The State of Radiotherapy Physics Through the Eyes of a Quality Auditor

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THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER Making Cancer History®

RPC Radiological Physics Center Excellence through Quality Assurance

Brief Background

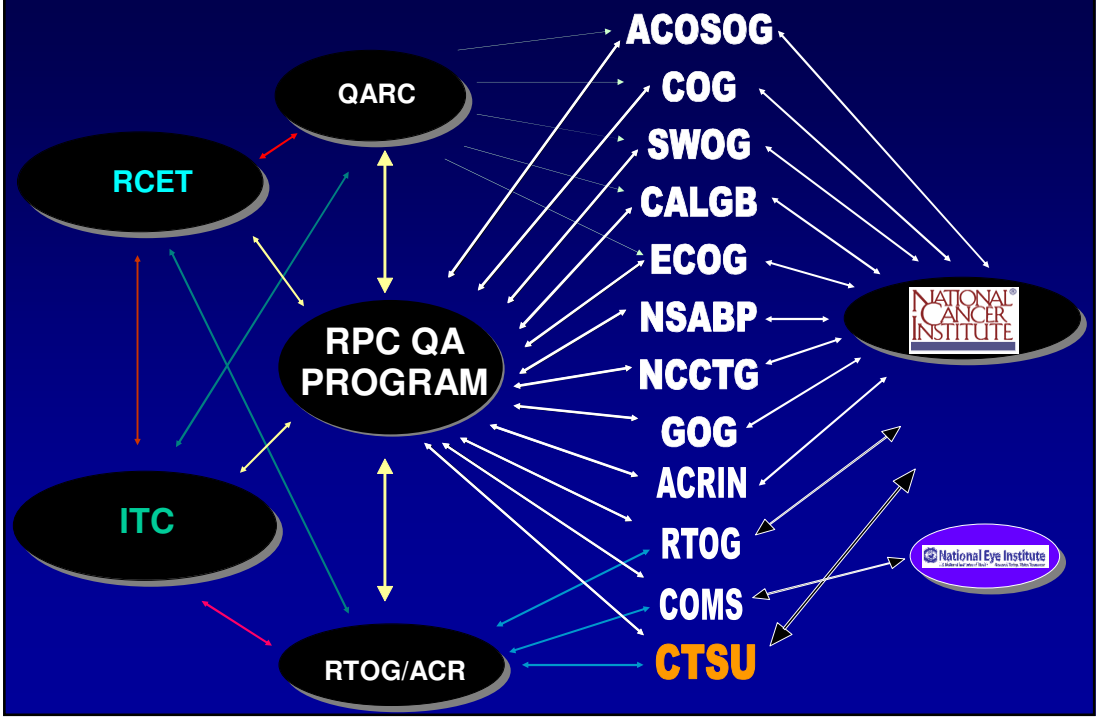
- Originated through agreement between AAPM and CRTS
- Founded in 1968 to monitor institution participation in clinical trials
- Funded continuously by NCI as structure of cooperative group programs have changed
- Now 38 years of experience of monitoring institutions and reporting findings to study groups and community

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.

Only QA Office with relationships with all study groups

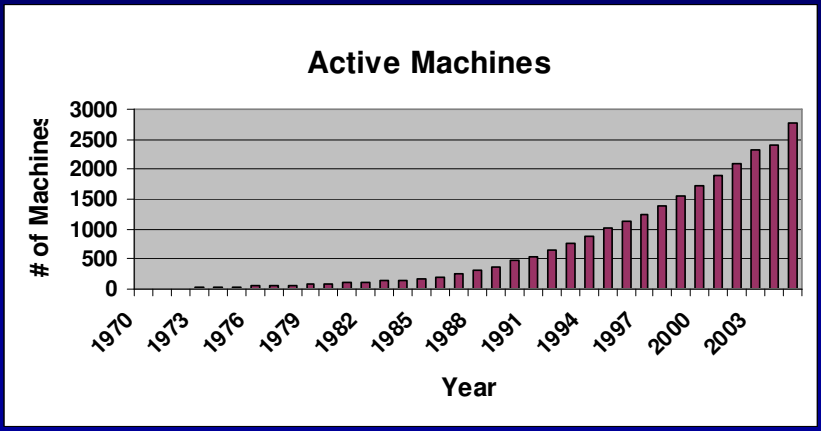


On-Site Dosimetry Reviews

- **RPC Medical Physicists**
  - M.S. or Ph.D. in Medical Physics or associated field
  - Licensed
  - Credentialed for clinical service
  - Board certified or eligible
  - Continuing education requirements
  - 6 - 9 months of training
    - TLD review/resolution of discrepancies
    - dry run measurement/calculation sessions
    - 3 - 4 visits
    - patient record review
  - RPC resources available
    - 6 physicists (>75 yrs. exp.)
    - 4 dosimetrists (>45 yrs. exp.)
    - MDACC Clinic

Clinical Trial Participants

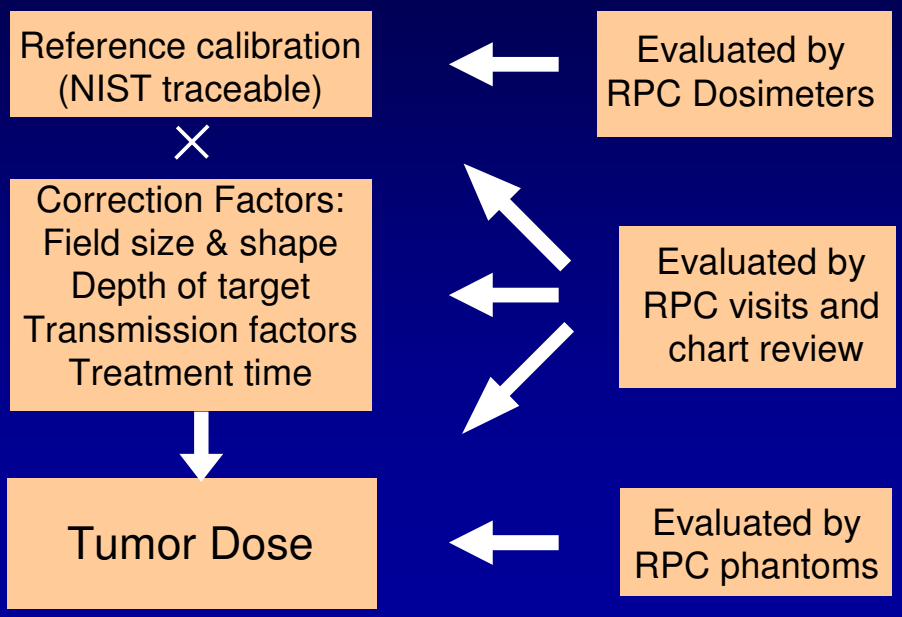
- Number of Active Institutions – 1482
  - 2918 megavoltage machines
  - 7472 active megavoltage beams



RPC QA Audit Techniques

- On-site Dosimetry Review Visits
- Remote Reviews
- - TLD Program
- - Phantom Program
- - Off-site Dosimetry Reviews
- - Patient Dosimetry Reviews
- - Benchmark case Reviews
- - QA Program Reviews

RPC Verification of Institutions' Delivery of Tumor Dose

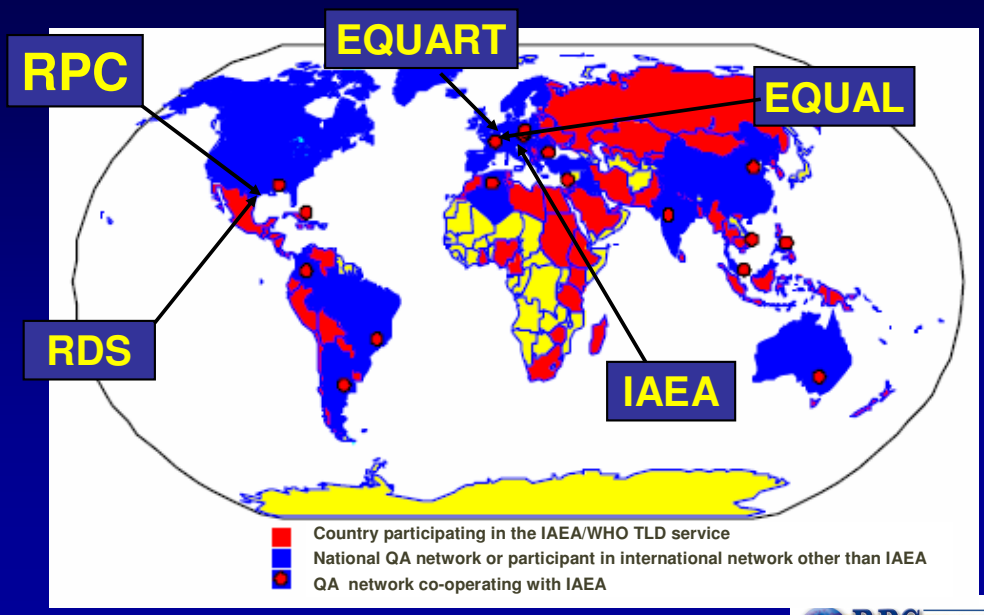


The Thermoluminescent Dosimetry (TLD) Program

- Largest of its kind in operation (> 30 years)
- Verifies dose output and energy on megavoltage units (>12,000 beams in 2006).
- Measure consistency of institutions based on TLD history
- Provides independent audit of the output as required by many states
- Other similar programs

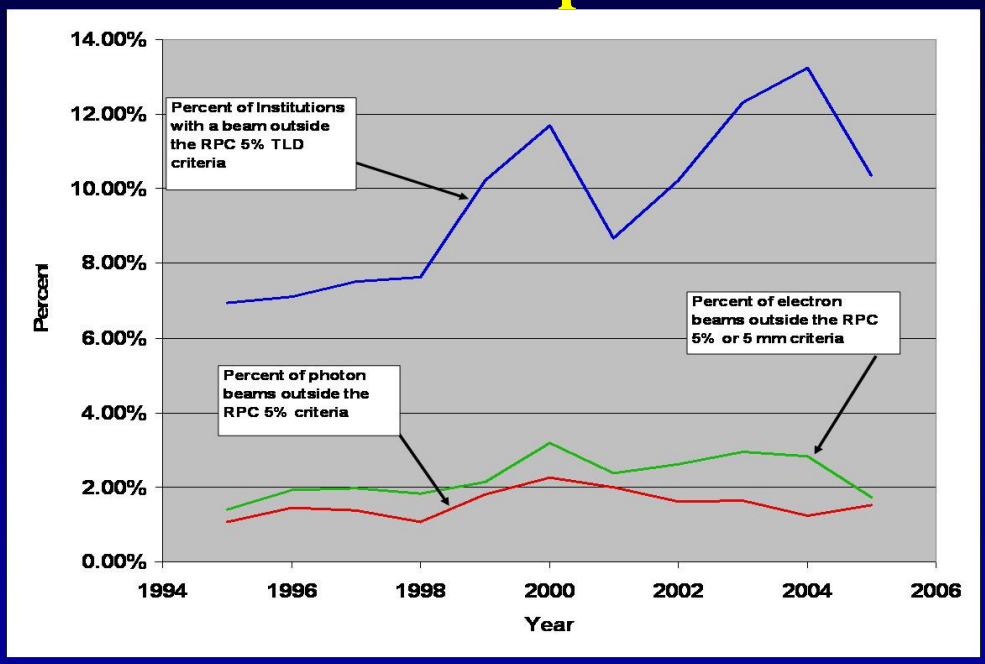
Irradiation Setup

TLD Programs



Data from J. Izewska

TLD Discrepancies



13 institutions visited recently to resolve TLD problems

Protocol Patient Chart Review

Purpose

- Correct errors in patient treatments
- Provide correct and comparable data
- Improve quality of care for all RT patients
- Charts from 1003 different institutions
- Only the RPC and RTOG HQ Dosimetry Group confirm doses for external beam
- Only QAO confirming implant doses

Chart Review Process

- Radiotherapy records, calculations & films received from study group

↓

Independent dose recalculation (±5%)

↓

Resolve errors with institution

↓

Discuss results with Group and Study Chair

↓

Facilitate clinical review at meetings, RPC, HQ

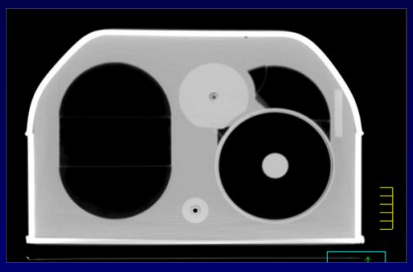
Results of Chart Review

- 1% Systematic errors
  - Potential to impact every patient treated by institution
- 10% Individual errors
  - Impacts study groups and institution
- 25% Reporting errors
  - Impacts study group and institution

Without RPC review 36% of the doses used by the study group would be incorrect

RPC Phantoms

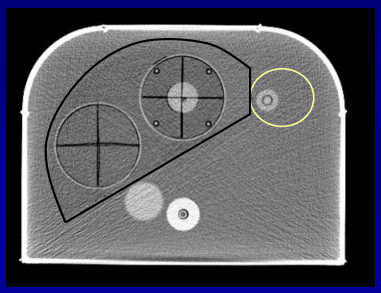
Pelvis



Thorax

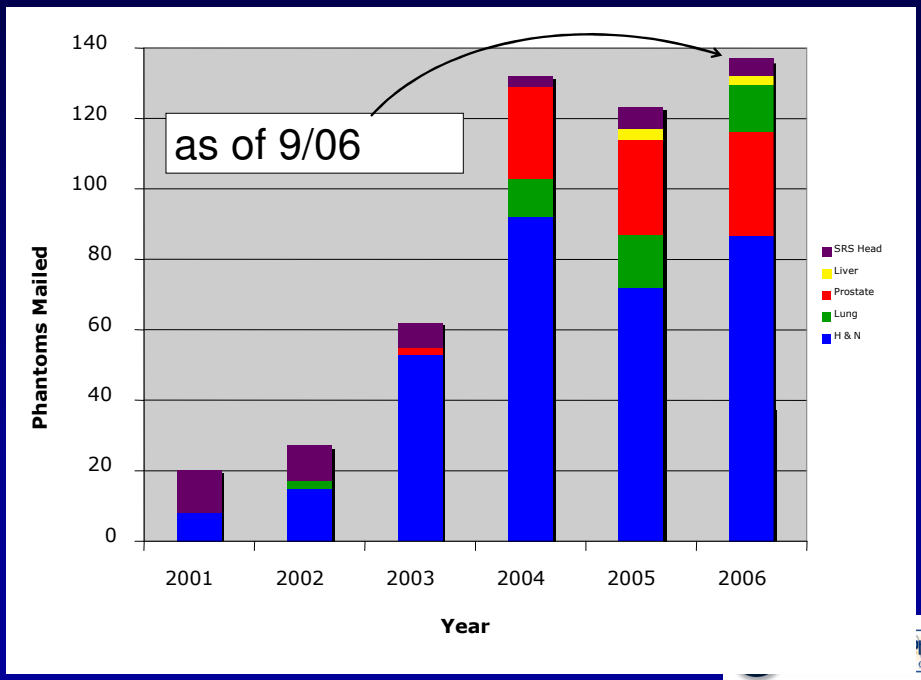
H&N IMRT

SRS Head



Liver

Number of H&N Phantom Mailings



Phantom Credentialing Process

- Call the RPC and get placed on the request list
-
-
-
-
-
-

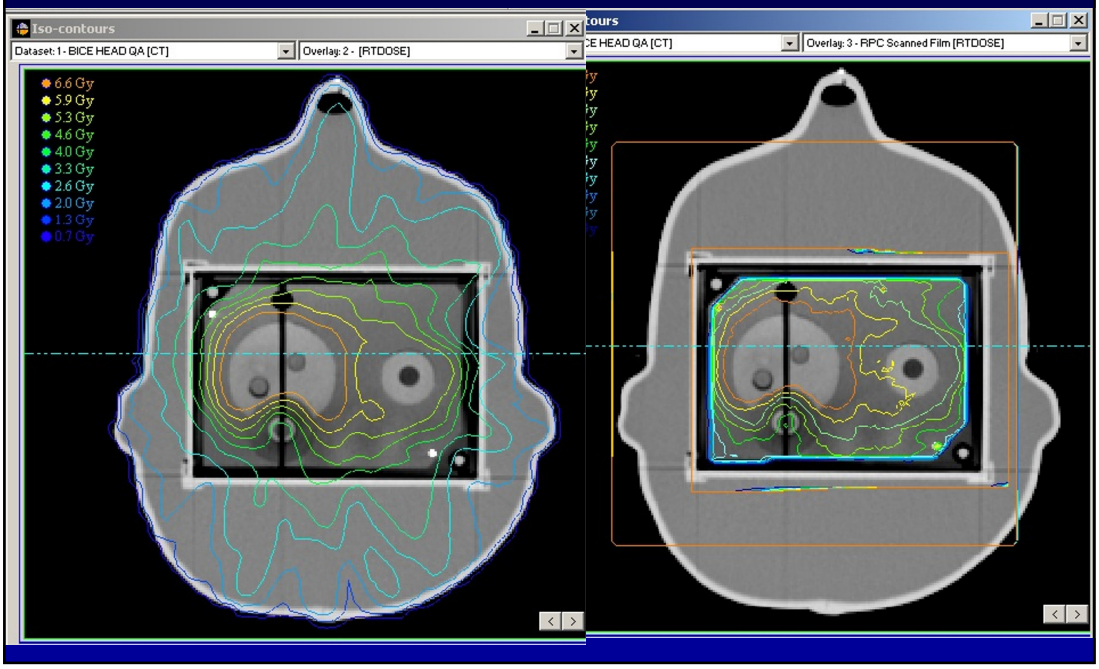
The phantom is to be treated as if it were a patient.

ITC

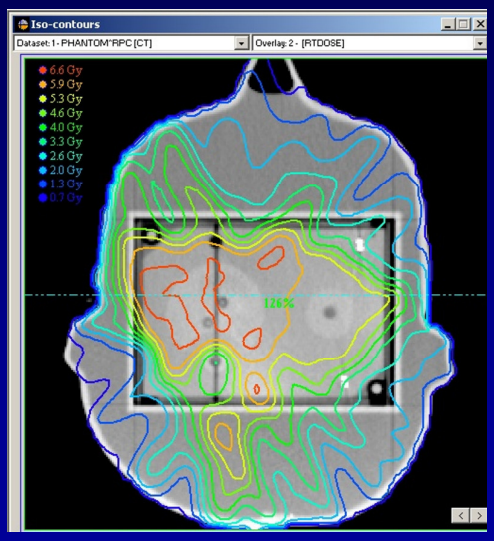
Some institutions go overboard!!

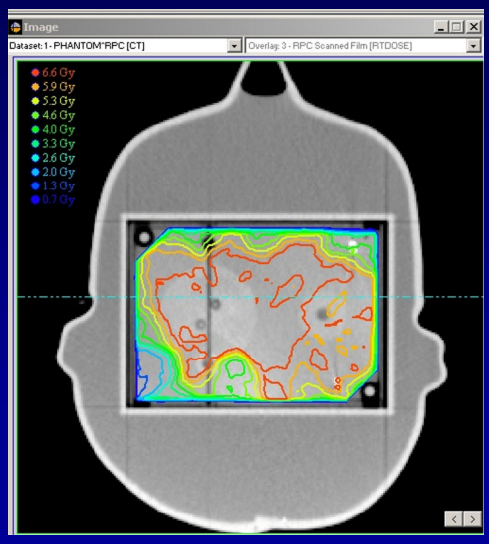
Some patients just want to better understand their treatment.

Plan vs. Treatment



Examples of Failures





Phantom Results

Phantom	H&N	Prostate	Thorax	Liver
Irradiations	217	55	25	5
Pass	146	41	14	2
Fail	57	14	3	1
Under analysis or at institution	12	13	6	2
Unevaluable	12	3	4	1
Year introduced	2001	2004	2004	2005
Failure Rate	28%	25%	18%	33%

27% FAILED
FIRST IRRADIATION!

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Explanations for Failures

- The following are known explanations for some of the failures:
- incorrect output factors in TPS
- incorrect PDD in TPS
- Incorrect CT number to density correction
- inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)
- not adjusting MU to account for dose differences measured with ion chamber
- errors in couch indexing with Peacock system
- setup errors

Phantom Results

TPS	Dose Calc. Algorithm	# irradiations	Center of Tumor TPS D_{hetero}/D_{homo}
Precise	Scatter Int. Clarkson	2	1.19 ± 2.6%
BrainLab	Clarkson & Pencil beam	4	1.21 ± 0.1%
Eclipse	Pencil Beam	2	1.19 ± 4.6%
Ergo	3D Convol. Pencil Beam	1	1.19 ± 0.1%
RenderPlan	Change in primary attenuation	1	1.20
Pinnacle	Adaptive convolve	8	1.13 ± 2.1%
XiO	Superposition/Convolution	3	1.12 ± 2.4%

Clearly, there are two groupings

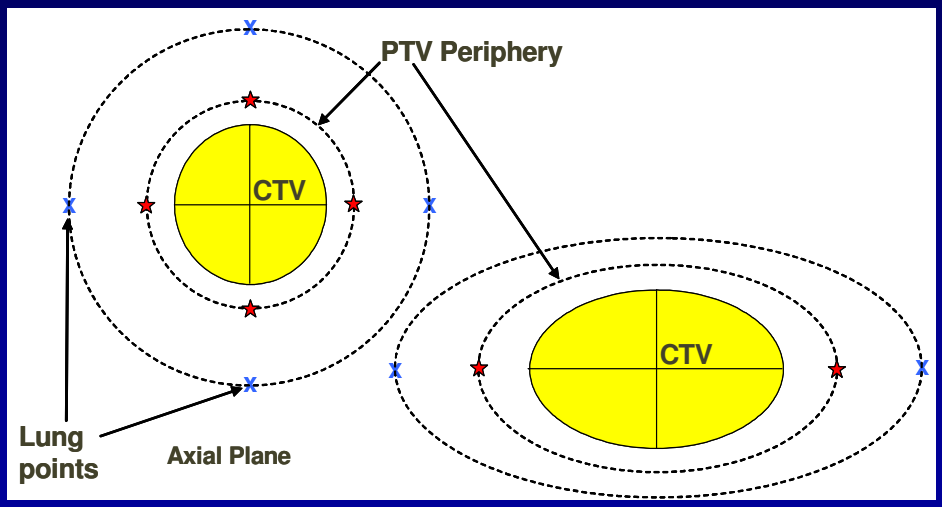
Phantom Results (cont'd)

TPS	Dose Calc. Algorithm	# irradiation	Center of Tumor Measured D_{TLD}/D_{hetero}
Precise	Scatter Int. Clarkson	2	0.99 ± 3.1%
BrainLab	Clarkson & Pencil beam	4	0.96 ± 2.7%
Eclipse	Pencil Beam	2	0.97 ± 1.6%
Ergo	3D Convol. Pencil Beam	1	0.98 ± 3.2%
RenderPlan	Change in primary attenuation	1	0.92
Pinnacle	Adaptive convolve	8	0.99 ± 2.3%
XiO	Superposition/Convolution	1	0.96

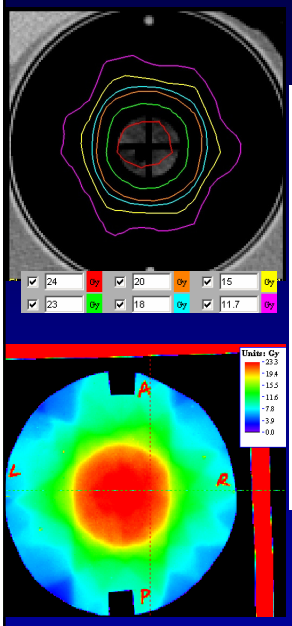
PTV Periphery and Lung Points

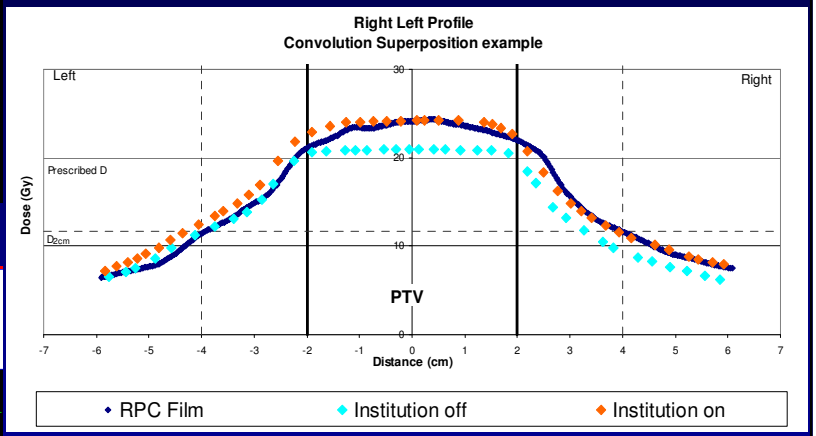
PTV = Tumor (CTV) + 0.5 cm in axial plane + 1 cm in longitudinal plane.

Lung constraint: points 2 cm from the PTV



Profile analysis





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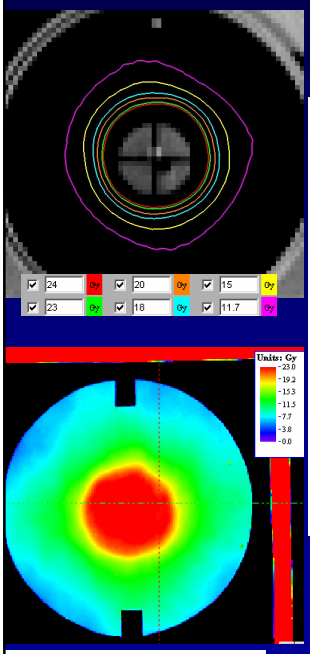

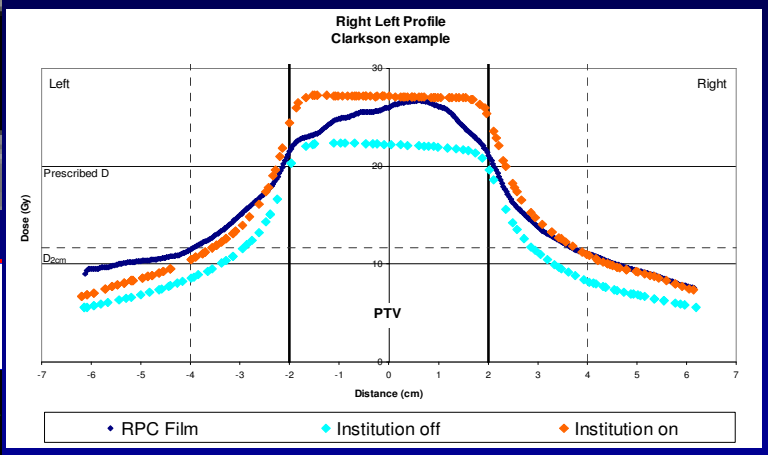

Phantom Results (PTV Periphery)

TPS	Dose Calc. Algorithm	# irradiation	TPS D_{hetero}/D_{homo} Axial plane
Precise	Scatter Int. Clarkson	2	1.21 ± 2.7%
BrainLab	Clarkson & Pencil beam	1	1.26 ± 3.5%
Eclipse	Pencil Beam	2	1.18 ± 4.0%
Ergo	3D Convol. Pencil Beam	2	1.19 ± 1.8%
Pinnacle	Adaptive convolve	8	1.04 ± 6.1%
XiO	Superposition/Convol.	2	1.11 ± 6.4%

Two separate groupings again

Phantom Results (Lung points)

TPS	Dose Calc. Algorithm	# irradiation	TPS D_{hetero}/D_{homo} Axial plane
Precise	Scatter Int. Clarkson	2	1.19 ± 4.2%
BrainLab	Clarkson & Pencil beam	1	1.23 ± 5.7%
Eclipse	Pencil Beam	2	1.18 ± 11.2%
Ergo	3D Convol. Pencil Beam	2	1.20 ± 5.3%
Pinnacle	Adaptive convolve	8	1.12 ± 6.0%
XiO	Superposition/Convol.	2	1.14 ± 6.5%

Two separate groupings again

Phantom Results (PTV Periphery) Measurements

TPS	Dose Calc. Algorithm	# irradiation	PTV Periphery measured D_{TLD}/D_{hetero}
Precise	Scatter Int. Clarkson	2	0.88
BrainLab	Clarkson & Pencil beam	1	0.79
Eclipse	Pencil Beam	2	0.92
Ergo	3D Convol. Pencil Beam	2	0.84
Pinnacle	Adaptive convolve	8	0.98
XiO	Superposition/Convol.	1	0.96

Two separate groupings again

Comments

- The average target TLD/Inst ratio is 0.97 (range 0.92 to 0.99). Good agreement for Convolution Superposition algorithms in the target.
- Large differences exists between the Convolution Superposition heterogeneity corrected dose calculations and other algorithms (ratios of 1.13 vs. 1.20).
- Heterogeneity corrected doses at the PTV periphery and lung points are higher than uncorrected doses.
- The Convolution Superposition algorithm calculations agree with the RPC measurements.

On-Site Dosimetry Review Visit

- **The <u>only</u> completely independent comprehensive radiotherapy quality audit in the USA and Canada**
  - Identify errors in dosimetry and QA program and suggest methods of improvements.
  - Collect and verify dosimetry data needed to review patient charts.
  - Improve quality of patient care for all patients.

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On-Site Dosimetry Review Visit

~1435 institutions participating in clinical trials

	visited	not visited yet
Institutions:	728	707
Patient accrual:	20,130 (95%)	1,095 (5%)

Prioritization schema focuses our visit resources where the majority of the patients are treated!

Dosimetry Equipment Q.A. Prior to the Review Visit

- 1. Mechanical and Electrical Components Checks
- 2. Check of Aneroid Barometers and Thermometers
- Against:

Reference Barometer (Hg)
Reference Standard Thermometer

Dosimetry Equipment Q.A. Prior to the Review Visit

- 3. Verification of NIST Traceability of RPC's cylindrical
- and parallel plate field ion chambers. Measurements are performed in a Co-60 beam.

RPC Standards:
MDACC ADCL
Chamber Calibrated at NIST

- - This unit is used by the MDACC ADCL with its own independent standards and is also used for the RPC TLD program.

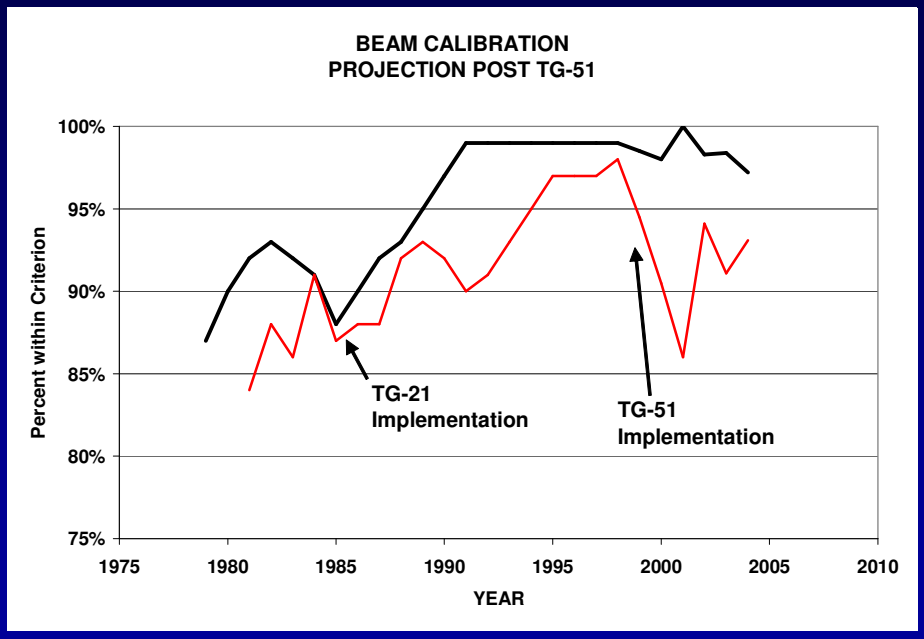
Dosimetry Equipment Q.A. Prior to the Review Visit

- 4. Verification of brachytherapy ion chamber calibration factors.

Cs-137 Standard Source
Ra-226 Standard Source
Am-241 Constancy Check Source

- For Ir-192 and I-125 NIST calibrated or traceable sources are bought if recalibration is needed.

Reference Calibration



On-Site Dosimetry Reviews

- **Measurement Criteria**
- External Beam Dose
  - Delivery of Absorbed ±5%
  - Calibration ±3%
  - Relative Measurements ±2%
  - Mechanical ±3 mm
  - Depth dose (e^-) ±3 mm
- Brachytherapy Dose
  - Delivery of Absorbed ±15%
  - Calibration ±5%

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On-Site Dosimetry Review Visit

Errors Regarding:	Percent of Institutions Receiving
Review QA Program	(84%)
*Photon Depth Dose	(30%)
Switch to TG-51	(24%)
*Wedge Transmission	(24%)
*Electron Calibration	(22%)
*Photon Calibration & FSD	(24%)
*Off-axis Factors	(16%)

***70% of institutions received at least one of the significant dosimetry recommendations.**

Examples of Errors

1. Pressure reading.
2. Incorrect PDD to go from 10cm or d_{ref} to d_{max} (photons and electrons).
3. Incorrect P_{grad} for electrons.
4. Poor beam modeling (PDD).
5. No depth or FS dependence of wedge factors.
6. FSD for small fields (chamber used too large).
7. OAF not matched between machines.
8. Use of % ionization instead of % dose for electrons (calibration and PDD).
9. Not allowing chamber to re-equilibrate after bias or polarity change.
10. Reliance on other's data.

On-Site Dosimetry Review Visit for TLD Problems

Clinac 23EX
Reason: Electron output low for two energies

E	TLD Before	Ion chamber Visit	Compounding Individual errors
16 MeV	0.948	0.961	0.963
20 MeV	0.943	0.942	0.946

1. Dosimetry system comparison (- 0.1 %)
2. Incorrect barometric pressure (+ 1.3%)
3. Incorrect $N_{d,w}K_{ecal}$ for parallel plate chamber (- 2.0%)
4. Use of %Ion for d_{ref} to d_{max} correction (-2.9 to -5.4%)

On-Site Dosimetry Review Visit for TLD Problems

Inst. # 367, Cl 6/100
Reason: 6 MV output high

TLD Before	Ion chamber Visit	TLD After Visit
1.057	1.038	1.005

1. Revise temperature measurement technique and incorporate Temp. & Grav. barometric pressure corrections (1.4%)
2. Repair ODI and lasers (1%)
3. Improve QA monitoring of beam output
4. Chamber intercomparison (0.8%)

On-Site Dosimetry Review Visit for TLD Problems

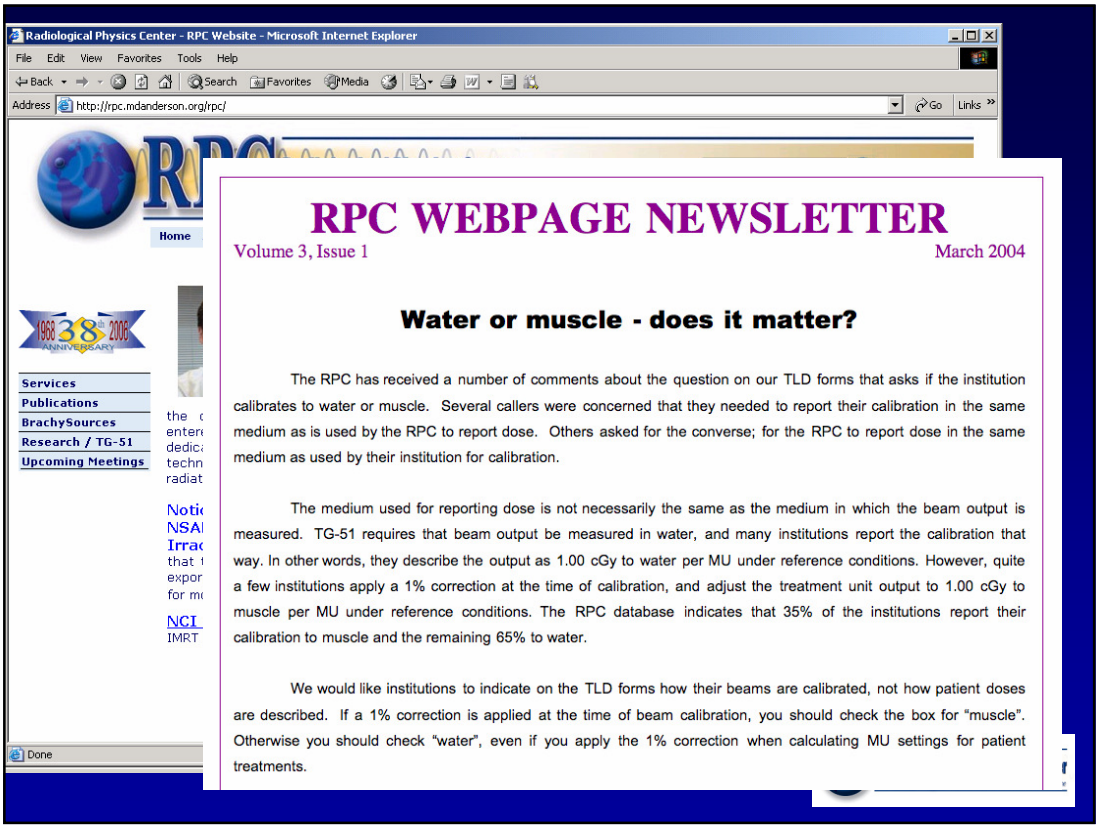
Inst. # 66, Philips SL22
Reason: Electron outputs consistently low

E	TLD Before	Ion chamber Visit	TLD Visit	TLD After Visit
6 MV	0.992	0.998	0.986	-
18 MV	0.993	1.013	1.023	-
8 MeV	0.951	0.969	0.973	1.000
10 MeV	0.943	0.967	0.963	-
12 MeV	0.976	0.971	0.980	1.000
15 MeV	0.967	0.968	0.967	-

1. Review electron PDD curves (1 - 2 %)
2. Incorporate P_{repl} for parallel plate charger (1.5 - 0.5%)
3. Review L/ρ values for new calibration depths (1%)
4. Incorporate new N_X value into N_{gas}

Visit Recommendations

Over 500 errors and 85 lapses in QA programs were identified at institutions visited by the RPC during this past 5 year period



Ongoing Communications with Community

1. Via the web site and email
2. AAPM newsletter
3. Workshops, Posters, oral talks and publications
4. Phone (713) 745-8989

Redundancy

Vigilance

Resolution

Time

Support

There is no other organization within the USA and Canada that serves as a

National Resource

for the Radiation Oncology Community like the RPC does.