Radiation Dose: External Beam Radiation Therapy Conventions and the Evolving Field of Radiopharmaceutical Therapy

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Disclosures

• No financial disclosures
• I work in therapeutic medical physics
External Beam Radiation Therapy

• In external beam therapy, patients receive a conformal radiation dose to targets, while healthy structures receive minimal radiation dose.

• Every treatment plan is designed for the individual patient. Most patients treatment plans are based upon CT and/or MR images.

• Patient setup is highly reproducible; most patients are setup with daily x-ray images and/or CBCT images.

An example of a patient treatment plan
Commissioning of Linear Accelerators

• Before a linear accelerator is used for clinical treatments it is fully characterized.

• A complex beam model is created in the treatment planning system (TPS)

• The beam model is validated by creating many treatment plans that test the system, and measuring the dose (point or 3D measurements)
Output Calibrations: TG-51

After characterizing the radiation produced by the linac, physicists will calibrate the output so that a known number of monitor units produce a known amount of radiation:

e.g. 100 MU = 100 cGy for a 10 cm X 10 cm field at 100 cm SSD at a depth of dmax.
External Validation : IROC OSLDs

Institutions can verify the calibration by irradiating small phantoms with TLDs or OSLDs inserted in them.

A known radiation dose is delivered and the phantoms are returned to IROC.

The received radiation dose is externally verified by IROC.

Listed below are the results for the TLD irradiated June 26, 2014 on the Mobetron s/n 49:

<table>
<thead>
<tr>
<th>Electron Energy</th>
<th>TLD Ratio – MDACC/INST (difference in mm between TLD depth and Inst depth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 MeV</td>
<td>1.00 (-1 mm)</td>
</tr>
<tr>
<td>9 MeV</td>
<td>1.00 ( 0 mm)</td>
</tr>
<tr>
<td>12 MeV</td>
<td>1.00 ( 0 mm)</td>
</tr>
</tbody>
</table>

From : http://rpc.mdanderson.org/RPC/home.htm
In addition ...

- To participate in clinical trials, end-to-end testing is also required.
- Phantoms with TLDs are shipped to the institution where they are imaged and a treatment plan is created and delivered.
- The phantoms are then shipped back to IROC, where the radiation dose delivered to the TLDs is determined.
- The credentialing process ensures that participating sites are capable of delivering complex radiation treatment plans as intended.
Daily, Monthly and Annual QA

- In addition to the calibration described, routine QA is performed on linacs to ensure dose constancy.
- This includes daily QA, monthly QA and performing TG-51 annually.
- IROC OSLDs are irradiated annually.
- For complex treatments (e.g. IMRT), patient specific QA is also performed before the patient receives treatment.
Training physicists in external beam RT

• Board certification by the ABR in therapeutic radiation physics requires a CAMPEP accredited residency

• Residents have many opportunities to learn how accelerators are calibrated and how routine QA is performed
Part 2: Radionuclide Therapy

$^{177}$Lu-DOTATATE

Image courtesy of Dr. Thomas Hope, UCSF Department of Radiology
What would we get if we asked for the radiation dose record for a patient treated with TRT?
**Supplementary Table S2. {superscript}177 Lu-DOTATATE Exposure.**

<table>
<thead>
<tr>
<th>Number of administrations</th>
<th>Patients who completed treatment phase (N=1031)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no. (%)</td>
</tr>
<tr>
<td>4</td>
<td>79 (77)</td>
</tr>
<tr>
<td>3</td>
<td>6 (6)</td>
</tr>
<tr>
<td>2</td>
<td>12 (12)</td>
</tr>
<tr>
<td>1</td>
<td>5 (5)</td>
</tr>
<tr>
<td>0</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

**All treated patients (N=111)**

<table>
<thead>
<tr>
<th></th>
<th>No DMT</th>
<th>DMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>103 (93)</td>
<td>8 (7)</td>
</tr>
</tbody>
</table>

*DMT denotes dose-modifying toxicity.
† Excluding patients still under treatment (n=8) or no treatment (n=5).
24 hour post-administration SPECT/CT

All patients treated with Lu-177 DOTATATE at UCSF have a 24 hour post-administration SPECT/CT scan.

These scans are used qualitatively.
Beyond Administered Activity...

- To report patient dose in Gy requires several additional steps
  - **Calibrated** SPECT/CT or PET/CT scanner
  - **Validated** dose calculation algorithm
  - Recording the dose in a standardized format (e.g. RTDose)

MIRD Pamphlet No. 26: Joint EANM/MIRD Guidelines for Quantitative $^{177}$Lu SPECT Applied for Dosimetry of Radiopharmaceutical Therapy

Michael Ljungberg¹, Anna Celler², Mark W. Konijnenberg³, Keith F. Eckerman⁴, Yuni K. Dewaraja⁴, and Katarina Sjögren-Gleisner¹


Kinetics of the agent must also be considered
Work done in collaboration with Dr. Thomas Hope, UCSF Department of Radiology
External Beam RT

Standardized Calibration Procedures

External Dose Validation Methods (phantoms)

Training for physicists who perform calibrations

Routine QA & tolerances

Targeted Radionuclide Therapy