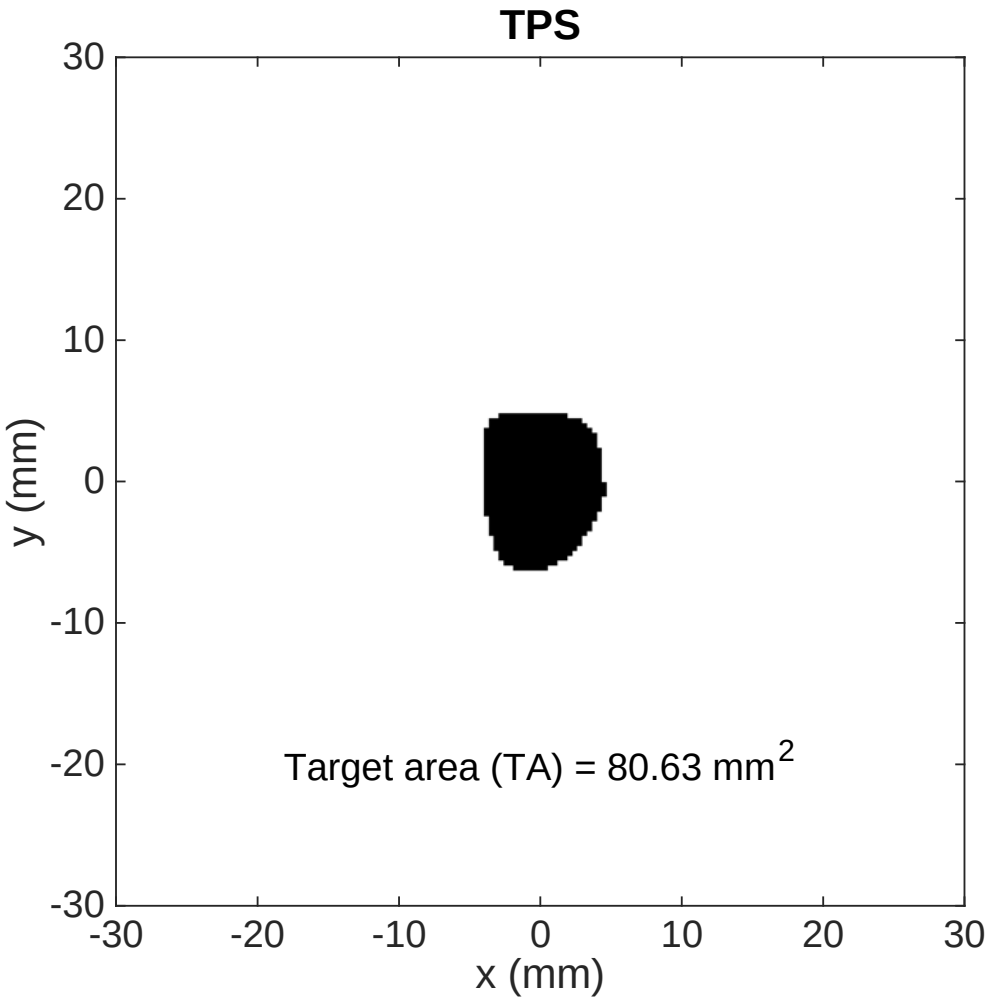

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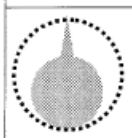	TV = 5 cm³* V_{RI} = 10 cm³ § TV_{RI} = 5 cm³ ¶	**2**	**1**	**0.50**	**0.50**
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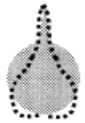	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 4 cm³	**1**	**0.80**	**0.80**	**0.64**
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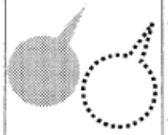	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 0 cm³	**1**	**0**	**0**	**0**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 5 cm³	**1**	**1**	**1**	**1**

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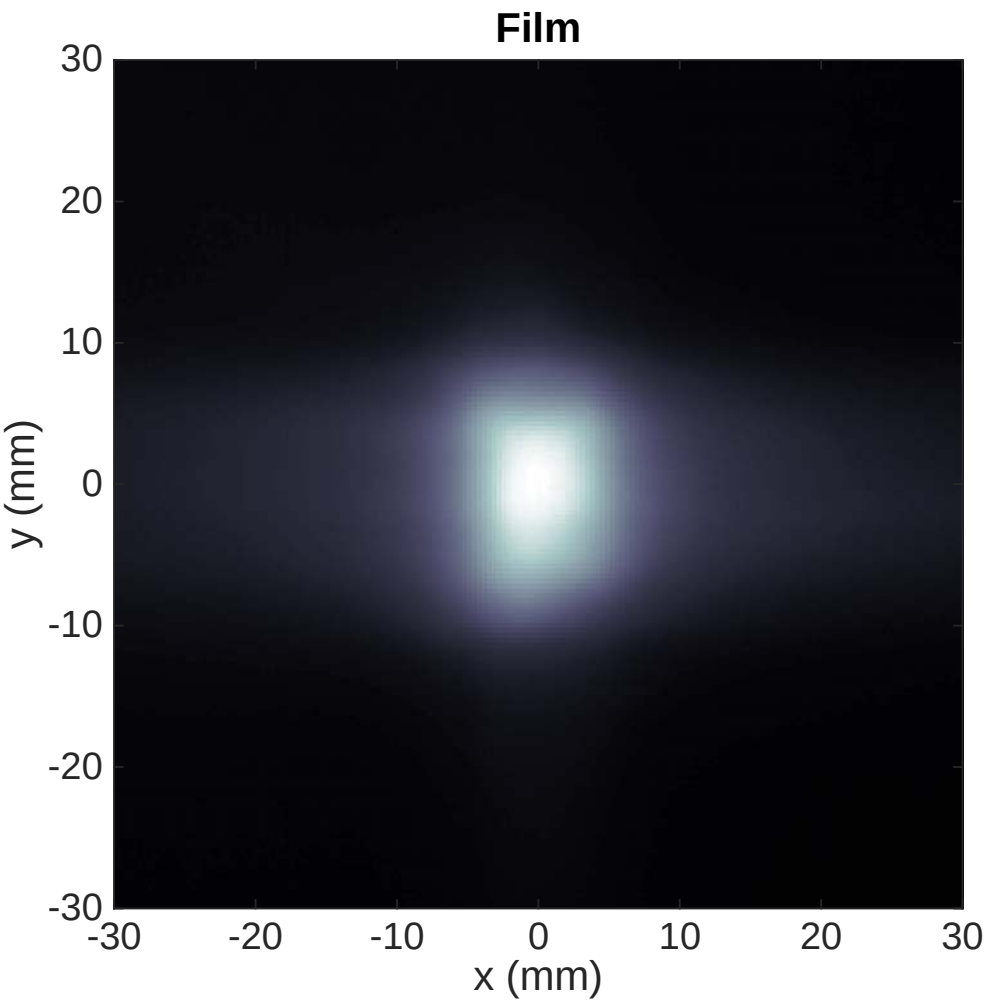

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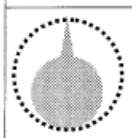
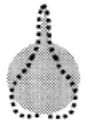
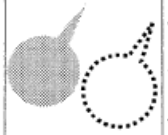
	TV = 5 cm³* V_{RI} = 10 cm³ § TV_{RI} = 5 cm³ ¶	**2**	**1**	**0.50**	**0.50**
	TV = 5 cm³ V_{RI} = 3 cm³ TV_{RI} = 3 cm³	**0.60**	**0.60**	**1**	**0.60**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 4 cm³	**1**	**0.80**	**0.80**	**0.64**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 2.5 cm³	**1**	**0.50**	**0.50**	**0.25**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 0 cm³	**1**	**0**	**0**	**0**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 5 cm³	**1**	**1**	**1**	**1**

Abbreviations: TV = Target Volume (gray); V_{RI} = Volume of the Reference Isodose (dotted line); TV_{RI} = Target volume covered by the Reference Isodose = intersection of TV and V_{RI}.

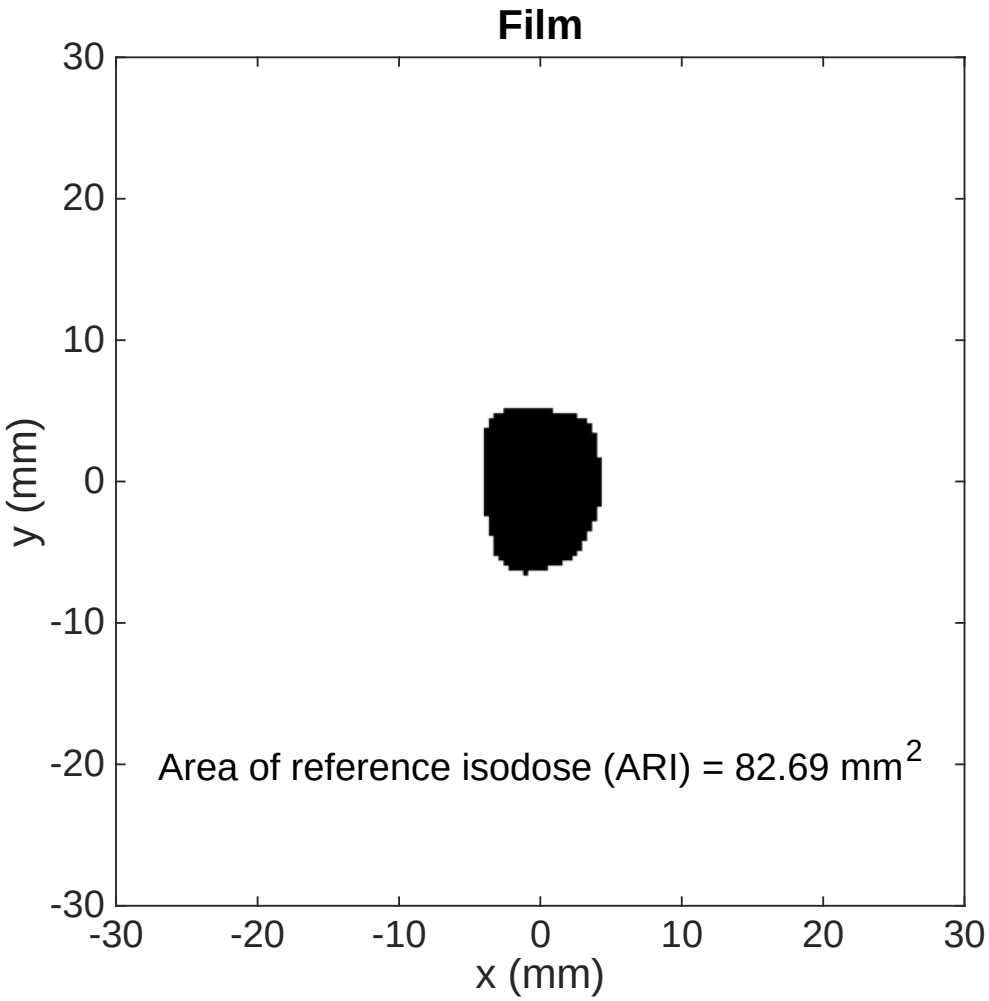
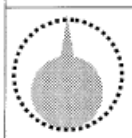
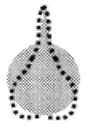
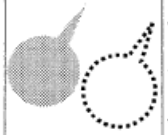


Table 2. Comparison of the various volume-based conformity indices in various clinical settings

Treatment plan	Parameters	$\frac{V_{RI}}{TV}$ RTOG (1)	$\frac{TV_{RI}}{TV}$ SALT-Lomax (28,32)	$\frac{TV_{RI}}{V_{RI}}$ Lomax (32)	$\frac{TV_{RI} \times TV_{RI}}{TV \times V_{RI}}$ Van't Riet (33)
	TV = 5 cm^3* V_{RI} = 10 cm^3 § TV_{RI} = 5 cm^3 ¶	**2**	**1**	**0.50**	**0.50**
	TV = 5 cm^3 V_{RI} = 3 cm^3 TV_{RI} = 3 cm^3	**0.60**	**0.60**	**1**	**0.60**
	TV = 5 cm^3 V_{RI} = 5 cm^3 TV_{RI} = 4 cm^3	**1**	**0.80**	**0.80**	**0.64**
	TV = 5 cm^3 V_{RI} = 5 cm^3 TV_{RI} = 2.5 cm^3	**1**	**0.50**	**0.50**	**0.25**
	TV = 5 cm^3 V_{RI} = 5 cm^3 TV_{RI} = 0 cm^3	**1**	**0**	**0**	**0**
	TV = 5 cm^3 V_{RI} = 5 cm^3 TV_{RI} = 5 cm^3	**1**	**1**	**1**	**1**

Abbreviations: TV = Target Volume (gray); V_{RI} = Volume of the Reference Isodose (dotted line); TV_{RI} = Target volume covered by the Reference Isodose = intersection of TV and V_{RI}.

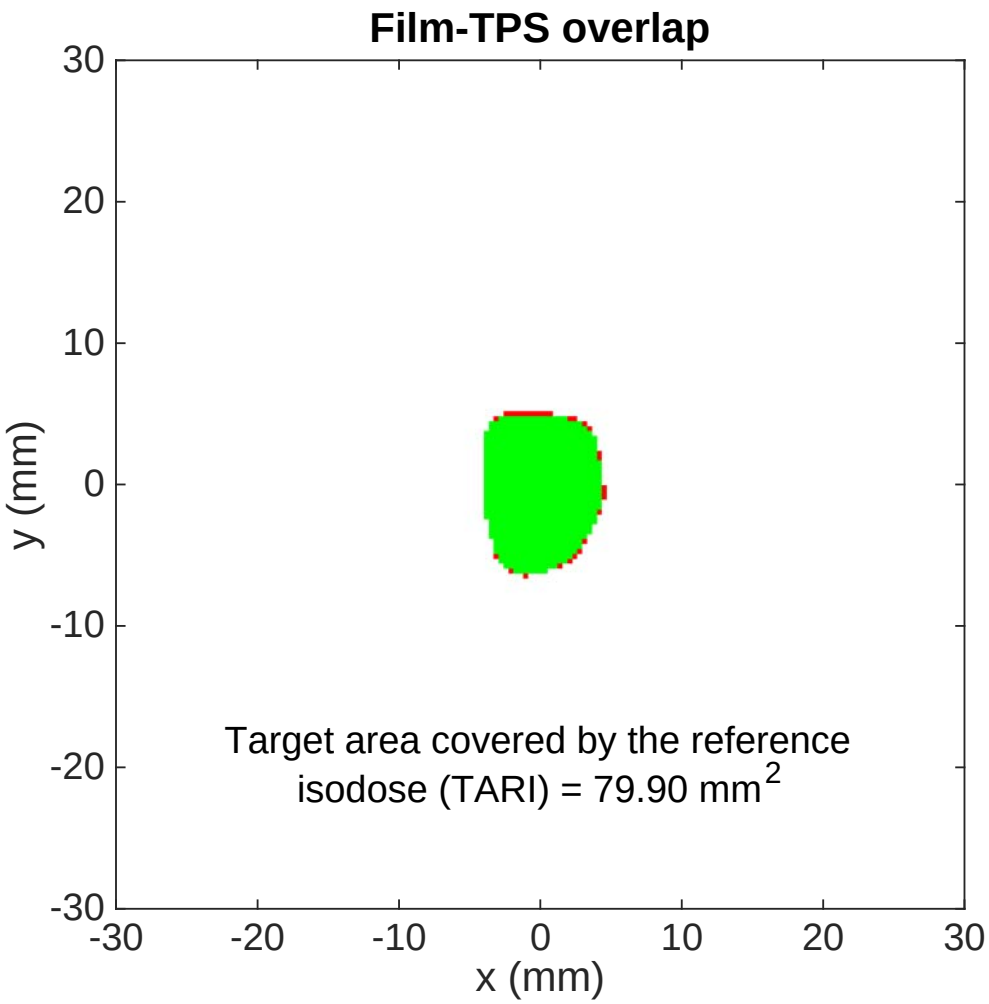
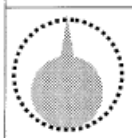
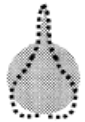
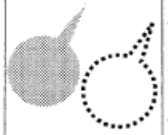
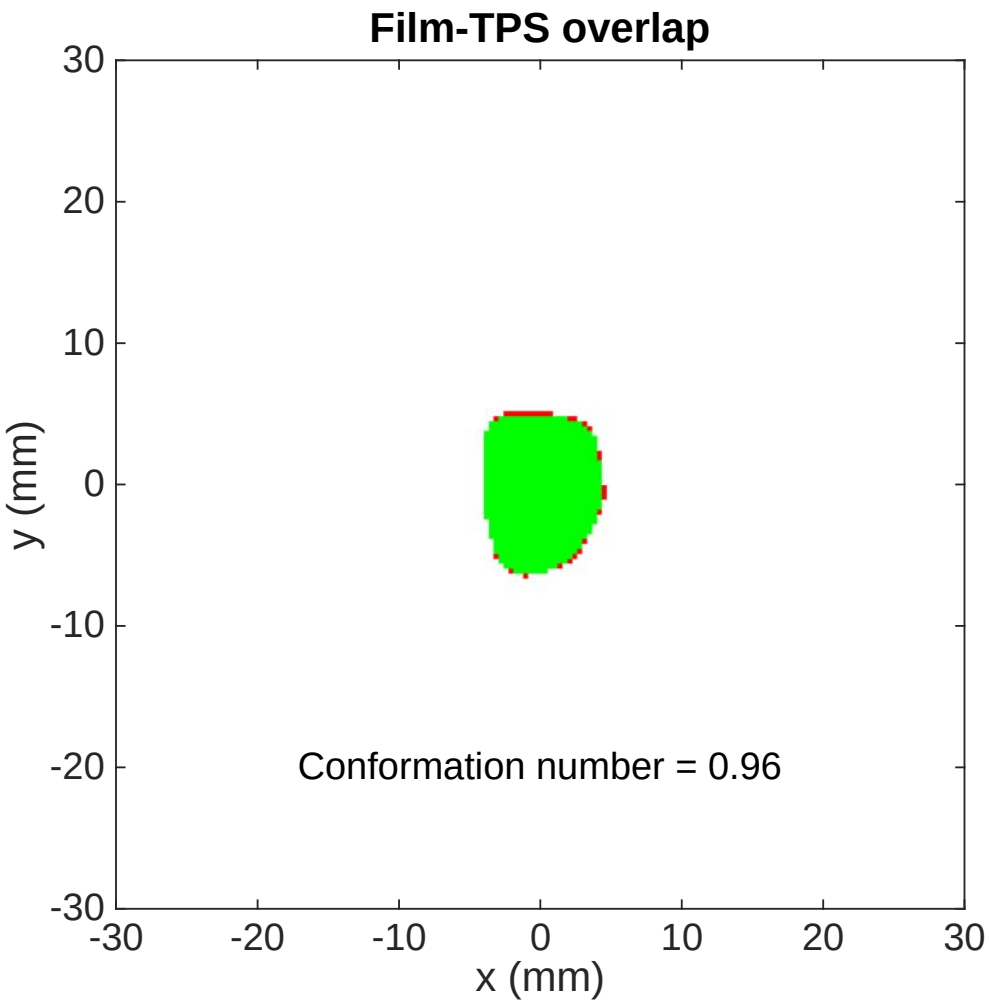
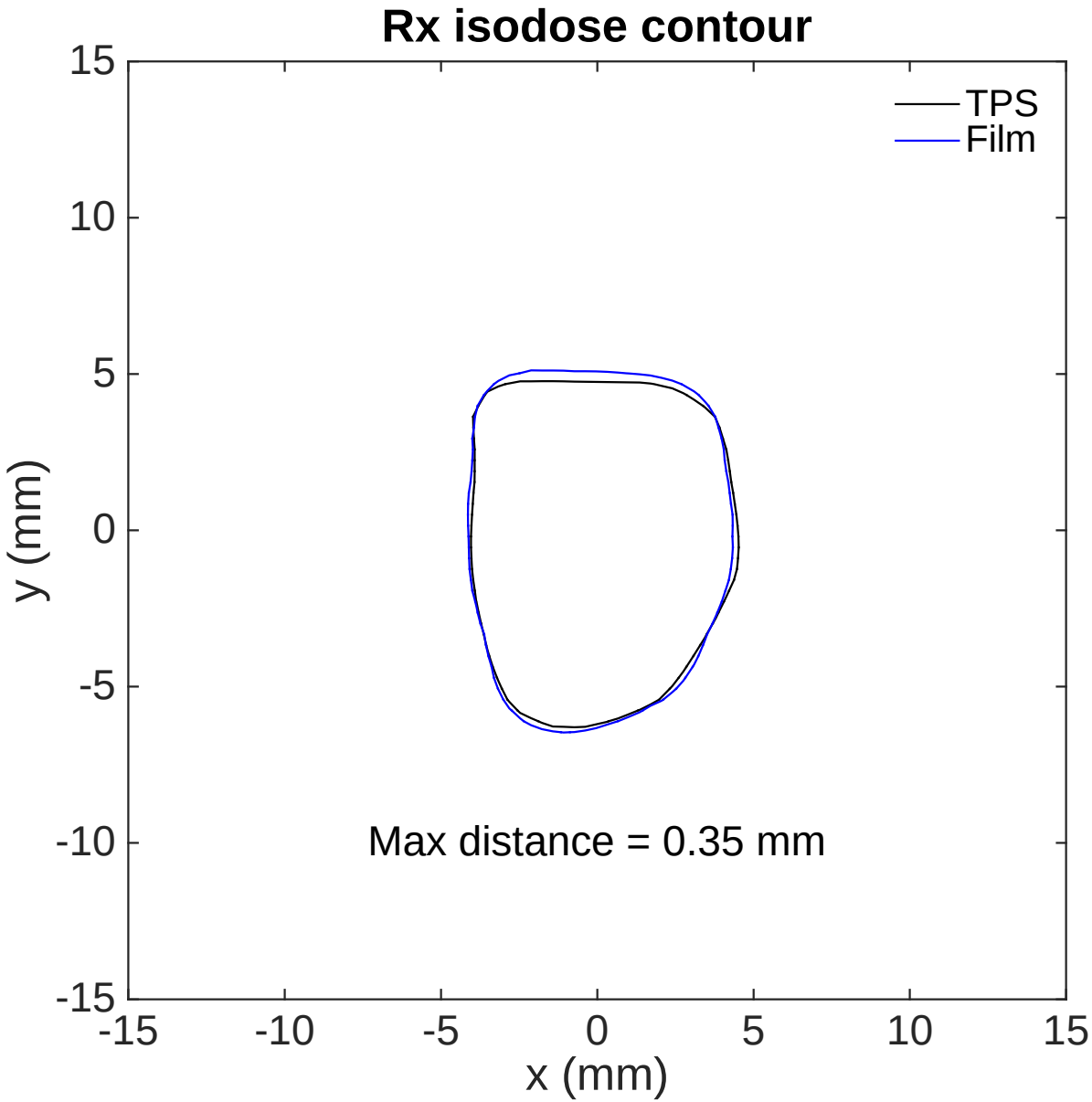


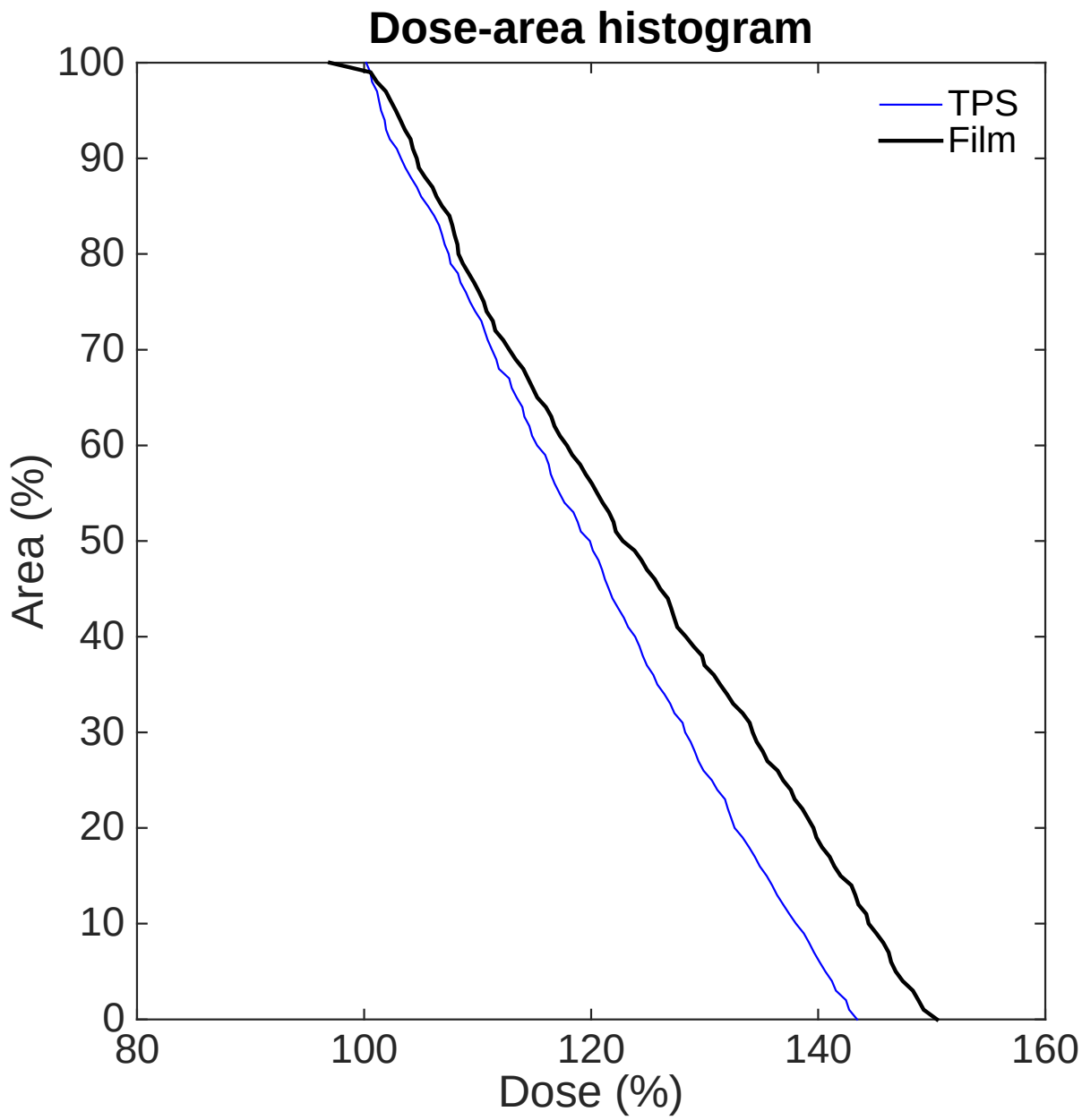
Table 2. Comparison of the various volume-based conformity indices in various clinical settings

Treatment plan	Parameters	$\frac{V_{RI}}{TV}$ RTOG (1)	$\frac{TV_{RI}}{TV}$ SALT-Lomax (28,32)	$\frac{TV_{RI}}{V_{RI}}$ Lomax (32)	$\frac{TV_{RI} \times TV_{RI}}{TV \times V_{RI}}$ Van't Riet (33)
	TV = 5 cm³* V_{RI} = 10 cm³ § TV_{RI} = 5 cm³ ¶	**2**	**1**	**0.50**	**0.50**
	TV = 5 cm³ V_{RI} = 3 cm³ TV_{RI} = 3 cm³	**0.60**	**0.60**	**1**	**0.60**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 4 cm³	**1**	**0.80**	**0.80**	**0.64**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 2.5 cm³	**1**	**0.50**	**0.50**	**0.25**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 0 cm³	**1**	**0**	**0**	**0**
	TV = 5 cm³ V_{RI} = 5 cm³ TV_{RI} = 5 cm³	**1**	**1**	**1**	**1**

Abbreviations: TV = Target Volume (gray); V_{RI} = Volume of the Reference Isodose (dotted line); TV_{RI} = Target volume covered by the Reference Isodose = intersection of TV and V_{RI}.



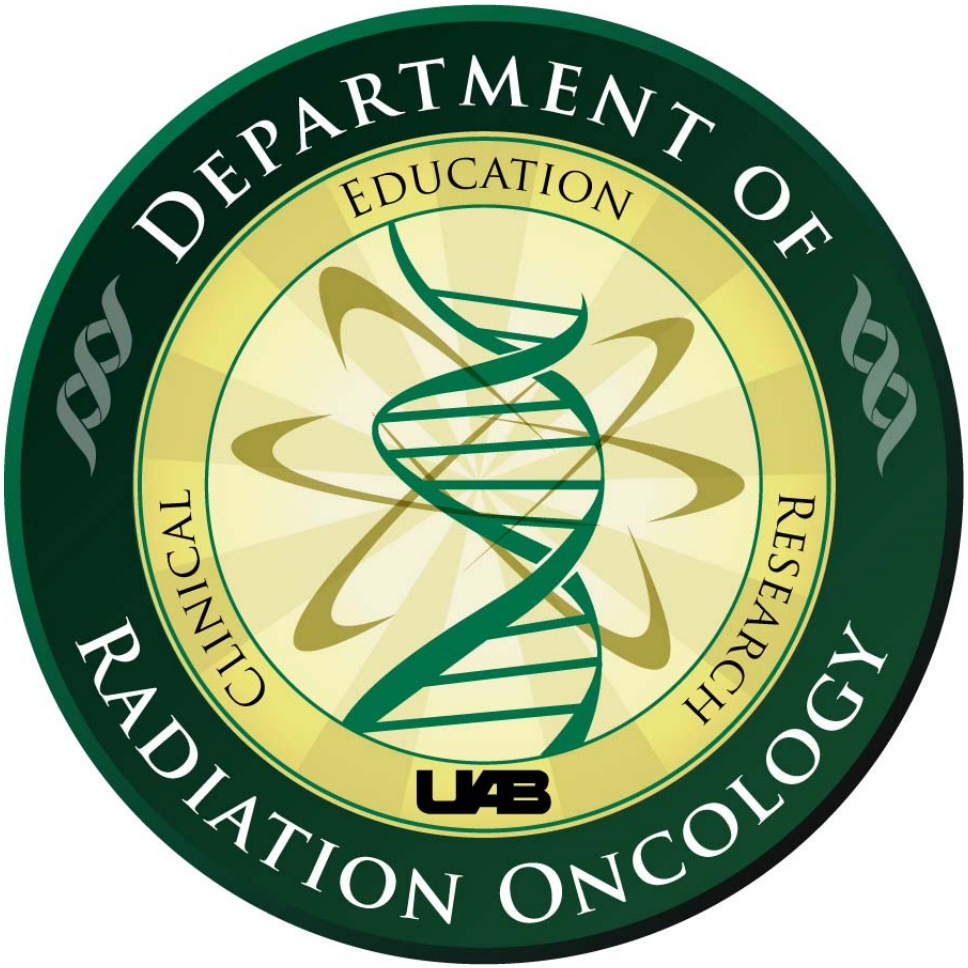



Dose-area histogram
TPS
Film
Area (%)
Dose (%)
0
10
20
30
40
50
60
70
80
90
100
80
100
120
140
160

Conclusion

- Quality assurance for small targets is challenging but doable.
- Need to use film with careful calibration.
- Use a chamber whenever possible – use to cross check film.
- Patient specific geometric QA can be achieved using IGDQA.
- Which evaluation metrics are most useful for small target QA is still an open question.

Questions?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