The Radiological Physics Center
A QA Resource in Radiation Therapy

AAPM Refresher Course
Seattle, July 28, 2005
Geoffrey S. Ibbott, Ph.D.
RPC: Houston
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 36 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 informing the community of our findings.
RPC Activities

- Remote Reviews
- Patient Dosimetry
- On-site Reviews
- Support of Study Groups
- Research/Outreach
RPC Verification of Institutions’ Delivery of Tumor Dose

Reference calibration (NIST traceable)

Correction Factors:
- Field size & shape
- Depth of target
- Transmission factors
- Treatment time

Tumor Dose

Evaluated by
- RPC Dosimeters
- RPC visits and chart review
- RPC phantoms
Remote Audit Tools: The Thermoluminescent Dosimetry (TLD) Program
TLD as a Remote Tool

• Verify dose outputs and energy on radiotherapy units.
• Verify doses at points of interest in anthropomorphic phantoms
• Measure consistency of institutions based on TLD history
• Provide data for patient chart review
Additional Benefits

- Changes in equipment
- Changes in personnel
- Satisfies requirement for an independent quality assurance audit
- Promotes alertness
Characteristics of the Program

• 28 years in operation
• Monitoring 1,387 megavoltage therapy sites (80% of US centers)
• Last year, ~8,800 radiation beams monitored with TLD
• Largest of its kind
• Other programs (IAEA, ESTRO, RDS)
RPC TLD Activities

2000 2001 2002 2003 2004

ELECTRONS
PHOTONS
COMBINED
Comparison of TLD Results
Photons

TG-51
4161 data
Avg: 1.006
SD: 1.6%

TG-21
10565 data
Avg: 1.014
SD: 1.6%

TLD/Inst
TLD Discrepancies

13 (of 69) institutions visited in last 2 yrs to resolve TLD problems
Benefits of the TLD Program

• Verifies calibrations periodically thus helping institutions to keep vigilant of their quality assurance program

• Problems found contribute to determine priorities for site visits

• Identifies problems that have direct impact on every patient treated

• It is a model for other remote programs
## Institutions Monitored by the RPC

<table>
<thead>
<tr>
<th>As of...</th>
<th>Active Institutions</th>
<th>Active - no XRT</th>
<th>CTSU (Pending)</th>
<th>Total Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/1/2004</td>
<td>1,306</td>
<td>71</td>
<td>5</td>
<td>1,382</td>
</tr>
<tr>
<td>1/1/2005</td>
<td>1,329</td>
<td>71</td>
<td>9</td>
<td>1,409</td>
</tr>
<tr>
<td>7/1/2005</td>
<td>1,387</td>
<td>94</td>
<td>12</td>
<td>1,493</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time Span</th>
<th>New machines added</th>
<th>New beams added</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003 - 2004</td>
<td>260</td>
<td>1,659</td>
</tr>
<tr>
<td>2004 - 2005</td>
<td>236</td>
<td>1,349</td>
</tr>
</tbody>
</table>
Credentialing Techniques

- Phantoms
- Benchmarks
Purpose of Credentialing

- 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
- Electronic data submission
- RPC QA & dosimetry review
- Clinical review by radiation oncologist

Feedback to Institution
Credentialing
3D Conformal Radiation Therapy (3D CRT)

- Innovative high-technology radiation technique where multiple beams are shaped to treat only the tumor
- Evaluate 3D treatment planning process and ability to provide documentation
- North Central Cancer Treatment Group (NCCTG) – October 1, 2004
- 42 institutions credentialed to date
Credentialing
LDR and HDR Brachytherapy

- Evaluate
  - Implant technique
  - Dosimetry
  - Documentation
  - Protocol compliance
Brachytherapy Studies Requiring Credentialing

- Cervix
  - GOG 165, 191
  - RTOG 0116, 0128
- Breast
  - RTOG 95-17
  - RTOG 0413 / NSABP B-39
- Prostate
  - NCCTG N-0052
  - RTOG 98-05, 0019, 0232, 0321
## Credentials Awarded (based on benchmarks)

<table>
<thead>
<tr>
<th>Credentials</th>
<th>Credentials</th>
<th>Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostate LDR (0232)</td>
<td>66</td>
<td>59</td>
</tr>
<tr>
<td>Prostate HDR (0321)</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Breast 3D CRT (0413)</td>
<td>158</td>
<td>77</td>
</tr>
<tr>
<td>Breast Mammosite®</td>
<td>71</td>
<td>53</td>
</tr>
<tr>
<td>Breast Multicatheter</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>Other 3D CRT (NCCTG)</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Cervix (GOG)</td>
<td>55</td>
<td>46</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>434</strong></td>
<td><strong>297</strong></td>
</tr>
</tbody>
</table>
## Results of Credentialing

(closed studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Major Deviations</th>
<th>Minor Deviations</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOG 165 HDR Cervix Credentialed inst</td>
<td>0</td>
<td>15</td>
<td>70</td>
</tr>
<tr>
<td>RTOG 95-17 HDR &amp; LDR Breast (all)</td>
<td>0</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>RTOG 0019 LDR Prostate (values for dose only)</td>
<td>0</td>
<td>6</td>
<td>117 reviewed (total 129 eligible)</td>
</tr>
</tbody>
</table>
### Results of Credentialing (closed studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Major Deviations</th>
<th>Minor Deviations</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOG 165 HDR Cervix Credentialed inst</td>
<td>0</td>
<td>15</td>
<td>70</td>
</tr>
<tr>
<td>Non-credentialed</td>
<td>57</td>
<td>87</td>
<td>275</td>
</tr>
<tr>
<td>RTOG 95-17 HDR &amp; LDR Breast (all)</td>
<td>0</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>RTOG 0019 LDR Prostate (values for dose only)</td>
<td>0</td>
<td>6</td>
<td>117 reviewed (total 129 eligible)</td>
</tr>
</tbody>
</table>
3,040 Treatment Machines Monitored by the RPC

- Clinac 2100, 21EX
- Clinac 1800, 2000
- Clinac 2300, 2500
- Clinac 4, 6, etc.
- Novalis
- Mevatron
- Primus
- Primus, Primart
- Oncor
- Precise
- Sl, Sli
- Mobetron
- Tomotherapy Hi-Art
- CyberKnife
- Cobalt-60
- Other
RPC Phantoms

prostate RTOG 0126 (IMRT)

H&N IMRT
RTOG 0225, 0126; COG ACNS0331

thorax RTOG 0236 (SBRT)

liver RTOG 0438
Plan vs. Treatment
Number of Phantom Mailings

Year

2001 2002 2003 2004 2005

0 20 40 60 80 100 120 140

Prostate
Lung
H&N

Radiological Physics Center
Excellence through Quality Assurance
## Phantom Results

<table>
<thead>
<tr>
<th>Phantom</th>
<th>H&amp;N</th>
<th>Prostate</th>
<th>Thorax</th>
<th>Liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiations</td>
<td>157</td>
<td>27</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>Pass</td>
<td>109*</td>
<td>24</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Fail</td>
<td>48</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Under analysis or at institution</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Year introduced</td>
<td>2001</td>
<td>Spring 2004</td>
<td>Spring 2004</td>
<td>Spring 2005</td>
</tr>
</tbody>
</table>

* 33% of institutions failed H&N phantom on the first attempt
Explanations for Failures

- Incorrect data in planning system
- Output factors, %dd
- Inadequacies in beam modeling (Cadman, et al; PMB 2002)
- Not adjusting irradiation time according to measurements
- Errors in indexing Peacock system
- Setup errors
Examples of Failures
Peacock Indexing Error
Comparison:
Planned vs. Delivered Distribution
Number of Institutions Converting to TG-51
Protocol Patient Review
Purpose of Chart Review

• Correct errors in patient treatments
• Provide correct and comparable data
• Improve quality of care for all RT patients
• Reviewed charts from 1003 institutions
• Only the RPC and RTOG HQ Dosimetry Group confirm doses for external beam
• Only QAO confirming implant doses
Study Groups Relying on RPC Chart Review

- **GOG**  Gynecologic Oncology Group
- **NCCTG**  North Central Cancer Treatment Group
- **NSABP**  National Surgical Adjuvant Breast and Bowel Project
- **RTOG**  Radiation Therapy Oncology Group
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
Priority for Visits

- TLD Problem
- Problem Chart
- Other
- Patient Accrual
On-Site Dosimetry Review Visit

• The only 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.
On-Site Dosimetry Review Visit

~1387 institutions participating in clinical trials

<table>
<thead>
<tr>
<th></th>
<th>visited</th>
<th>not visited yet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutions:</td>
<td>715</td>
<td>672</td>
</tr>
<tr>
<td>Patient accrual:</td>
<td>20,130</td>
<td>1,095</td>
</tr>
<tr>
<td>(95%)</td>
<td></td>
<td>(5%)</td>
</tr>
</tbody>
</table>

Diagram showing the cumulative number of institutional visits from 2000 to 2004.
On-Site Dosimetry Review Visit

~1387 institutions participating in clinical trials visited

<table>
<thead>
<tr>
<th>Institutions:</th>
<th>715</th>
<th>672</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient accrual:</td>
<td>20,130</td>
<td>1,095</td>
</tr>
<tr>
<td>(95%)</td>
<td></td>
<td>(5%)</td>
</tr>
</tbody>
</table>

Prioritization schema focuses our visit resources where the majority of the patients are treated!
On-Site Dosimetry Review Visit Errors

99% of the Institutions visited have one or more errors
Over 500 errors and 85 lapses in QA programs were identified at institutions visited by the RPC during the past 5 years.

These errors potentially impacted on all patients treated at these institutions.
### On-Site Dosimetry Review Visits
Selected discrepancies discovered during 2004

<table>
<thead>
<tr>
<th>Errors Regarding:</th>
<th>Percent of Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review QA Program</td>
<td>(84%)</td>
</tr>
<tr>
<td>*Photon Depth Dose</td>
<td>(30%)</td>
</tr>
<tr>
<td>Switch to TG-51</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Wedge Transmission</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Photon Calibration &amp; FSD</td>
<td>(24%)</td>
</tr>
<tr>
<td>*Electron Calibration</td>
<td>(22%)</td>
</tr>
<tr>
<td>*Off-axis Factors</td>
<td>(16%)</td>
</tr>
</tbody>
</table>

*70% of institutions received at least one of the significant dosimetry recommendations.
Calibration Procedures (1)

Reference calibration adjusted to dose in:

- Muscle
- Water
Review of Institutions Dosimetry Program Remotely

How can we evaluate institutions and find errors for the nearly 700 institutions that have a low priority for a visit?

Use the RPC standard data.
RPC Remote Data Review

What are the RPC Standard Data?

• Compilation of RPC measured *average* data
  1. 2350 photon beams
  2. 81 accelerator model/energy combinations
• Specific to make/model/energy
• ≥ 5 sets of RPC measured data

Analyses of these data indicate that machines of same make/model/energy have same radiation characteristics.
## RPC Remote Data Review

### Can standard data discover errors?  
(analysis of 7,864 data points from 150 institutions)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosimetry review visit found discrepancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6890</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td>(87.7%)</td>
<td>(5.7%)</td>
</tr>
<tr>
<td>No</td>
<td>378</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>(4.8%)</td>
<td>(1.9%)</td>
</tr>
</tbody>
</table>
RPC Remote Data Review

Can standard data discover errors?
(analysis of 7,864 data points from 150 institutions)

- No: 450 (5.7%)
- Yes: 6890 (87.7%)

Std. Data indicates discrepancy

Dosimetry review visit found discrepancy
- Yes
- No

Failed to predict
(10.5%)
Calibration Procedures (2)
Communications and Support of the Radiation Oncology Community

(RPC: National Resource)

Only QA group within USA and Canada that interacts with oncologists, medical physicists, dosimetrist and other medical staff at 1,400 institutions, regardless of their affiliation or location.
Strongest Interaction is with the Physics Community in Support of Clinical Trials

American Association of Physicists in Medicine (AAPM)

• Therapy Physics Committee
• Brachytherapy dosimetry in clinical trials
• Implementation of new calibration protocol
Only QA Office with relationships with all study groups
About the ATC
Cooperative Groups
How to participate
Contact Us

News
2004 DICOMConnectathon
2004 ATC DICOM Workshop

ATC Members
Image-Guided Therapy Center (ITC)
Quality Assurance Review Center (QARC)
Radiation Therapy Oncology Group (RTOG)
Radiological Physics Center (RPC)
Resource Center for Emerging Technologies (RCET)

Supported by the
Consortium of 5 quality assurance offices

- RPC
- RTOG QA
- QARC
- ITC
- RCET

Role is to interact with study groups

Role is to develop tools for electronic data submission and review
# Ongoing Communications with Community

1. Via the web site and email burst
2. AAPM newsletter
3. Workshops/posters/oral presentations/publications
4. Phone!
Ongoing Communications with Community

1. Via the web site and email burst
2. AAPM newsletter
3. Workshops/posters/oral presentations/publications
4. Phone!

RPC WEBPAGE NEWSLETTER
Volume 3, Issue 1
March 2004

Water or muscle - does it matter?

The RPC has received a number of comments about the question on our TLD forms that asks if the institution calibrates to water or muscle. Several callers were concerned that they needed to report their calibration in the same medium as is used by the RPC to report dose. Others asked for the converse; for the RPC to report dose in the same medium as used by their institution for calibration.

The medium used for reporting dose is not necessarily the same as the medium in which the beam output is measured. TG-51 requires that beam output be measured in water, and many institutions report the calibration that way. In other words, they describe the output as 1.00 cGy to water per MU under reference conditions. However, quite a few institutions apply a 1% correction at the time of calibration, and adjust the treatment unit output to 1.00 cGy to muscle per MU under reference conditions. The RPC database indicates that 35% of the institutions report their calibration to muscle and the remaining 65% to water.

We would like institutions to indicate on the TLD forms how their beams are calibrated, not how patient doses are described. If a 1% correction is applied at the time of beam calibration, you should check the box for “muscle”. Otherwise you should check “water”, even if you apply the 1% correction when calculating MU settings for patient treatments.
Institutions participating in monitoring program

<table>
<thead>
<tr>
<th>Institution</th>
<th>Address</th>
<th>City</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univ of Pretoria</td>
<td>2099 Private Bag X 169</td>
<td>PRETORIA</td>
<td>RSA</td>
</tr>
<tr>
<td>Univ of Rochester Med. Center</td>
<td>2613 601 Elmwood Ave Box 647</td>
<td>Rochester</td>
<td>NY</td>
</tr>
<tr>
<td>Univ of South Alabama Cancer Ctr.</td>
<td>2614 307 University Blvd. - CG/CG 135</td>
<td>Mobile</td>
<td>AL</td>
</tr>
<tr>
<td>Univ of Southern California</td>
<td>1674 1200 N State St</td>
<td>Los Angeles</td>
<td>CA</td>
</tr>
<tr>
<td>Univ of Tennessee - Chattanooga</td>
<td>1406 975 E Third St</td>
<td>Chattanooga</td>
<td>TN</td>
</tr>
<tr>
<td>Univ of Tennessee Medical Center</td>
<td>2616 1924 Alcoa Highway</td>
<td>Knoxville</td>
<td>TN</td>
</tr>
<tr>
<td>Univ of Tennessee Medical Ctr.</td>
<td>2616 1924 Alcoa Highway</td>
<td>Knoxville</td>
<td>TN</td>
</tr>
<tr>
<td>Univ of Tennessee Memorial Hosp.</td>
<td>2616 1924 Alcoa Highway</td>
<td>Knoxville</td>
<td>TN</td>
</tr>
<tr>
<td>Univ of Texas - S.W. Medical</td>
<td>2569 5323 Harry Hines Blvd.</td>
<td>Dallas</td>
<td>TX</td>
</tr>
<tr>
<td>Univ of Texas Medical Branch</td>
<td>2618 301 Univ. Blvd; 1.400 K McCullough Bldg</td>
<td>Galveston</td>
<td>TX</td>
</tr>
<tr>
<td>Univ of Utah Hospitals and Clinics</td>
<td>2619 AB25 MC</td>
<td>Salt Lake City</td>
<td>UT</td>
</tr>
<tr>
<td>Univ of Utah Medical Center</td>
<td>2619 AB25 MC</td>
<td>Salt Lake City</td>
<td>UT</td>
</tr>
<tr>
<td>Univ of Vermont</td>
<td>1427 111 Colchester Ave.</td>
<td>Burlington</td>
<td>VT</td>
</tr>
<tr>
<td>Univ of Virginia Hospital</td>
<td>2620 Jefferson Pk. Ave. West, Rm. 2691</td>
<td>Charlottesville</td>
<td>VA</td>
</tr>
<tr>
<td>Univ of Washington Medical Center</td>
<td>2621 1950 N.E. Pacific St., (Box 35604-3)</td>
<td>Seattle</td>
<td>WA</td>
</tr>
<tr>
<td>Univ of West Virginia Med. Ctr.</td>
<td>2723 P.O. Box 8150 Medical Center Drive</td>
<td>Morgantown</td>
<td>WV</td>
</tr>
<tr>
<td>Univ of Western Ontario</td>
<td>1714 790 Commissioners Rd E</td>
<td>LONDON</td>
<td>ONTARIO</td>
</tr>
<tr>
<td>Univ of Wisconsin Med. Center</td>
<td>2622 600 Highland Ave K4/B100-0600</td>
<td>Madison</td>
<td>WI</td>
</tr>
<tr>
<td>Univ of Texas South West - Moncrief</td>
<td>1749 911 Foster Lane</td>
<td>Weatherford</td>
<td>TX</td>
</tr>
</tbody>
</table>
Ongoing Communications with Community

1. Via the web site and email burst

2. AAPM newsletter

3. Workshops/ posters/ oral presentations/ publications

4. Phone!
Ongoing Communications with Community

1. Via the web site and email burst
2. AAPM newsletter
3. Workshops/posters/oral presentations/publications
4. Phone!
Ongoing Communications with Community

1. Via the web site and email burst
2. AAPM newsletter
3. Workshops/ posters/ oral presentations/ publications
4. Phone!
Ongoing Communications with Community

Since 2000

> 69 oral presentations/posters
39 scientific publications
10 workshops
Ongoing Communications with Community

1. Via the web site and email burst
2. AAPM newsletter
3. Workshops/ posters/ oral presentations/ publications
4. Phone/ email!
Ongoing Communications with Community

The RPC interacts with the Radiation Oncology community over 100 times per week.
Calibration Procedures (3)

At other depth

In air

At $d_{\text{max}}$
Gel Dosimetry

- Expanded use of gels, adapt to additional phantoms
- Investigation of new gel/solid dosimeters
Relative Evaluation
Phantom Development

- Design of “liver” phantom, with simulated respiratory motion, for RTOG 0438
- STTR proposed: Dynamic phantom for gated & adaptive therapy
Simulation of Respiratory Motion
0438 - Liver primary or mets

- Questionnaires
- Liver phantom on reciprocating table
- Digital submission
Influence of Lung Tissue on Tumor Dose

- RPC phantom contains lung-equivalent regions
- Comparison of calculations with measurements
Lung Phantom Comparison
Summary of Gamma-Index Comparison

![Gamma-Index Comparison Chart]

- **6 MV Offset**
- **6 MV Centered**
- **18 MV Offset**

**Software**:
- Pinnacle
- Convolution
- Eclipse
- XiO
- Clarkson

**Comparison Metrics**:
- 5% / 3mm
Gynecological Insert for Pelvic Phantom
Improvements to Remote Audits

• Alternatives to Lithium Fluoride, automatic TLD readers

• Elimination of %DD measurements

• Expanded audits: non-reference dosimetry, other detectors

• Introduction of Monte Carlo-calculations
  – Supplement “Standard Data”
  – Facilitate validation of complex treatments
Proton Beam Clinical Trials

- Project to investigate radiochromic film
- Anticipate additional projects
  - Other dosimeters
  - Phantoms
  - Visits
- Coordinating with MDACC
Other Aspects …

- Continue efforts to improve efficiency and service
- Further implement electronic data exchange
- Remain vigilant to needs of study groups and community
The End