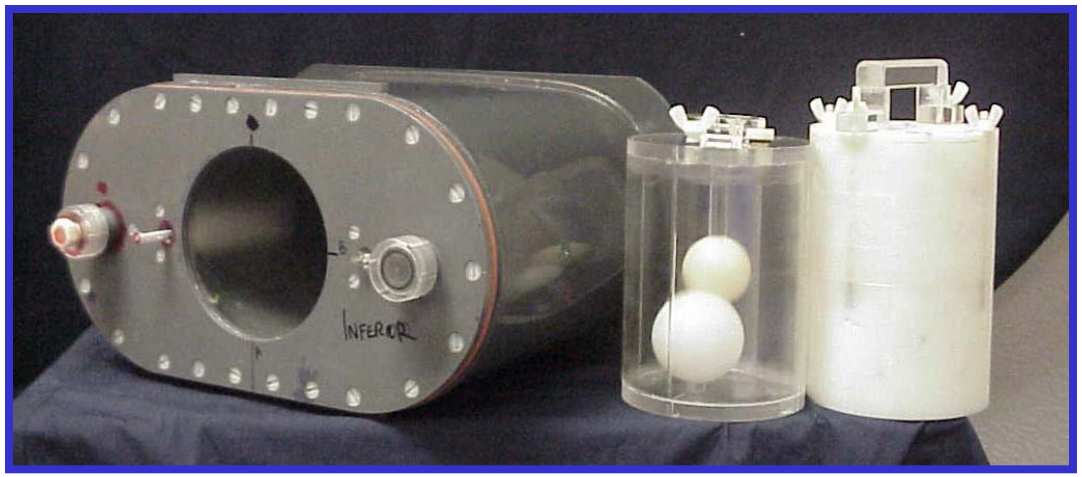
RPC's IMRT Phantoms



SWAAPM

October 2007

RPC Radiological Physics Center
Excellence through Quality Assurance

THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER

RPC's Phantom Team

Paola Alvarez

Carrie Amador

Teresa Collier

David S. Followill

Sarai Garcia

Franklin Hall

Nadia Hernandez

Geoffrey S. Ibbott

Sophia Jaramillo

Mary Lou Lesseraux

Jessica Lowenstein

Andrea Molineu

Robert Pinney

Brief background

- **Originated through agreement between AAPM and CRTS**
- **Founded in 1968 to monitor institution participation in clinical trials**
- **Funded continuously by NCI as structure of cooperative group programs have changed**
- **Now 39 years of experience of monitoring institutions and reporting findings to study groups and community**

RPC Radiological Physics Center
Excellence through Quality Assurance

Why do we do this?

We have an NCI grant to:

1. **Assure NCI and cooperative groups that institutions participating in clinical trials deliver prescribed doses that are comparable and consistent.**

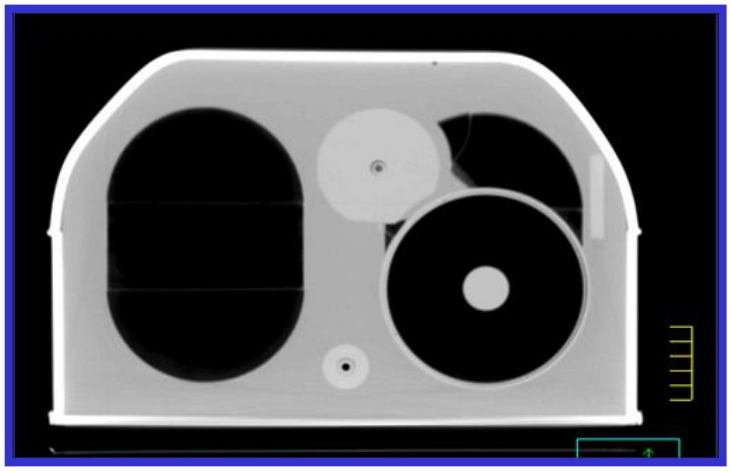
2. **Help institutions to make any corrections that might be needed.**

3. **Report findings to the community.**

RPC Radiological Physics Center
Excellence through Quality Assurance

RPC Phantoms

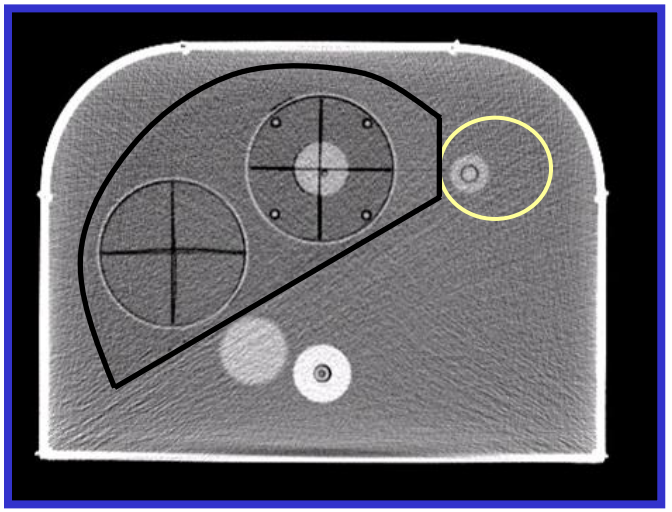
Pelvis (4)



Thorax (9)

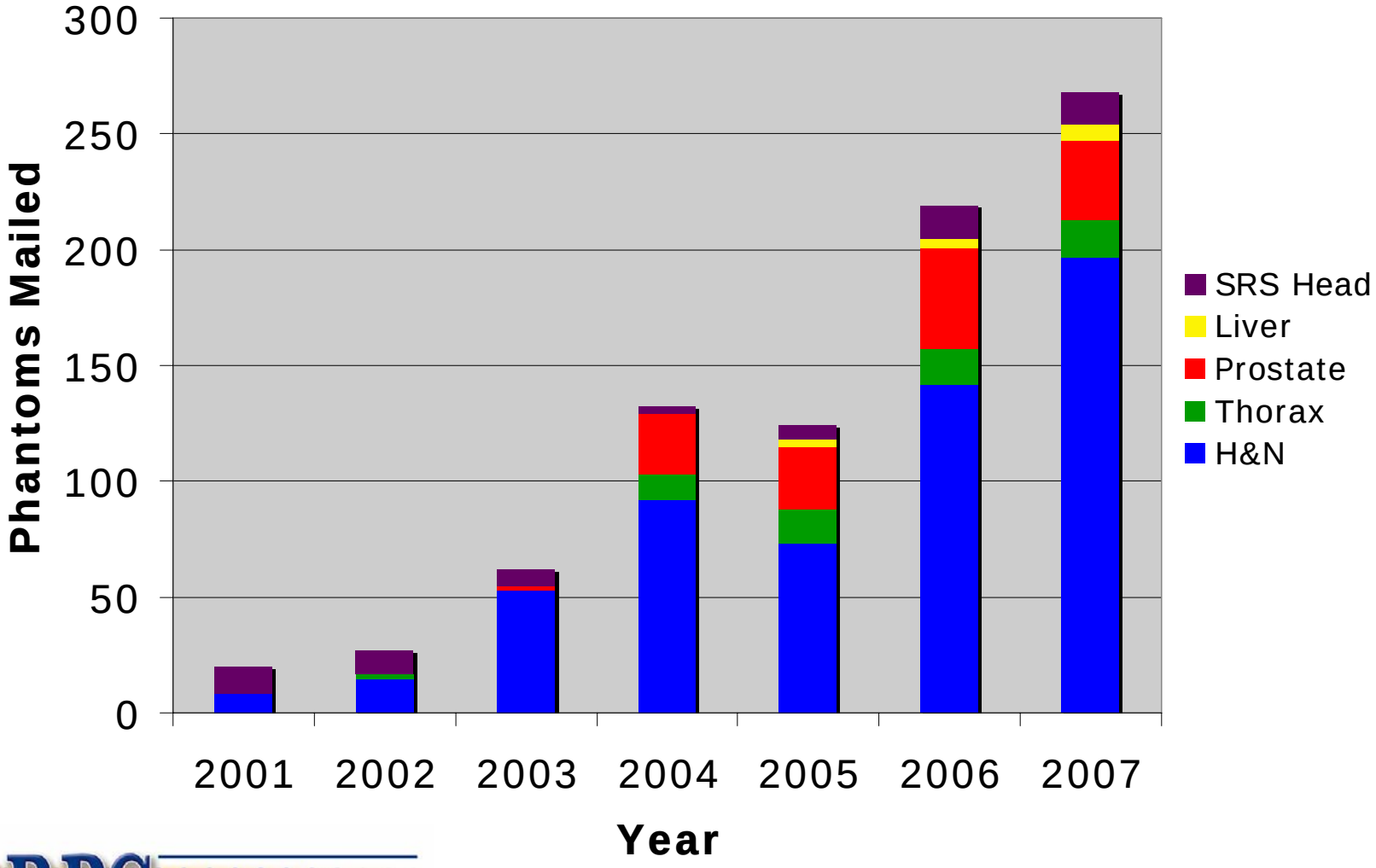
H&N IMRT (25)

SRS Head (4)



Liver (2)

Number of phantom mailings



RPC Radiological Physics Center
Excellence through Quality Assurance

The thermoluminescent dosimetry (TLD) program

- **Largest of its kind in operation (> 30 years)**
- **Verifies dose output and energy on megavoltage units (>9100 beams in 2006).**
- **Measure consistency of institutions based on TLD history**
- **Provides independent audit of the output as required by many states**

RPC Radiological Physics Center
Excellence through Quality Assurance

Radiochromic film

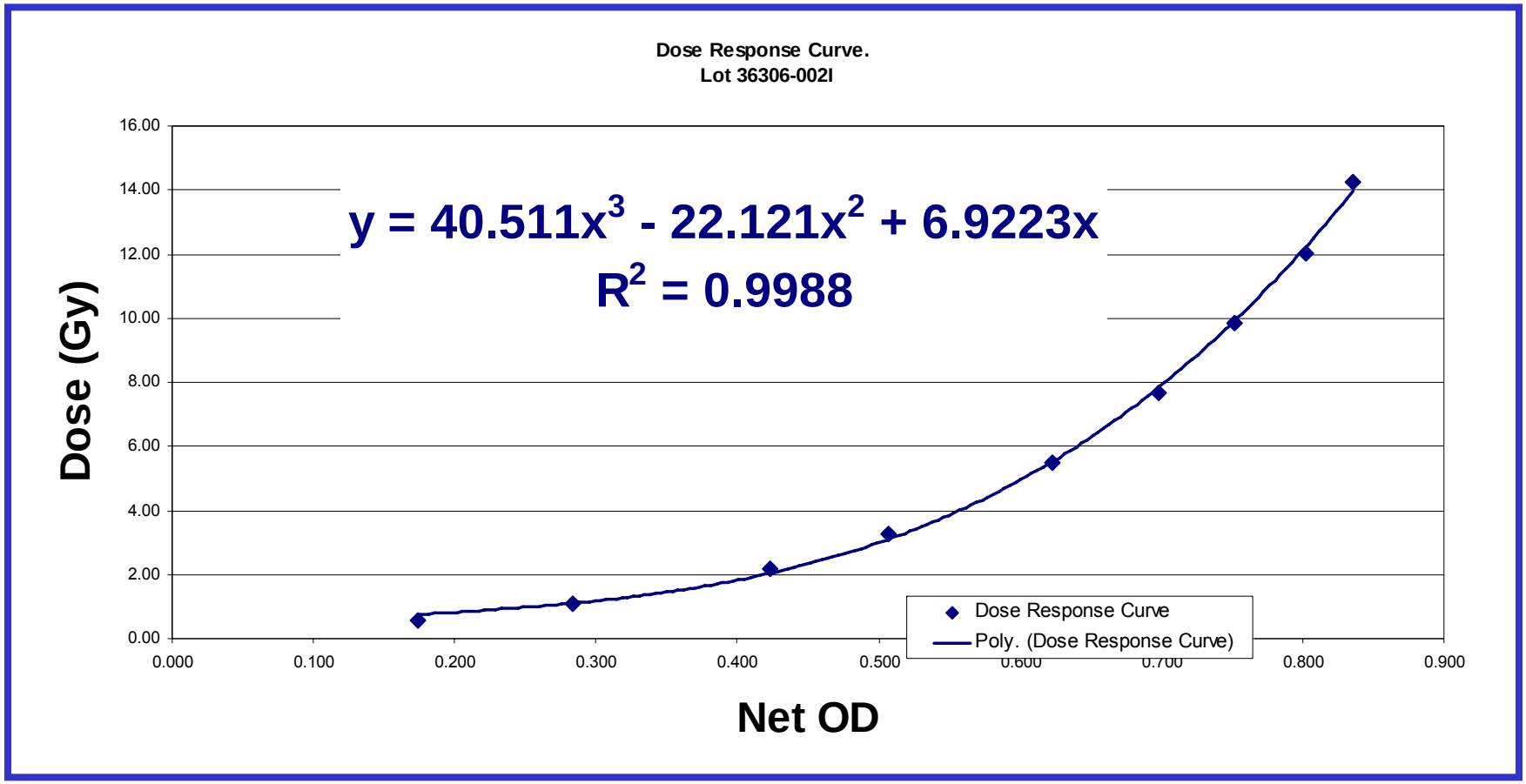
- Originally used MD-55
- Currently use EBT
- Good for doses 2-10 Gy
- Read on densitometer by Photoelectric
- Currently working with CERR group at Washington University on 2D analysis software package

RPC Radiological Physics Center
Excellence through Quality Assurance

Densitometer

Radiological Physics Center
Excellence through Quality Assurance

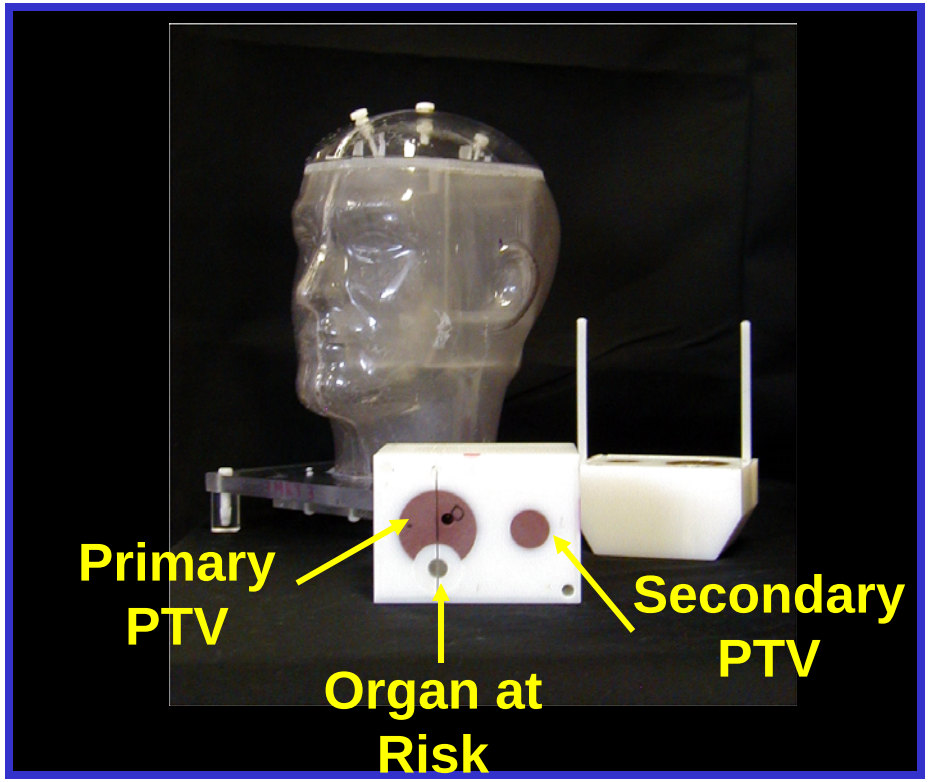
Densitometer



RPC Radiological Physics Center
Excellence through Quality Assurance

IMRT H&N phantom

- **Primary PTV**
  - **4 cm diameter**
  - **4 TLD**
- **Secondary PTV**
  - **2 cm diameter**
  - **2 TLD**
- **Organ at risk**
  - **1 cm diameter**
  - **2 TLD**
- **Axial and sagittal radiochromic films**



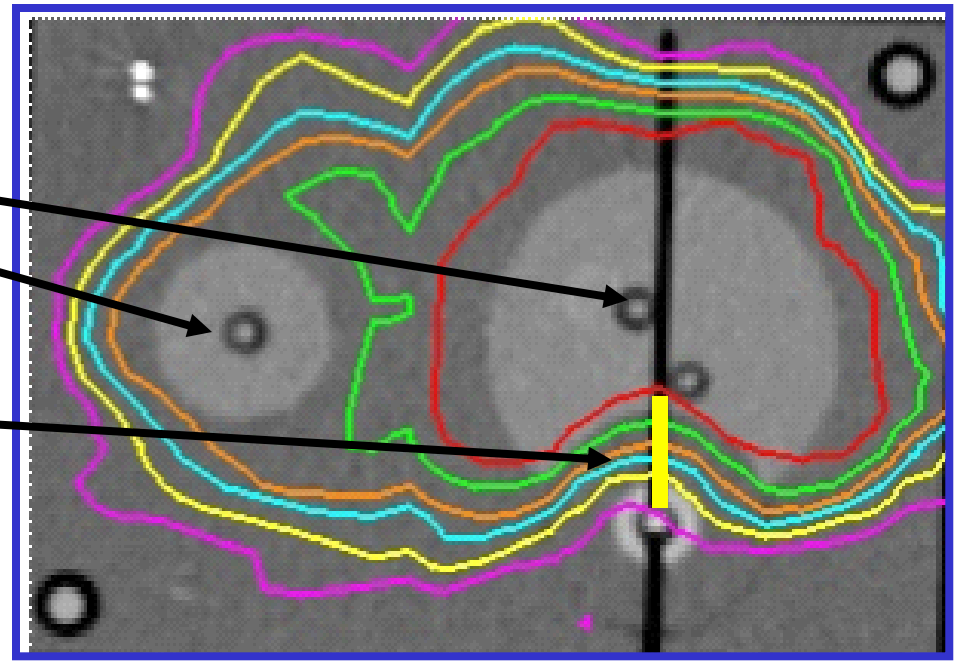
- **1º PTV treated to 6.6 Gy**
- **2º PTV treated to 5.4 Gy**
- **OAR limited to < 4.5 Gy**

Designed in collaboration with RTOG;
Molineu et al, IJROBP, October 2005

RPC Radiological Physics Center
Excellence through Quality Assurance

Criteria for credentialing

- **RPC/Inst dose in PTVs: 0.93-1.07**
- **distance to agreement in high gradient region near OAR: ≤ 4 mm**



RPC Radiological Physics Center
Excellence through Quality Assurance

IMRT H&N phantom results

- 419 irradiations were analyzed
- 322 irradiations passed the criteria
  - 68 institutions irradiated multiple times
- 97 irradiations did not pass the criteria
- 322 institutions are represented

Only 76% of institutions passed the criteria on the first irradiation.

RPC Radiological Physics Center
Excellence through Quality Assurance

IMRT H&N phantom results cont

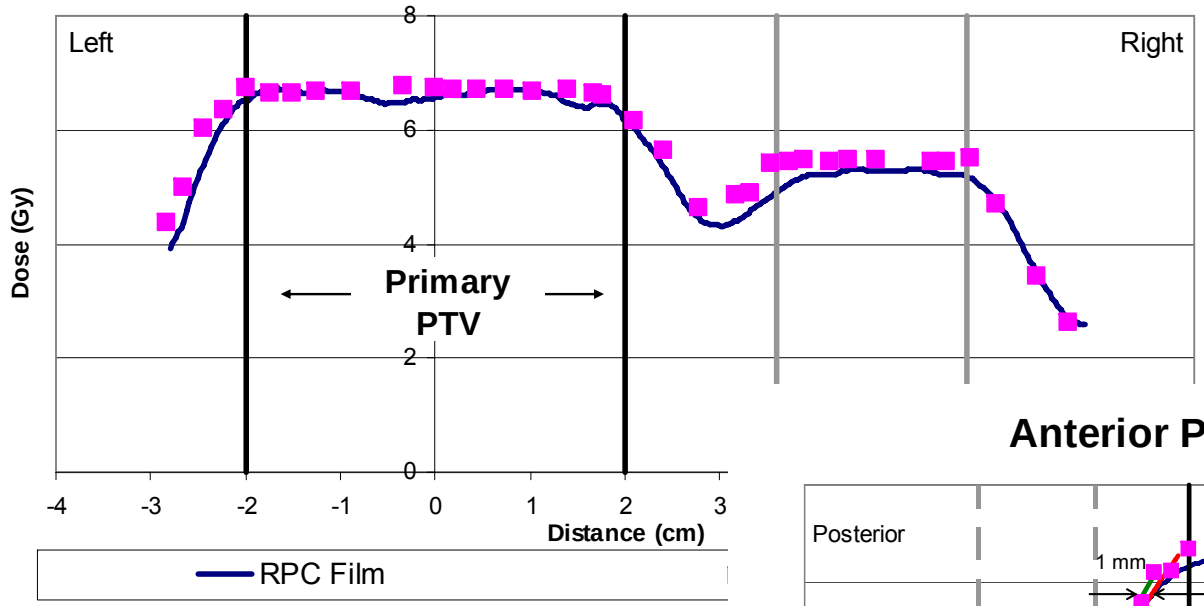
- **65 failed by absolute dose only**
- **13 failed by DTA only**
- **19 failed by both absolute dose and DTA**

	1PTV	2PTV	Displ.(mm)
mean	0.99	0.98	0.1
std dev	0.050	0.046	2.9
count	1447	721	419
range	0.49-1.15	0.57-1.23	*-15 -17*

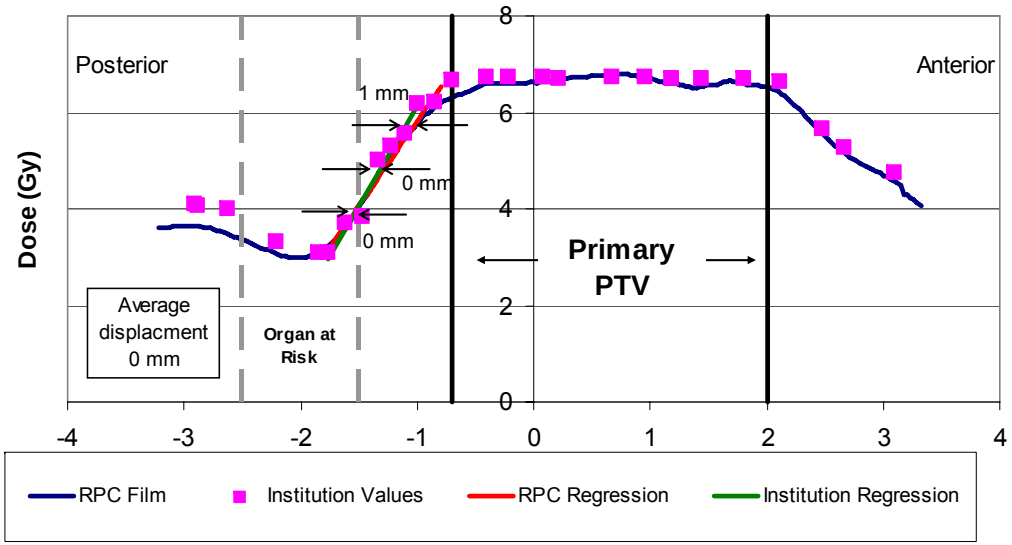
RPC Radiological Physics Center
Excellence through Quality Assurance

Good HN profile

Right Left Profile

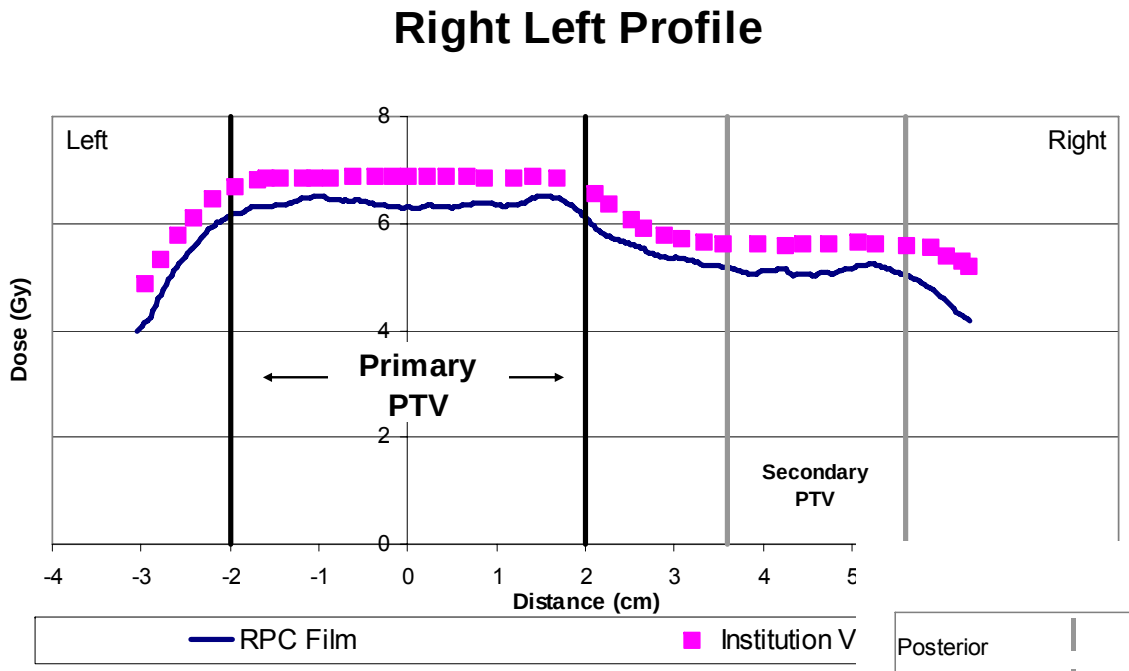


Anterior Posterior Profile

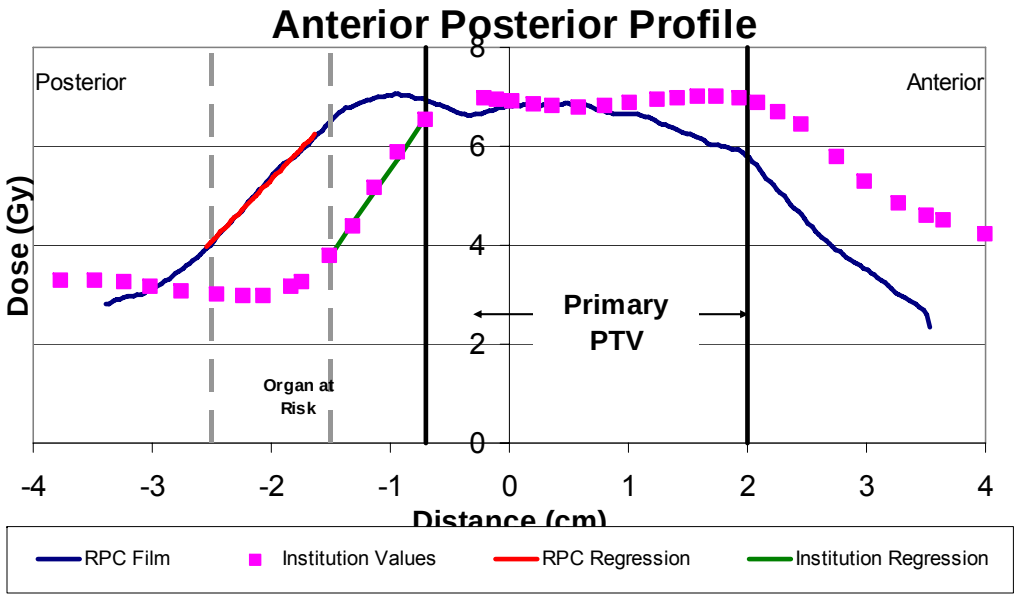


RPC Radiological Physics Center
Excellence through Quality Assurance

Not so good HN profile



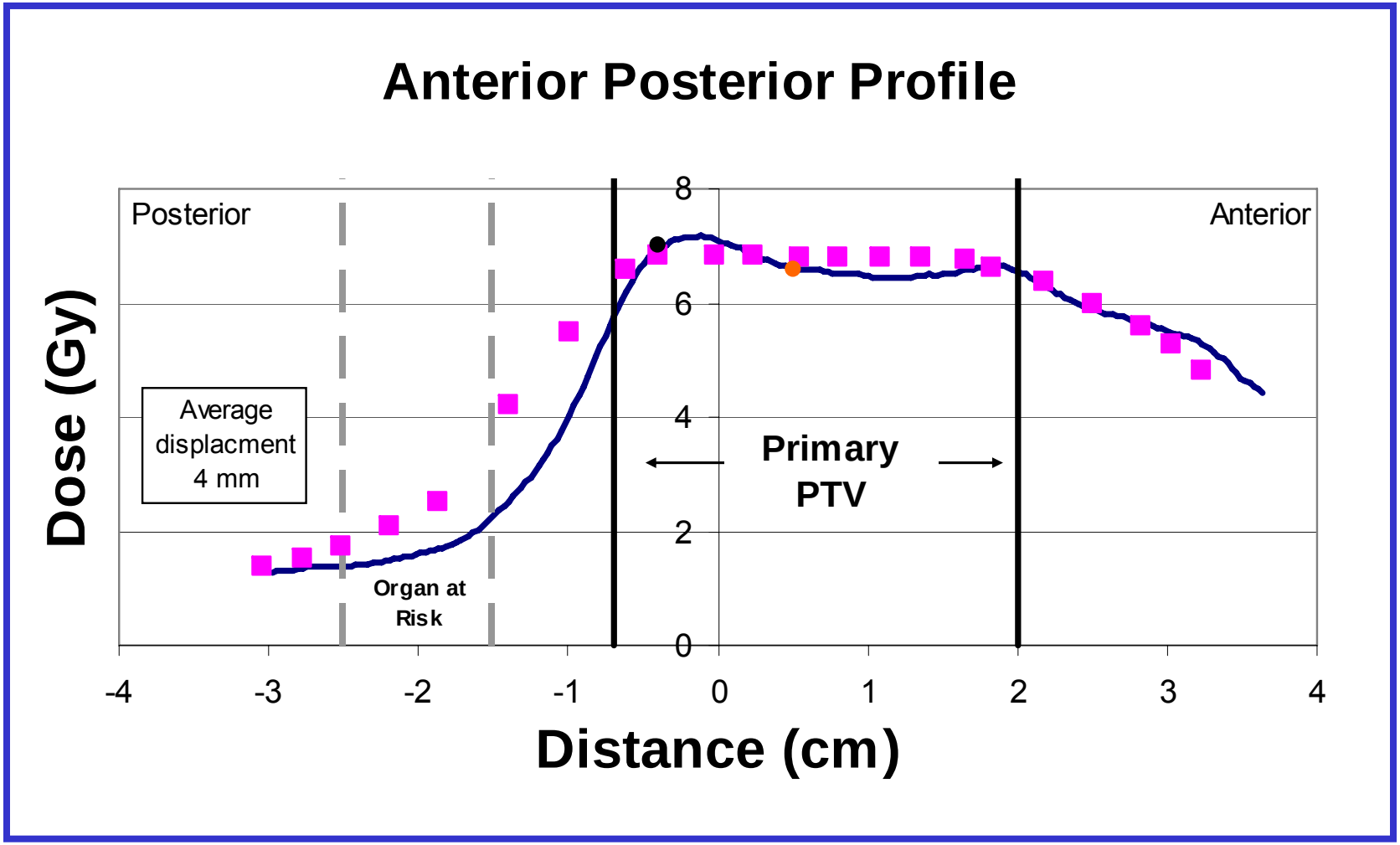
TLD 5-8% low



10 mm shift

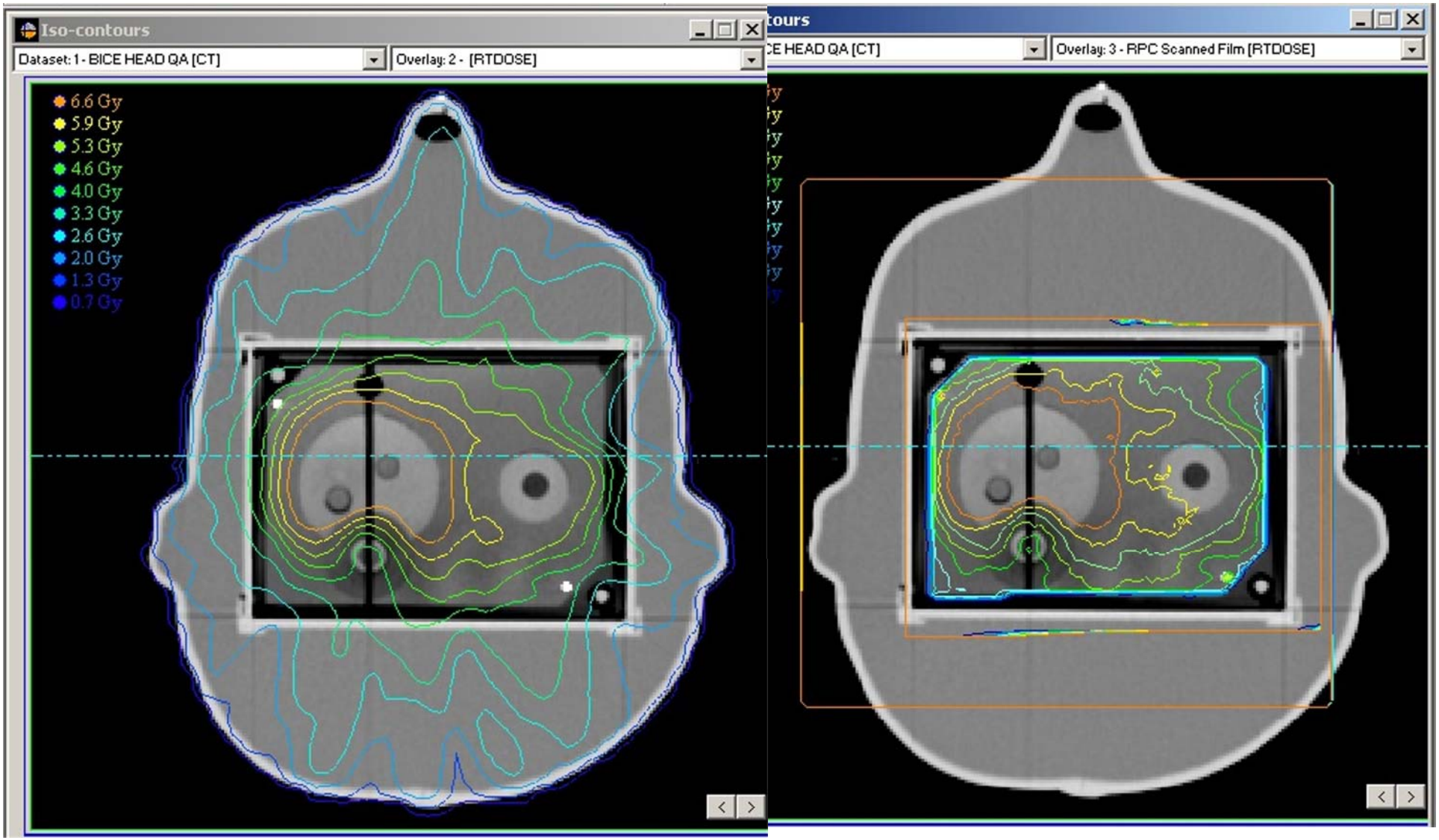
RPC Radiological Physics Center
Excellence through Quality Assurance

Not so good HN profile

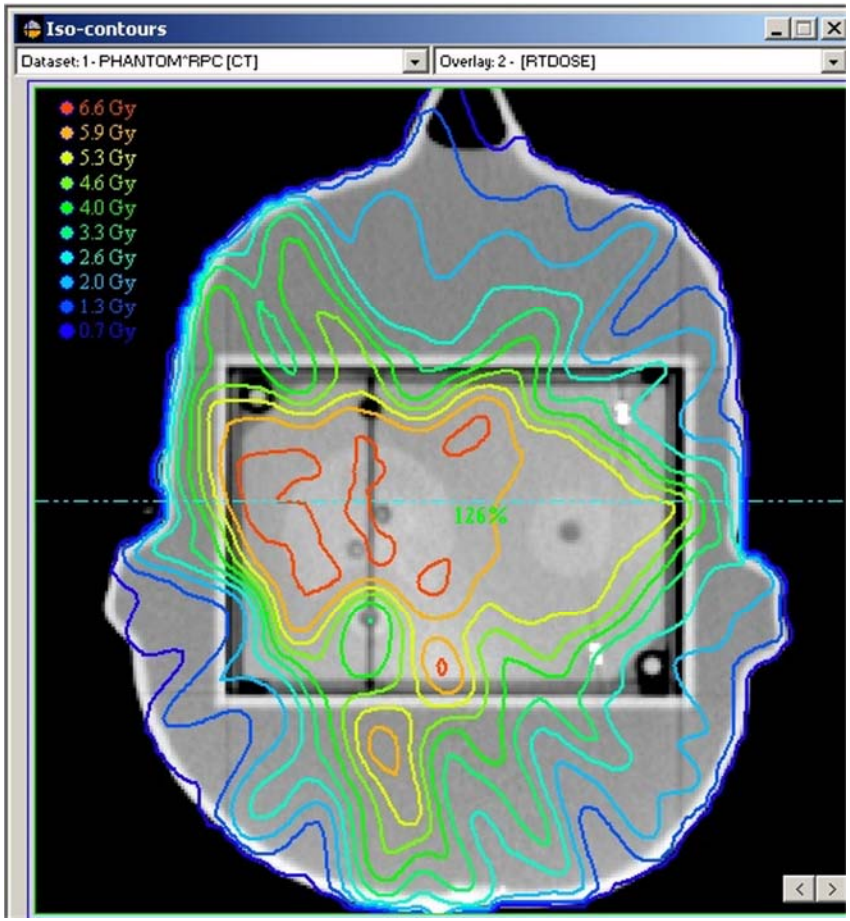


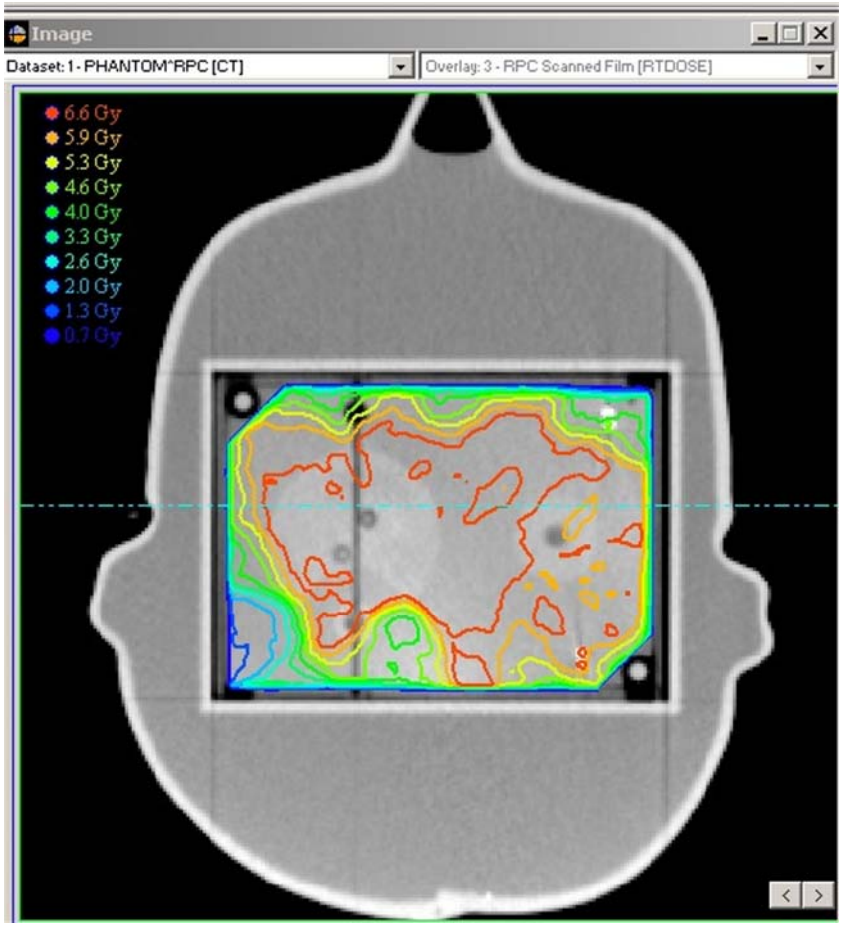
RPC Radiological Physics Center
Excellence through Quality Assurance

Plan vs. Treatment

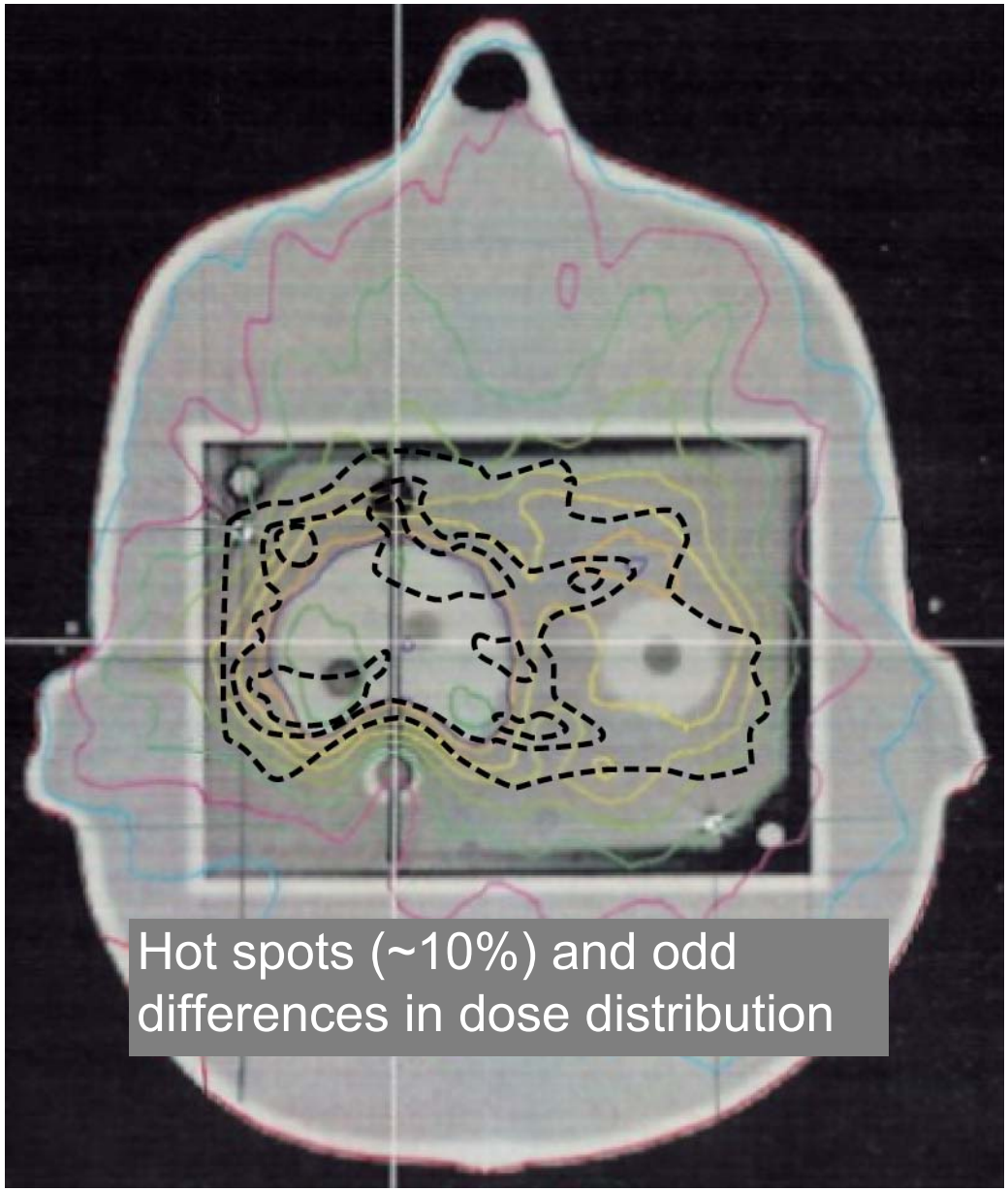


Examples of failures





Comparison: planned vs. delivered distribution

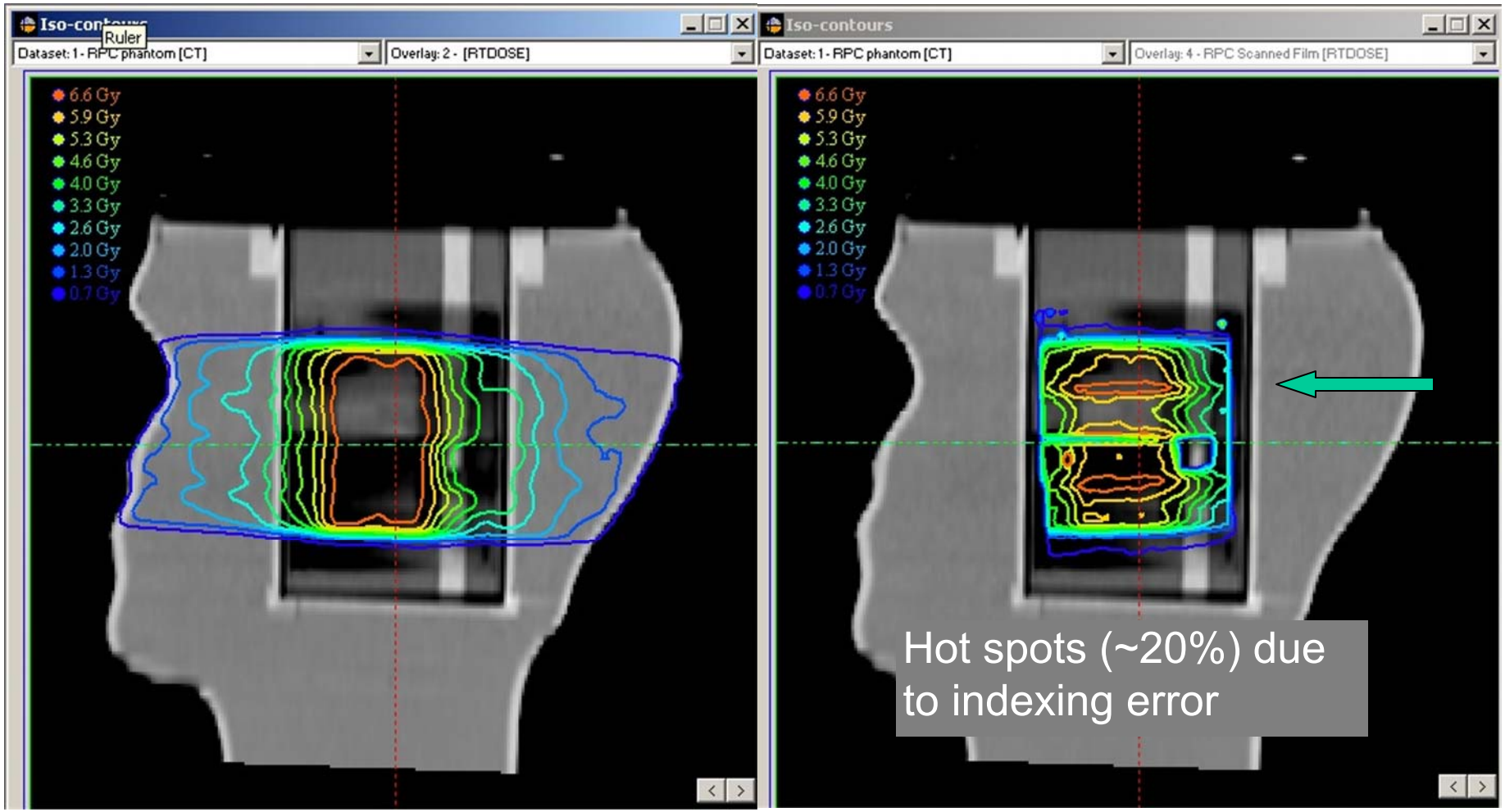


RPC Radiological Physics Center
Excellence through Quality Assurance

Couch indexing error

Institution's Plan

Delivered Dose



HN results grouped by accelerator manufacturer

Linear Accelerator Manufacturer	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
BrainLab	100	5	0	0	0
Elekta	60	35	11	2	1
Siemens	71	56	10	2	4
TomoTherapy	73	22	5	1	0
Varian	80	301	39	8	14
total		419	65	13	19

RPC Radiological Physics Center
Excellence through Quality Assurance

HN results grouped by TPS

Treatment planning system	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Corvus	75	32	7	0	1
Eclipse	85	114	10	4	3
Pinnacle	73	168	33	4	8
TomoTherapy	73	22	5	1	0
XiO	73	59	7	4	5
Other	79	24	3	0	2
total		419	65	13	19

RPC Radiological Physics Center
Excellence through Quality Assurance

HN results grouped by machine/TPS

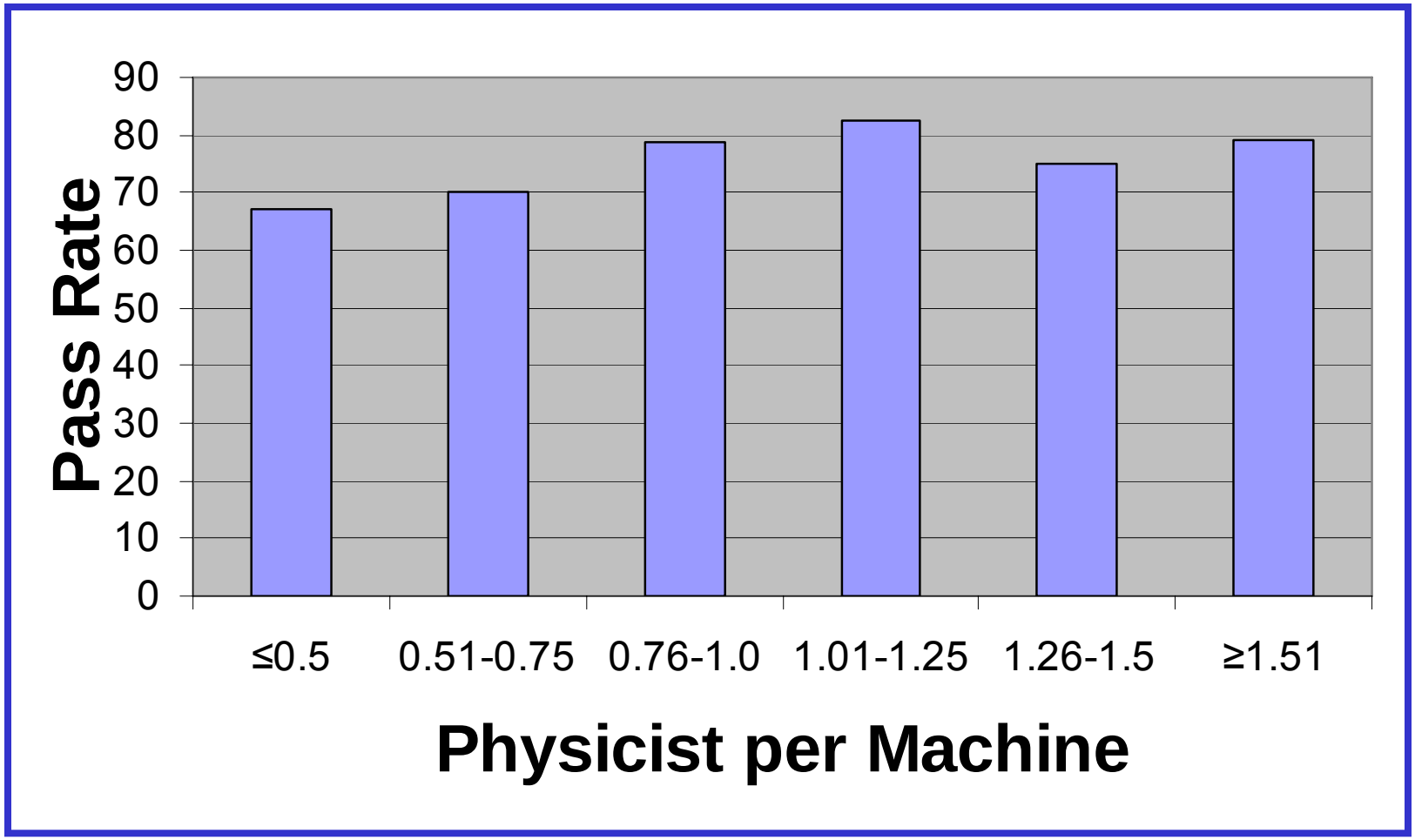
Manufacturer/TPS Combination	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Elekta/Corvus	0	1	1	0	0
Elekta/Pinnacle	67	21	6	1	0
Elekta/XiO	56	9	2	1	1
Elekta/Other	50	4	2	0	0
Siemens/Corvus	88	8	1	0	0
Siemens/Pinnacle	70	27	5	0	3
Siemens/XiO	77	13	1	1	1
Siemens/Other	67	6	1	1	0
Varian/Corvus	73	22	5	0	1
Varian/Eclipse	86	110	9	3	3
Varian/Pinnacle	75	121	22	3	5
Varian/XiO	76	37	4	2	3
Varian/Other	77	13	1	0	2
Other	77	26	5	1	0
total		418	65	13	19

HN results grouped by technique

IMRT technique	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Dynamic MLC	87	110	9	2	3
IMAT	50	12	5	0	1
Segmental	74	279	47	10	15
TomoTherapy	76	17	3	1	0
Experimental	0	1	1	0	0
total		419	65	13	19

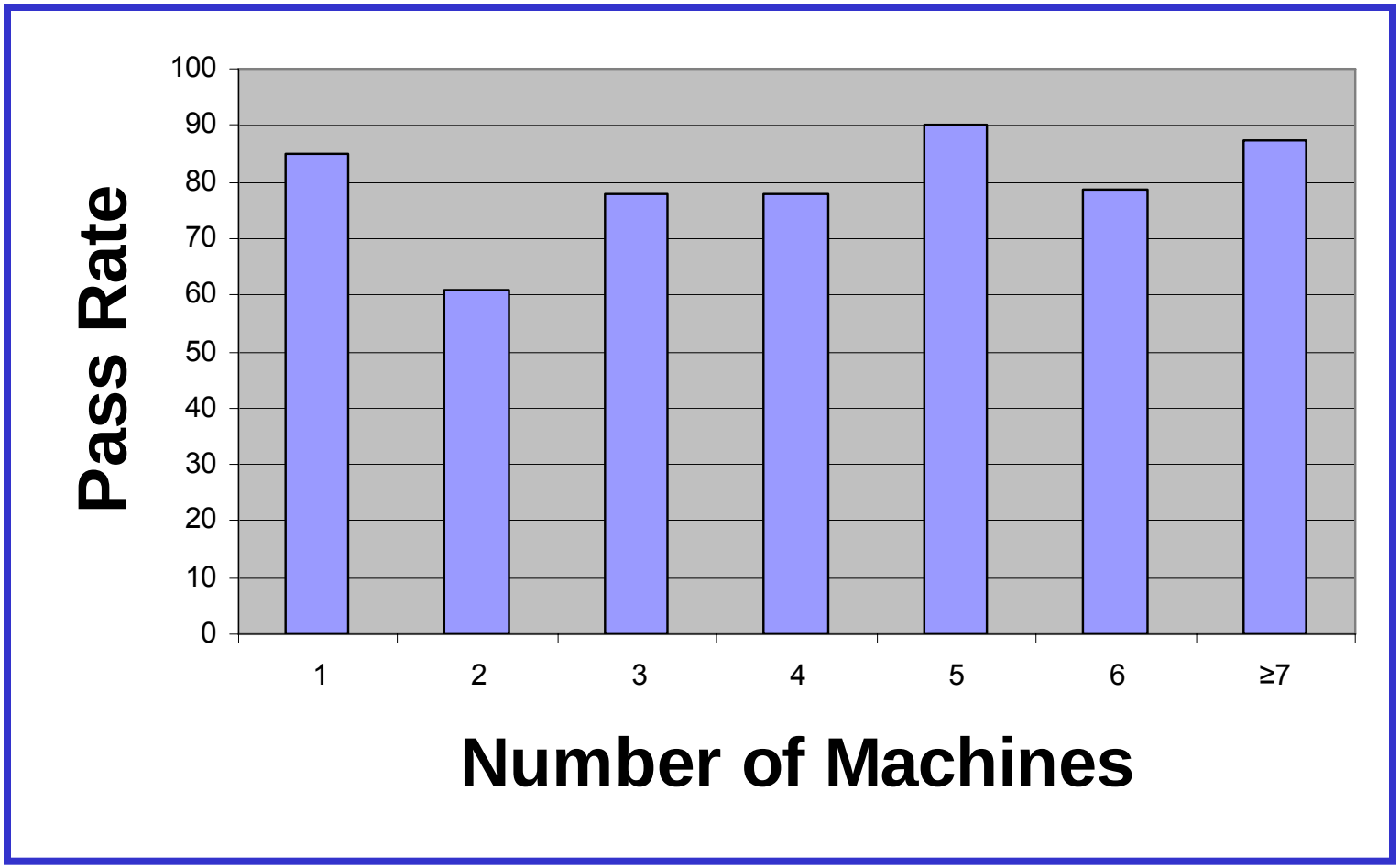
RPC Radiological Physics Center
Excellence through Quality Assurance

Physicist per machine



RPC Radiological Physics Center
Excellence through Quality Assurance

Number of machines



RPC Radiological Physics Center
Excellence through Quality Assurance

HN QA Dose criterion

148 institutions reported point dose measurements and criterion

Dose Criterion	Number of Institutions
2% - 3%	96
4% - 5%	52
> 5%	0

RPC Radiological Physics Center
Excellence through Quality Assurance

HN QA DTA criterion

111 institutions reported distance to agreement measurements and criterion

DTA Criterion	Number of Institutions
2 mm	4
3 mm	84
4 mm	11
5 mm	12

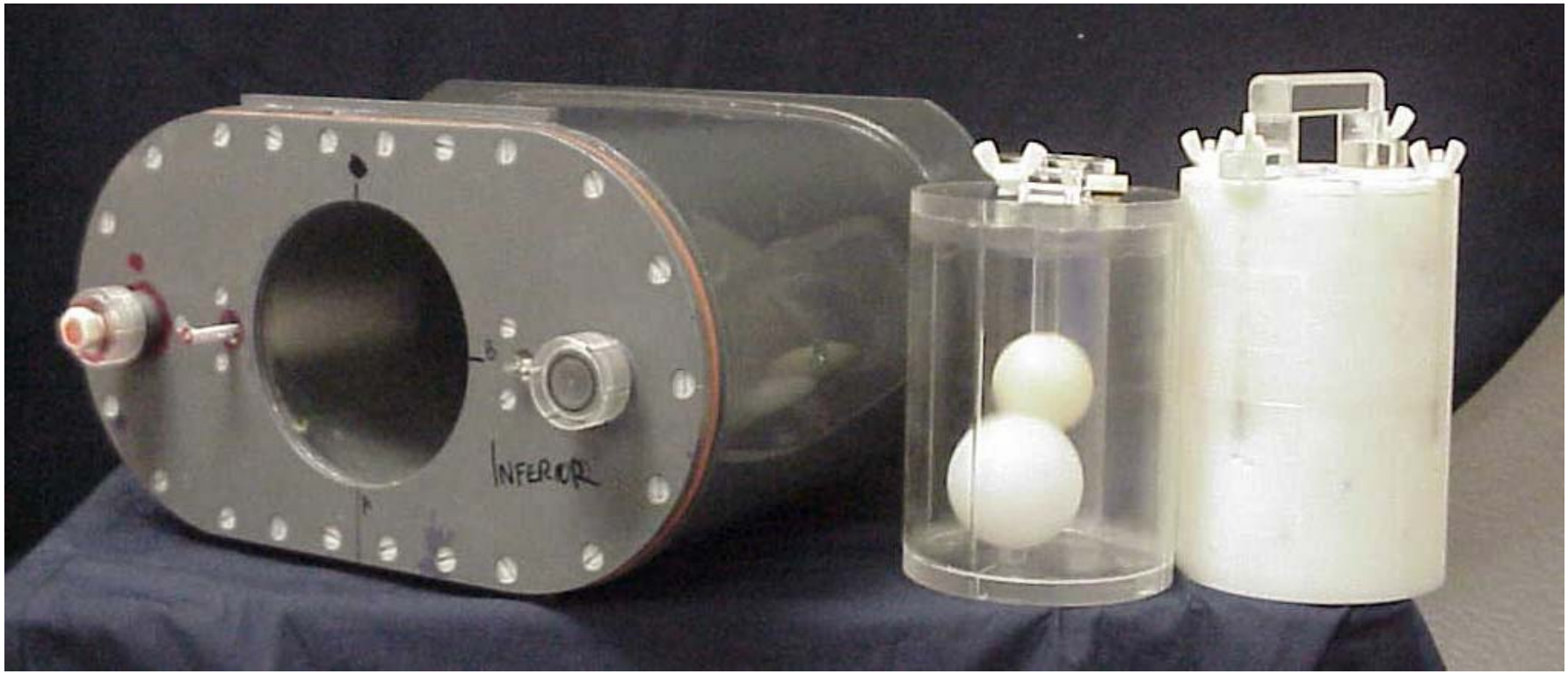
RPC Radiological Physics Center
Excellence through Quality Assurance

HN dose adjustments based on QA

- 11 institutions adjusted MU delivered based on their QA
  - 4 of these institutions failed anyway
- 63 of the failing institutions reported making no changes based on QA measurements
  - 13 of these measured dose in the same direction as the failure

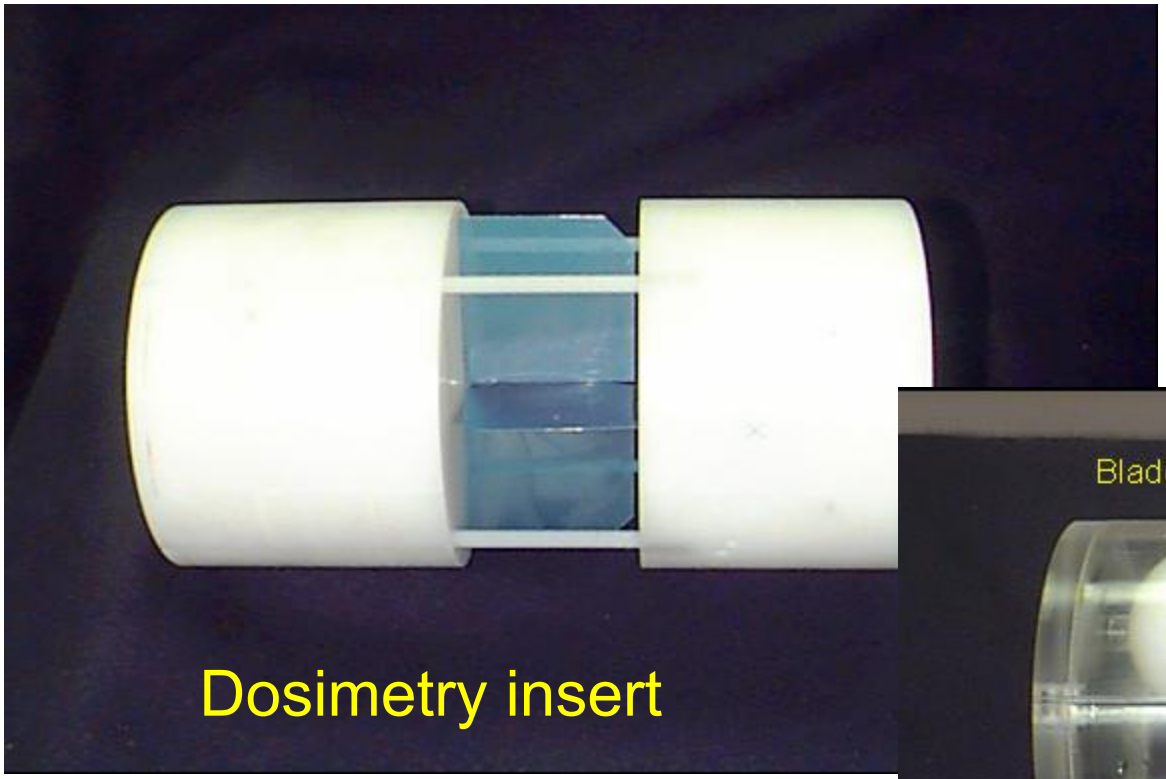
RPC Radiological Physics Center
Excellence through Quality Assurance

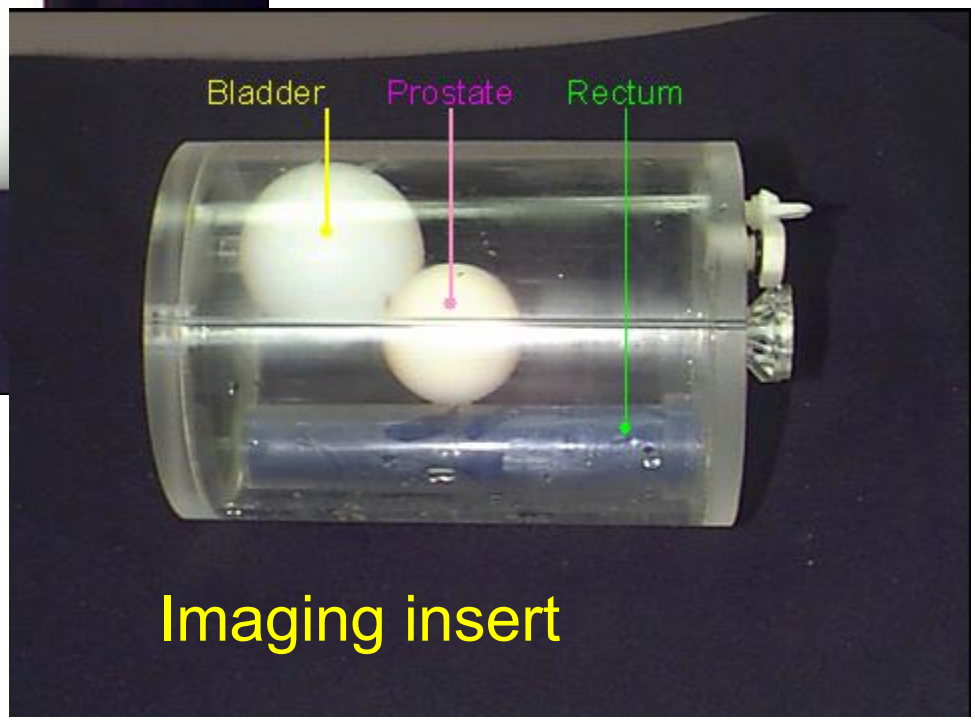
Prostate Phantom



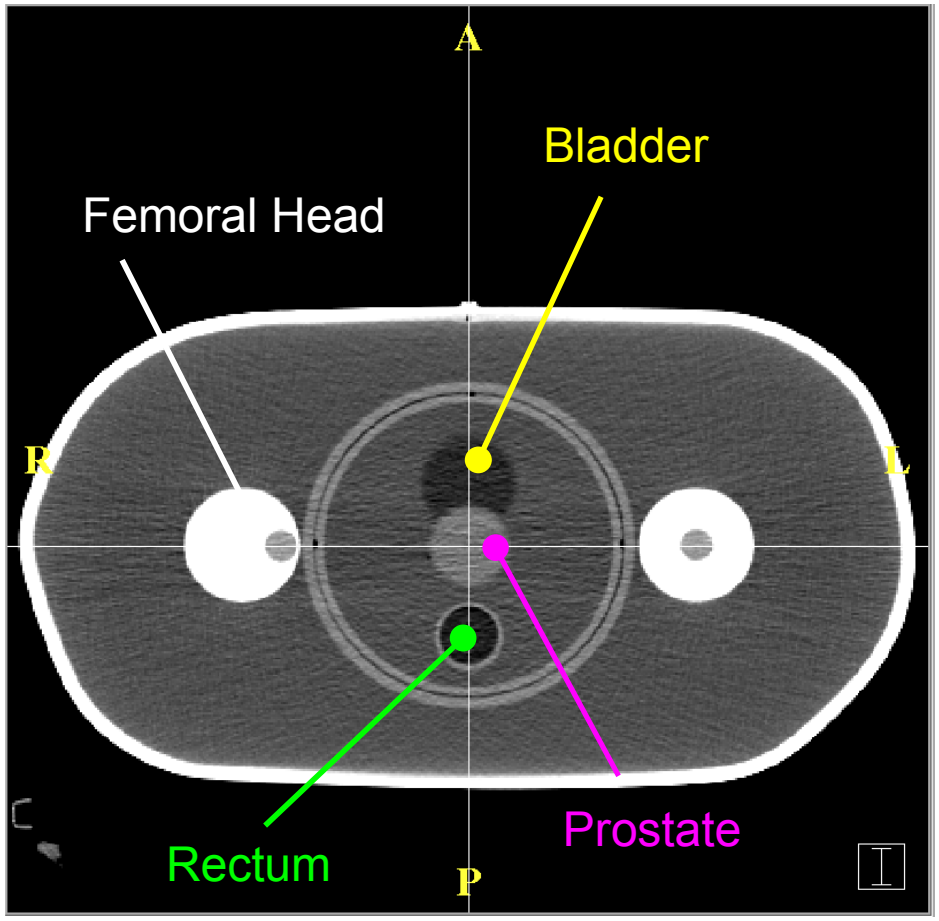
RPC Radiological Physics Center
Excellence through Quality Assurance

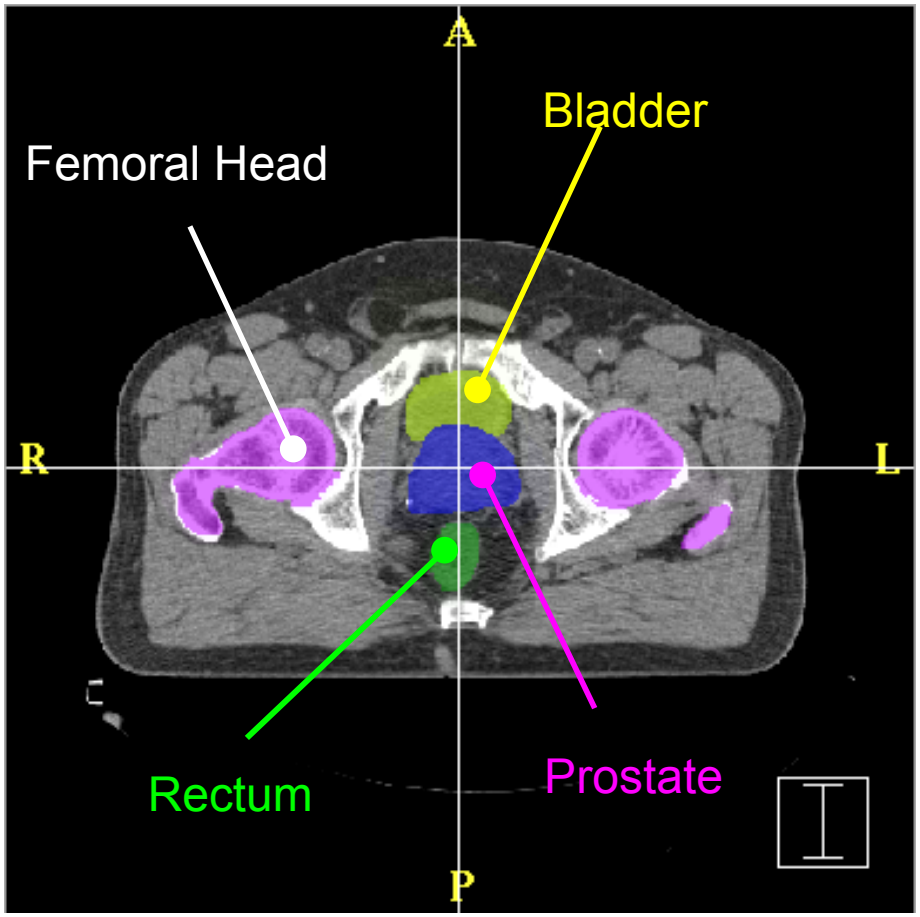
Prostate phantom inserts





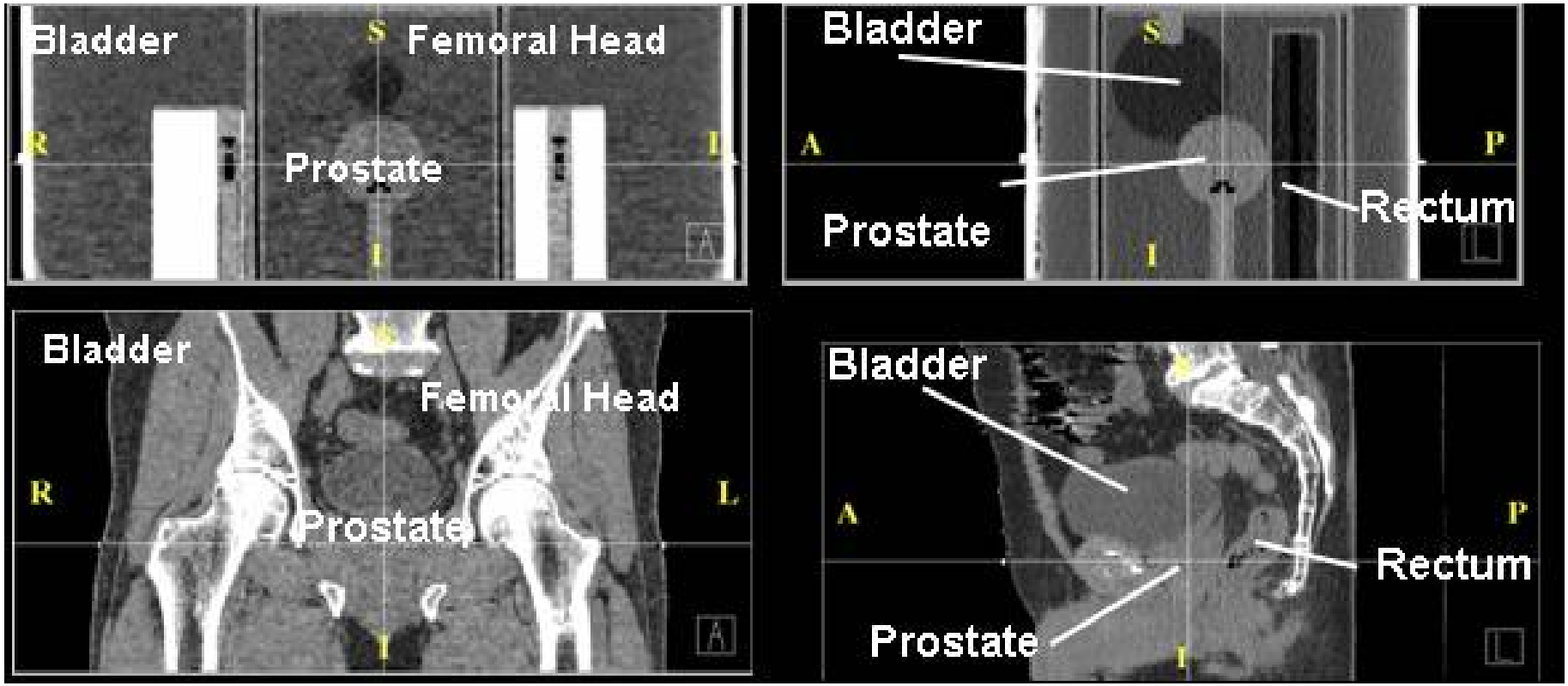
Prostate phantom





RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate phantom



RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate phantom Rx

- 6 Gy to prostate
- 50% of bladder limited to 5.7 Gy
- 25% of bladder limited to 6.3 Gy
- 50% of rectum limited to 5.0 Gy
- 25% of rectum limited to 6.0 Gy

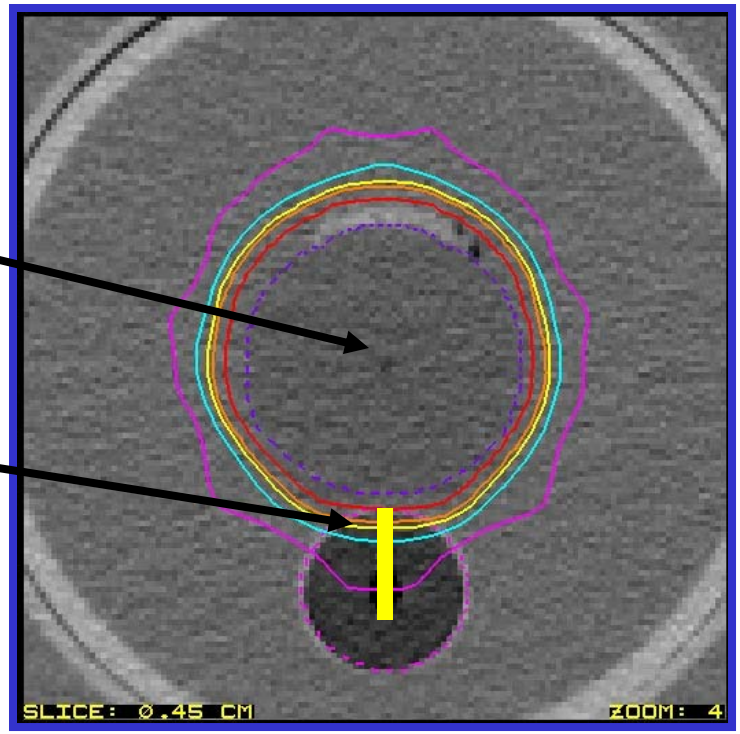
RPC Radiological Physics Center
Excellence through Quality Assurance

Criteria for credentialing

- **RPC/Inst dose in PTV: 0.93-1.07**
- **distance to agreement in high gradient regions near OARs: ≤ 4 mm**

Dose region

Distance to agreement region



RPC Radiological Physics Center
Excellence through Quality Assurance

IMRT prostate phantom results

- 93 irradiations were analyzed
- 76 irradiations passed the criteria
  - 7 institutions irradiated multiple times
- 17 irradiations did not pass the criteria
- 85 institutions are represented

Only 79% of institutions passed the criteria on the first irradiation.

RPC Radiological Physics Center
Excellence through Quality Assurance

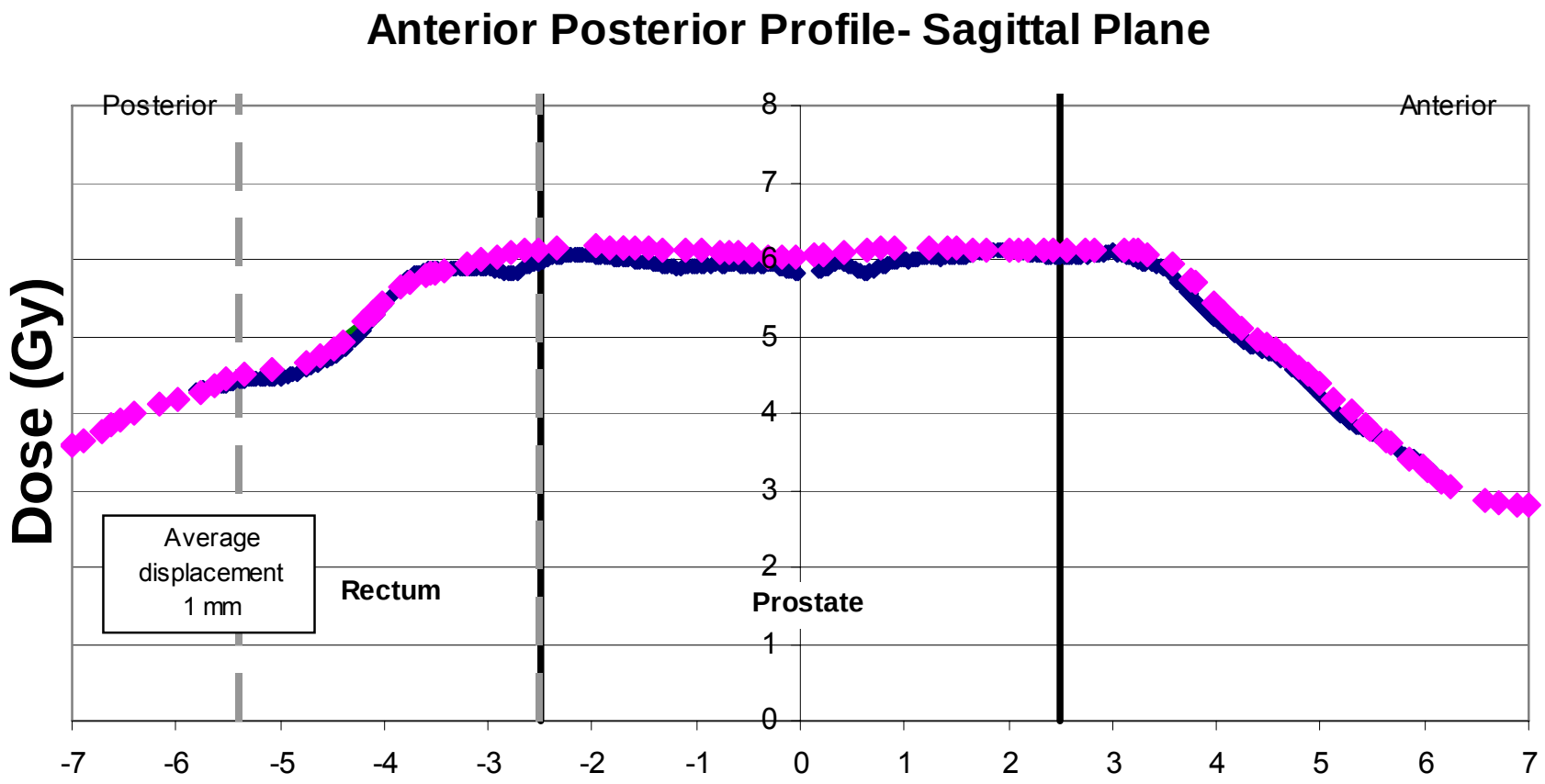
Prostate phantom results cont

- **0 failed by absolute dose only**
- **16 failed by DTA only**
- **1 failed by both absolute dose and DTA**

	PTV	DTA bladder (mm)	DTA rectum (mm)
mean	1.00	-0.52	0.89
std dev	0.029	3.926	2.483
count	184	92	91
range	0.92 - 1.06	-8 - 18	-5 - 7

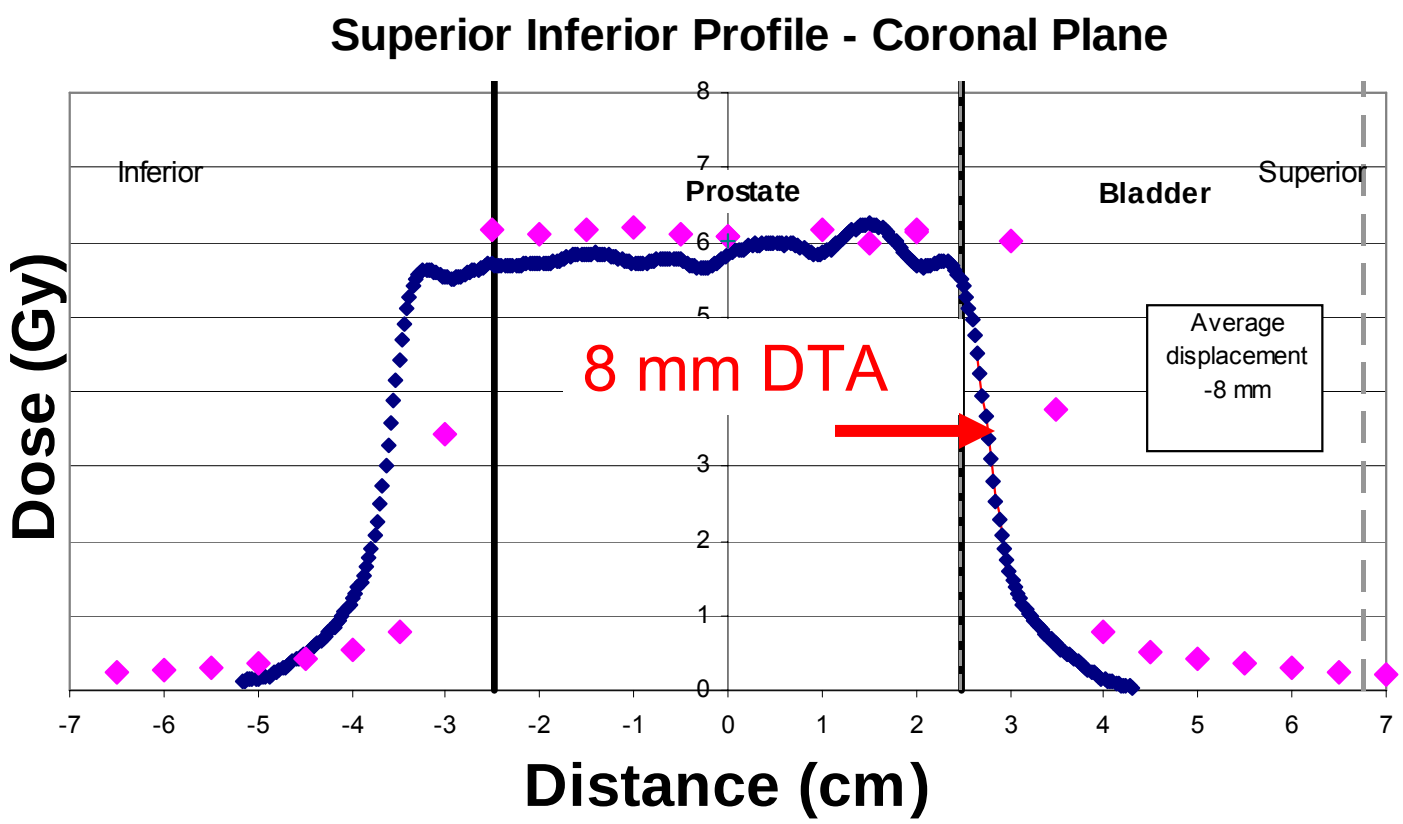
RPC Radiological Physics Center
Excellence through Quality Assurance

Good prostate profile



RPC Radiological Physics Center
Excellence through Quality Assurance

Not so good prostate profile



RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate results grouped by accelerator manufacturer

Linear Accelerator Manufacturer	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Elekta	60	5	0	2	0
Siemens	82	17	0	3	0
TomoTherapy	100	2	0	0	0
Varian	83	69	0	11	1
total		93	0	16	1

RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate results grouped by TPS

Treatment planning system	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Eclipse	90	21	0	2	0
Pinnacle	80	45	0	9	0
XiO	82	17	0	3	0
Other	70	10	0	2	1
total		93	0	16	1

RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate results grouped by machine/TPS combo

Manufacturer/TPS Combination	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Elekta/Pinnacle	60	5	0	2	0
Siemens/Corvus	50	2	0	1	0
Siemens/Pinnacle	100	8	0	0	0
Siemens/XiO	71	7	0	2	0
Varian/Corvus	60	5	0	1	1
Varian/Eclipse	90	21	0	2	0
Varian/Pinnacle	78	32	0	7	0
Varian/XiO	90	10	0	1	0
Other	100	3	0	0	0
total		93	0	16	1

RPC Radiological Physics Center
Excellence through Quality Assurance

Prostate results grouped by technique

IMRT technique	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Dynamic MLC	84	19	0	2	1
IMAT	33	3	0	2	0
Segmental	83	69	0	12	0
TomoTherapy	100	2	0	0	0
total		93	0	16	1

RPC Radiological Physics Center
Excellence through Quality Assurance

Explanations for failures

incorrect output factors in TPS
incorrect PDD in TPS
inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)
not adjusting plan to account for dose differences measured with ion chamber

RPC Radiological Physics Center
Excellence through Quality Assurance

Explanations for failures cont

errors in couch indexing with Peacock system
2 mm tolerence on MLC leaf position
setup errors
target malfunction
Treatment planning bug
MLC sag

RPC Radiological Physics Center
Excellence through Quality Assurance

Changes made by institutions that resulted in acceptable phantom irradiation

input new output factors

remeasured PDD and modeled beam based on new values

adjusted leaf end modeling

updated software version

upgraded MLC leaves

more accurate setup

replaced target

RPC Radiological Physics Center
Excellence through Quality Assurance

Conclusions

- **The RPC's IMRT phantoms provide a comprehensive evaluation of IMRT for clinical trials**
- **QA of IMRT is important!**

The investigation was supported by PHS grants CA10953 and CA81647 awarded by the NCI, DHHS.

RPC Radiological Physics Center
Excellence through Quality Assurance

http://rpc.mdanderson.org/rpc/

THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER