The RPC’s Evaluation of Advanced Technologies

Geoffrey S. Ibbott, Ph.D.
and RPC Staff

QA Infrastructure for Clinical Trials

Participating Institutions

Cooperative Groups
ACRIN

Funding Agency

RPC QA Office

AAPM July 27, 2009
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RPC QA Office

AAPM July 27, 2009
Radiological Physics Center

- Formed when AAPM received funding from NCI and announced competition
- Founded in 1968 to monitor institution participation in clinical trials
- Funded continuously by NCI as structure of cooperative group programs have changed
- Now 40 years of experience of monitoring institutions and reporting findings to study groups and community
Mission

The mission of the Radiological Physics Center is to assure NCI and the Cooperative Groups that institutions participating in clinical trials deliver prescribed radiation doses that are clinically comparable and consistent. We do this by assessing the institution’s radiotherapy programs, helping the institutions implement remedial actions, assisting the study groups in developing protocols and QA procedures, and summarizing our findings for the radiation therapy community.

Mandate from the Cancer Trials Evaluation Program (CTEP)
Components of a QA Program

Remote audits of machine output
- 1,674 institutions, 14,188 beams measured with TLD (2008)

Treatment record reviews
- Review for GOG, NSABP, NCCTG, RTOG (brachy)

Independent recalculation of patient dose
- Continue to find errors

On-site dosimetry reviews
- 50 institutions visited (~150 accelerators measured)

Credentialing
- Phantoms, benchmarks, questionnaires, rapid reviews
RPC TLD NETWORK

1,674 RT facilities in 27 countries throughout the world, including 58 EORTC members
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TLD IRRADIATION

Institutions receive acrylic block containing dosimeters
Distribution of Photon Beam TLD Measurements

s.d. = 1.8%
Institutions with One or More Unacceptable TLD Measurements

- Fraction of institutions: 0%, 5%, 10%, 15%, 20%, 25%
Benefits of the TLD Program

- Helps institutions stay vigilant
- Problems contribute to priorities for visits
- May satisfy state/local requirements for independent review
- Identifies problems that have direct impact on every patient treated
- It is a model for other remote programs
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RPC Patient Dose Review

- Independent calculation of tumor dose
- Agree within 5% (15% for implants)
- Verify dose, time, fractionation per protocol
- Notify institution if major deviation seen during review to prevent further deviations
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AAPM July 27, 2009
On-Site Dosimetry Review Visit

The only completely independent comprehensive radiotherapy quality audit in the USA and Canada

- Identify errors in dosimetry and QA and suggest improvements.
- Collect and verify dosimetry data for chart review.
- Improve quality of patient care.
### On-Site Dosimetry Review

Selected discrepancies discovered 2004 – 2008

<table>
<thead>
<tr>
<th>Errors Regarding</th>
<th>Number of Institutions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Review QA Program</strong></td>
<td>127 (77%)</td>
</tr>
<tr>
<td>*Wedge Transmission</td>
<td>53 (32%)</td>
</tr>
<tr>
<td>*Photon FSD (small fields)</td>
<td>46 (28%)</td>
</tr>
<tr>
<td><strong>Off-Axis, Beam Symmetry</strong></td>
<td>42 (25%)</td>
</tr>
<tr>
<td>*Photon Depth Dose</td>
<td>34 (21%)</td>
</tr>
<tr>
<td>*Electron Calibration</td>
<td>25 (15%)</td>
</tr>
<tr>
<td>*Photon Calibration</td>
<td>22 (13%)</td>
</tr>
<tr>
<td>*Electron Depth Dose</td>
<td>19 (12%)</td>
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</table>

*70% of institutions received at least one of the significant dosimetry recommendations.*
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- **Credentialing**
  - Phantoms, benchmarks, questionnaires, rapid reviews
Credentialing

Why?

- Education
- Evaluate ability to deliver dose
- Improve understanding of protocol

Reduce deviation rate
General Credentialing Process

- Previous patients treated with technique
- Facility Questionnaire
- Knowledge Assessment Questionnaire
- Benchmark case or phantom
- Electronic data submission
- RPC QA & dosimetry review
- Clinical review by radiation oncologist
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Feedback to Institution
RPC Phantoms

Pelvis (10)

Thorax (13)

H&N (31)

SRS Head (4)

Liver (2)
RPC Phantoms

Pelvis (10)

Thorax (13)

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Liver (2)

SRS Head (4)
Lung Phantom and Moving Platform
Treat phantom as if it were a patient
Deliver treatment
RPC Compares Treated Distribution with Plan
RPC Compares Treated Distribution with Plan
**Phantom Results**

Comparison between institution’s plan and delivered dose.
Criteria for agreement: 7% or 4 mm DTA (5%/5mm for lung)

<table>
<thead>
<tr>
<th>Site</th>
<th>Institutions</th>
<th>Irradiations</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>H&amp;N</td>
<td>472</td>
<td>631</td>
<td>75%</td>
</tr>
<tr>
<td>Pelvis</td>
<td>108</td>
<td>130</td>
<td>82%</td>
</tr>
<tr>
<td>Lung</td>
<td>67</td>
<td>77</td>
<td>71%</td>
</tr>
<tr>
<td>Liver</td>
<td>15</td>
<td>18</td>
<td>50%</td>
</tr>
</tbody>
</table>
# Explanations for Failures

<table>
<thead>
<tr>
<th>Explanation</th>
<th>Minimum # of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>incorrect output factors in TPS</td>
<td>1</td>
</tr>
<tr>
<td>incorrect PDD in TPS</td>
<td>1</td>
</tr>
<tr>
<td>IMRT Technique</td>
<td>3</td>
</tr>
<tr>
<td>Software error</td>
<td>1</td>
</tr>
<tr>
<td>inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)</td>
<td>14</td>
</tr>
<tr>
<td>QA procedures</td>
<td>3</td>
</tr>
<tr>
<td>errors in couch indexing with Peacock system</td>
<td>3</td>
</tr>
<tr>
<td>equipment performance</td>
<td>2</td>
</tr>
<tr>
<td>setup errors</td>
<td>7</td>
</tr>
</tbody>
</table>
Questions raised regarding RPC Credentialing Programs

- Credentialing process for lung protocols criticized in AAPM poster
- RTOG protocols (e.g., 0618, 0813) require RPC lung phantom
- ALL phantoms are commissioned, manufacturing verified, film registration confirmed, TLD dosimetry checked.
- Lung phantom was irradiated ≥ 50 times to assure reproducibility and accuracy
Criticisms of RPC Lung Phantom

- Procedure required homogeneous calculation, then correction turned on
  - Was a requirement of older protocol (institution began process >2 years ago)
  - Current protocols (and phantom procedures) require heterogeneous calculation
- Suggestion that this increased dose gradients
  - No evidence; data demonstrate uniform distribution
INSTITUTION’S PLAN
2D GAMMA INDEX EVALUATION CONVOLUTION ALGORITHM
Right-Left Profile

- Left
  - Average displacement: Left side: 1 mm
  - Prescribed D

- Right
  - Average displacement: Right side: 1 mm

Dose (Gy)

- D2cm
- PTV

Distance (cm)

-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7

- RPC Film
- Institution values
- RPC Regression
- Institution Regression
2D GAMMA INDEX EVALUATION
CONVOLUTION ALGORITHM

Pass = 99.71%
Fail = 0.29%

DTA = 5 mm
Dose Diff = 3 %
Ref Dose = 7.53 GY
Pass = 99.71% Fail = 0.29%

Pass < 1 Fail > 1

Gamma above 2 is snapped to 2
Criticism of RPC TLD System

• Volume of TLD too large

• Measurements with 0.6 cc ion chamber presented for comparison
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2.0 mm dia x 3.5 mm => 0.01 cc
TLD Capsule vs. 0.6 cc Chamber [2]

- RPC measurements are in 1 g/cc “tumor”
- Institution put ion chamber in low density “lung”
- Raises questions about electronic equilibrium
Recent New Programs

• Adopt OSL in place of TLD program
• Ongoing evaluation of gel dosimetry
• RPC audits of Proton treatment centers
• Implementation of Monte Carlo planning
• International collaboration and harmonization
Optically Stimulated Luminescence (OSL) Dosimeters

- Detector material of aluminum oxide crystals (Al$_2$O$_3$:C)
- Landauer’s InLight™ NanoDot™ dosimeters and microStar™ Reader
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Evaluations of Gel Dosimetry

- Comparison of PAGAT gel response to fractionated radiation (e.g., IMRT)
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* Comparison of PAGAT gel response to fractionated radiation (e.g., IMRT)
International Participation

• RPC has audited international institutions that are members of US study groups, as part of routine audits

• In 2007, RPC was approached by EORTC to consider offering TLD audits to EORTC members, at cost

• Following agreement among RPC, EORTC and NCI, EORTC began recommending RPC’s TLD service to their members

• Subsequent meetings between RPC, EORTC, and other groups have been held to discuss expanding auditing procedures

• RPC now auditing 100 non North-American institutions
  • Including 58 EORTC members
International Study Groups

• RPC has developed relationships with several international clinical trials QA offices, leading to reciprocal visits and collaborations:

  • TROG – Trans-Tasman Radiation Oncology Group
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  • Japanese National Cancer Center: Outreach Radiation Oncology and Physics

G. Ibbott meeting with staff of Japanese center and viewing calibration facilities
Irradiation of RPC Phantoms

• Through various arrangements, 18 international institutions have already irradiated RPC phantoms

• Arrangements are being discussed for providing phantoms to additional institutions in Europe, the Middle East, Australasia and Latin America

• Through agreement with the RTOG and NCI, international non-member institutions participating in RTOG trials will meet the same QA requirements as member institutions
PROTON FACILITY CREDENTIALING

* NCI Guidelines mandate –
  * Questionnaire - sent to facilities by QARC
    * Completed by 4 of 5 centers

  * TLD monitoring
    * Mailed to all 5 US centers + 1 Japanese center

* On-site dosimetry review visits
  * 1st visit completed

* Anthropomorphic phantom
  * Modified existing pelvis phantom
PROTON BEAM MONITORING

RPC/Institution vs. Irradiation date

- Irradiation dates: 6/1/07, 12/8/07, 6/15/08, 12/22/08, 7/1/09
- Values range from 0.900 to 1.200

Tuesday, August 4, 2009
PROTON BEAM MONITORING

RPC/Institution

Protons: 109 measurements
Photons: > 6,000 measurements

Frequency (%)
PHANTOMS

- Pelvis phantom has been developed
  - Evaluation is under way, will be completed this summer

- Lung phantom evaluation will begin this fall
  - Evaluation of materials will be considerably more complex
  - Likely to extend into next grant cycle
PHANTOM TREATMENT

- Treatment plan created with a prescription of 6 Gy to the prostate
- Plan delivered 3 times with film and TLD inserted in phantom
- Plan accounting for difference in patient and material SP to be delivered in near future
<table>
<thead>
<tr>
<th></th>
<th>PTV Right</th>
<th>PTV Left</th>
<th>Femur Right</th>
<th>Femur Left</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institution Predicted Dose (cGy)</strong></td>
<td>600.2</td>
<td>600.2</td>
<td>247.3</td>
<td>243.8</td>
</tr>
<tr>
<td><strong>TLD Measured Dose (cGy)</strong></td>
<td>589.8</td>
<td>595.1</td>
<td>242.1</td>
<td>240.4</td>
</tr>
<tr>
<td><strong>Measured / Predicted Dose</strong></td>
<td>0.983</td>
<td>0.992</td>
<td>0.979</td>
<td>0.986</td>
</tr>
</tbody>
</table>

- PTV within 1.7% of predicted value
- Femur within 2.1% of predicted value
FILM RESULTS

Anterior Posterior Profile- Sagittal Plane

Feb 19 2009  Trial 1

Average displacement 1 mm

1 mm

1 mm

1 mm

Dose (Gy)

Rectum

Di  Prostate

Anterior

Posterior

RPC Film
Institution Values
TLD Left
TLD Right
RPC Regression
Institution Regression
Primary PTV
ptv1
Critical Structure
crit struct

75%
50%
25%
**FILM RESULTS**

![Graph showing Anterior Posterior Profile - Sagittal Plane](image)

**Anterior Posterior Profile - Sagittal Plane**

- **Feb 19 2009 Trial 1**
- **Average displacement 1 mm**

### Key Points:
- **Dose (Gy)**
- **Distance (cm)**

**RPC Film**

**Institution Values**

**TLD Left**

**TLD Right**

**RPC Regression**

**Institution Regression**

**Primary PTV**

**ptv1**

**Critical Structure**

** Grant Poster SU-FF-T-370**

- **Septum**
- **Prostate**

**Average displacement 1 mm**

### Feb 19 2009 Trial 1 Average displacement 1 mm

- **Prostate**
  - 1 mm
  - 1 mm
  - 1 mm

**Grant Poster SU-FF-T-370**

**Tuesday, August 4, 2009**
VISITS

- Visit procedures have been developed at PTC-H
- First full visit conducted weeks of April 20 & June 8
  - F. H. Burr Proton Therapy Center @ MGH
  - Final report is in review

- Measurements made:
  - Mechanical tests, x-ray imaging/patient alignment
  - Output, depth dose, range (for variety of beam energies, modulation, field size, etc.)
  - Review of treatment planning procedures
MONTE CARLO CALCULATIONS
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Davidson Poster
SU-FF-T-444
Optically Stimulated Luminescence (OSL) Dosimeters

- Detector material of aluminum oxide crystals (Al$_2$O$_3$C)
- Landauer’s InLight™ NanoDot™ dosimeters and microStar™ Reader
Reproducibility - NanoDots

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<th>STDEV</th>
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<tr>
<td>DN09305639P</td>
<td>1.035</td>
<td>0.34%</td>
</tr>
<tr>
<td>DN09307843U</td>
<td>0.950</td>
<td>0.50%</td>
</tr>
<tr>
<td>DN09307865O</td>
<td>0.989</td>
<td>0.83%</td>
</tr>
<tr>
<td>DN09307916P</td>
<td>0.974</td>
<td>0.85%</td>
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<tr>
<td>DN09308972Q</td>
<td>1.045</td>
<td>1.34%</td>
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<tr>
<td>DN093090941</td>
<td>0.997</td>
<td>0.24%</td>
</tr>
<tr>
<td>DN09309159T</td>
<td>1.010</td>
<td>0.60%</td>
</tr>
<tr>
<td>DN09309249S</td>
<td>1.030</td>
<td>0.48%</td>
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AUDITS

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- Program of evaluation likely to extend into next grant cycle
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Including:
100 non-North American facilities
58 EORTC members
International Clinical Trials

• RTOG (and several other study groups*) are expanding trials to international participation

• Through agreements with EORTC, RPC will likely make phantoms available to international participants in NCI-sponsored clinical trials
  • Funding source yet to be determined

*NCCTG and GOG, among others
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http://rpc.mdanderson.org

Supported by NCI grants CA10953 and CA81647