Quality Management of LDR Sources

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Topic is limited to the sources themselves

• … planning, applicators, surveys …

• Outline
  - Acceptance testing
  - Periodic testing
  - Per-patient testing

• War stories??
Useful categories

- Temporary vs permanent
  - (i.e. >50 keV vs <50 keV)
- Long- or short-lived isotopes
  - (e.g. kept in inventory vs ordered per patient)
- Seeds or extended sources
  - (e.g. I-125 seeds vs Cs-137 tubes)
Preparation for calibration

• TG-56:
  - “Every institution practicing brachytherapy shall have a system for measuring source strength with secondary traceability for all source types used in its practice.”

• Secondary traceability:
  - use an instrument that has been calibrated at an ADCL (or NIST) for that source type
  - compare with a source of the same type that has been calibrated at an ADCL (or NIST)
Instrumentation

• So – get yourself a well chamber!
Preparation for calibration

• ... and get the chamber or a source calibrated
Well chamber QM

- Constancy check with Cs-137 standard
- Regular calibration cycle with needed source types
- Source holders and geometry factors
Acceptance testing of long-lived sources (kept in inventory)

1. Document the physical/chemical form and encapsulation in order to support dosimetry calculations

2. Document the initial leak test based on the manufacturer’s certification, and, optionally, repeat with local equipment (see below.)
Long-lived sources

3. Verify the uniformity of the activity distribution within each source (most likely with an autoradiograph; no tolerance limit is given.)

4. Verify the location of the activity distribution within each source relative to the exterior dimensions to a tolerance of 1 mm (most likely by combining an autoradiograph with a transmission radiograph.)
Fig 2.2 from Thomadsen: Achieving Quality in Brachytherapy
Checking sources with radiochromic film

GafChromic RTQA; ~10 minute exposure
Long-lived sources

5. Verify the identification of each source (serial numbers, color coding, etc.)

6. Calibrate each source
Calibration points

- If the measured source strength agrees with the manufacturer’s specification to within 3%, then either may be used for dose calculations.

- Differences larger than 3% should be investigated, and differences larger than 5% should be reported to the manufacturer.

- When sources are batched for dosimetry purposes, then the 3% tolerance applies to the mean of the batch, and the range of source strengths within the batch should not exceed 5%.
Leak testing

- At intervals of 6 months or 3 years, depending on the license conditions
- Need appropriate instrumentation for a minimum detectable activity of 0.005 μCi (185 Bq)
  - e.g. NaI well
  - μCi test source

See Thomadsen Chapter 2: Achieving Quality in Brachytherapy
Leak testing details

• Basic requirement:
  - Net counts must be reliably above background
  - Be able to measure 0.005 μCi (185 Bq)
• “Leak” testing typically means wiping with an alcohol swab; dry wipe may only be 3% efficient
If accept 5% false negatives (wipe has activity, but is called clean):

\[ C_T = \text{total counts} \]
\[ C_B = \text{background counts} \]
\[ C_T - C_B = C_{\text{wipe}} > 1.645 \times \left( C_B^{1/2} + (C_B + C_T)^{1/2} \right) \]
\[ C_{\text{wipe}} \approx 4 \times C_B^{1/2} \]

E.g. for background = 700 counts, net \( \geq 104 \) counts
Counts to activity

- Use standard source with similar energy and strength, so counting efficiency is similar
- If different source type, account for difference in number of photons emitted per decay
Counts to activity

\[ A \equiv \text{activity} \]
\[ C \equiv \text{counts} \]
\[ T \equiv \text{count time} \]
\[ P \equiv \text{photons per decay} \]

\[ A_{\text{wipe}} = \left( A_{\text{stndrd}} \right) \left[ \frac{C_{\text{wipe}}}{T_{\text{wipe}}} \right] \left[ \frac{C_{\text{stndrd}}}{T_{\text{stndrd}}} \right] \left[ \frac{P_{\text{stndrd}}}{P_{\text{wipe}}} \right] \]
For compliance ...

\[
0.005 \mu Ci = A_{\text{stdrd}} \times \left( \frac{C_{\text{wipe}}}{T_{\text{wipe}}} \right) / \left( \frac{C_{\text{stdrd}}}{T_{\text{stdrd}}} \right) \times \left( \frac{P_{\text{stdrd}}}{P_{\text{wipe}}} \right)
\]

\[
0.005 \mu Ci = A_{\text{stdrd}} \times \left( 4 \times C_B^{1/2} / T_{\text{wipe}} \right) / \left( \frac{C_{\text{stdrd}}}{T_{\text{stdrd}}} \right) \times \left( \frac{P_{\text{stdrd}}}{P_{\text{wipe}}} \right)
\]

Can use this to calculate the necessary count time once you know the background count rate and the standard count rate

e.g. for background = 700 counts, net \( \geq 104 \) counts;
So count long enough so 0.005 \( \mu \)Ci will give 104 counts
Acceptance testing of short-lived sources (TG-56)

1. Document the physical/chemical form and encapsulation in order to support dosimetry calculations.
2. Verify the uniformity of the activity distribution within each source, where applicable, or the distribution of seeds along an extended ribbon (e.g. autoradiograph each ribbon.)
Short-lived sources

3. Calibrate the sources, either individually or as a batch. Should agree with manufacturer within 3% with range of 5%

Issues:

Seeds in ribbon (e.g. Ir-192)
Loose seeds
Pre-sterilized seeds
Seeds in ribbon

- Can use source holder for well chamber that holds the ribbon in a coil.
- May need to develop correction factor vs. ribbon length.
- TG-40: For large number of ribbons, measure at least 10% of seeds
Loose seeds

- TG-56 allows for “secondary traceability by statistical inference” in which a “suitable random sample” is calibrated with secondary traceability.
- TG-40 and TG-56 call for that sample to comprise at least 10% of the total batch.
Loose seeds

• Can also measure the entire batch, using an empirical correction for geometry and self-absorption

Batch factor depends on system

\[ y = 0.9588e^{0.0033x} \]

\[ R^2 = 0.983 \]
Pre-sterilized seeds

- TG-56 recommends “purchasing and calibrating a single (non-sterile) seed for each designated-strength grouping.”
  - What is the connection between the seeds?
    - Same lot?
    - Different lot, same process?
  - Only one seed?
Pre-sterilized seeds: options

- Purchase and calibrate some loose seeds of the same type and activity, which are then discarded.
- Purchase and calibrate some assemblies of the same type and activity, which are then discarded.
Pre-sterilized seeds: options

- Calibrate some assemblies under sterile conditions in the OR
  - Sterilizable insert that can measure 5 of 10 seeds in one RAPID Strand™
- (calibrating sources actually used!)
Pre-sterilized seeds: options

• Use third-party service to assay (not limited necessarily to pre-sterilized seeds)

• Controversial with respect to end-user responsibilities

  - TG-64: “In whatever form the seeds are procured, the manufacturer’s assay must be independently confirmed.”
“...each physicist should continue to follow the recommendations of Task Groups 56 and 64 in their intent to place the patient’s needs foremost. For those already using a 3rd party calibration service, a prudent approach would be to perform some relevant in-house check of each order received.”

*under discussion within Therapy Physics Committee
Leak testing for short-lived sources

- Generally not necessary, unless
  - Keep I-125 stock > 6 months?
  - Used for second patient
  - After extensive handling
- Good practice to be prepared to test for potentially ruptured seed (c.f. recent NRC notice)
Periodic testing of sources kept in inventory

- Formal inventory (typical regulation calls for quarterly inventory)
- Annual calibration
  - Deviation from expected half life would indicate contamination with a different isotope
- Inspect identification, refresh color coding if necessary
- Leak test when required
<table>
<thead>
<tr>
<th>Drawer #</th>
<th>Nominal Source Strength</th>
<th>Color Code</th>
<th>Total # of Sources</th>
<th>Total Activity MgRaeq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 mgRaeq</td>
<td>Red</td>
<td>4</td>
<td>80 mgRaeq</td>
</tr>
<tr>
<td>2</td>
<td>15 mgRaeq</td>
<td>Green</td>
<td>4</td>
<td>60 mgRaeq</td>
</tr>
<tr>
<td>3</td>
<td>10 mgRaeq</td>
<td>Yellow</td>
<td>3</td>
<td>50 mgRaeq</td>
</tr>
<tr>
<td>4</td>
<td>10 mgRaeq</td>
<td>None</td>
<td>1</td>
<td>10 mgRaeq</td>
</tr>
</tbody>
</table>
Time for a paint job
Per-patient testing (… of sources)

- Inventory control, showing which sources are out of storage, where they are, when they were removed, and when they are returned
- Main concerns overlap with the more general quality management of the brachytherapy procedure
  - Right sources into right places …
Plan
Summary
and Implant
Record
From W. Butler

<table>
<thead>
<tr>
<th>Source No.</th>
<th>Source Ident.</th>
<th>Calibrated Activity</th>
<th>Calculated Activity</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

### Calculated Doses

<table>
<thead>
<tr>
<th>Calculation Point</th>
<th>Dose Rate (cGy/hr)</th>
<th>Time (hours)</th>
<th>Total Dose (cGy)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Implant applied: Date: ____________________________ Time: ______________________ Hours: ____________

Implant removed: Date: ____________________________ Time: ______________________ Hours: ____________

Calculated by: ________________________________

Checked by: ________________________________

Date: ________________________________ Date: ________________________________
Radioactive Materials Requisition

Patient: _______________________________  Room: ______________________

( ) Cesium - 137

<table>
<thead>
<tr>
<th>Tandem Loading</th>
<th>Upper, inner end</th>
<th>Color</th>
<th>Spacers</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mg Ra eq.)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10 = green</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 = yellow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 = orange</td>
<td>Outer end</td>
<td></td>
<td>Color</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ovoid Loading</th>
<th>Right</th>
<th>Left</th>
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<tbody>
<tr>
<td>(mg Ra eq.)</td>
<td></td>
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</tbody>
</table>

Date and Time needed: ________________________________
Radiation Oncologist: _______________________________  Date: ______________________
Requisition filled by: _______________________________  Date: ______________________
Checked by: _______________________________  Date: ______________________
### Cesium in Hot-Cell Storage Safe

<table>
<thead>
<tr>
<th>Quantity After Removal</th>
<th>Color Code</th>
<th>Quantity Stocked</th>
<th>Identity</th>
<th>Quantity After Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>6</td>
<td>10 mg Radium equivalent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>6</td>
<td>15 mg Radium equivalent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>4</td>
<td>20 mg Radium equivalent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Authorized Handler Initials

* * * * * * * * * * * * * * * * * * * * * * *

**Cs-137**

**In-use inventory**

From W. Butler

Authorized Handlers:

- Wayne Butler, Ph.D.
- Tapash Roy, Ph.D.
- Amber Hines, M.S.
- Brian Kurko, CMD
- Richard Anderson, CMD
- Brian Murray, CMD
- Gregory Merrick, M.D.
- Jondavid Pollock, M.D.
## Radioactive Materials Requisition

**Iridium - 192 (>4 ribbon types)**

<table>
<thead>
<tr>
<th>Number of Ribbons</th>
<th>No. of Seeds per Ribbon</th>
<th>Seed Spacing (mm)</th>
<th>Activity per seed (mg Ra eq)</th>
<th>Activity per seed (mCi)</th>
<th>Ribbon Color</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Date and Time needed: ________________________________

Radiation Oncologist: ________________________________ Date: _______________________

Requisition filled by: ________________________________ Date: _______________________

Checked by: ______________________________________ Date: _______________________
## Ir-192 Inventory

**From W. Butler**

### Receipt

<table>
<thead>
<tr>
<th>Manufacturer: _____________________</th>
<th>Received by: _____________________</th>
<th>Date: ____________</th>
<th>Time: ____________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ludlum 14C check lavender</td>
<td>Package Damaged?</td>
<td>Package Wipe Test &lt;6.6 kdpm/300cm²</td>
<td>Transport Index</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-----------------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Lavender</td>
<td>green</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Seed Calibration

<table>
<thead>
<tr>
<th>Lot Number / Ribbon color</th>
<th>Calibration Date</th>
<th>Activity per seed (mg Ra eq)</th>
<th>Calculated Activity ( (t_{1/2} = 73.83 \text{ d}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upon Receipt ( \text{days / D.F.} ) ( \text{mg Ra eq} ) ( \text{mCi} )</td>
<td>At start of treatment ( \text{days / D.F.} ) ( \text{mCi} )</td>
</tr>
</tbody>
</table>

### Inventory for Implant

<table>
<thead>
<tr>
<th>Ribbon Color</th>
<th>Number of Ribbons</th>
<th>No. of Seeds per Ribbon</th>
<th>Act. / Ribbon ( \text{mCi} )</th>
<th>Dose Calibrator Check ( \text{mCi} )</th>
<th>Total Number of Seeds</th>
<th>Total Activity ( \text{mCi} )</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

### Storage and Use Inventory

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>In Storage</th>
<th>Removed</th>
<th>Returned</th>
<th>Patient/Room</th>
<th>Init</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>mCi</td>
<td>No.</td>
<td>mCi</td>
<td>No.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Seed Return

<table>
<thead>
<tr>
<th>Shipper: _____________________</th>
<th>Date: ____________</th>
<th>Act./Seed: _____________________ mCi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of seeds</td>
<td>Total Activity: _____________________ mCi = ( \text{GBq} )</td>
<td></td>
</tr>
</tbody>
</table>
| Max. Surface Activity: ______ mR/hr | Exposure @ 1 meter: ______ mR/hr | Transport Index: """""""""""""""""""""""""""""""""""""

**Authorized Handlers:** Wayne Butler, PhD  Amber Hines, MS  Tapash Roy, PhD  Gregory Merrick, MD  Jondavid Pollock, MD
<table>
<thead>
<tr>
<th>Point</th>
<th>Location</th>
<th>Meter Reading (mR/h)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 meter to side of patient, unshielded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1 meter to side of patient, behind leaded shield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>“Safety Line” tape for visitors at 4 ft height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Outside room in adjacent corridor at 4 ft height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Adjacent room (202 or 224) at 4 ft height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Electric service room or outside corridor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Room above patient (301 or 344) at 1 ft height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Room below patient (1504 or 1702) at 6 ft height</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey by: __________ indicates no misplaced sources.

**DOSE LIMITS:** 10 CFR Part 20 limits the dose from external sources to unrestricted areas (Points D – H) to 2 mrem/h and the dose to any individual member of the public to 50 mrem/yr. The Radiation Oncologist and the Radiation Safety Officer must be notified if readings in unrestricted areas exceed 0.5 mR/h so that patient dose, room occupancy, shielding, or restricted areas be redefined to remain within the 50 mrem/yr limit.

**After Removal of Implant**

| I    | Patient body, clothing, and belongings | |
| J    | Bed, linens, trash, and afterloading applicators | |

Survey by: __________ indicates all sources are accounted for. Date: __________

Survey meter: __________ Check source: __________ Time: __________
War stories related to source control

“… the doc wouldn’t practice with the Mick before the procedure, and we had seeds all over the OR. Stuck in people’s shoes … everywhere. It was a mess.”
More stories …

On weekends, the practice was for the resident to unload the sources, do the survey, and take the pig back to the source room; physicist would return the sources to the safe on Monday morning. One Monday, found one source was missing … several days later it was found in the Atlanta landfill.
Conclusion

- Calibrate the sources
- Keep track of them!
- After that, on to more exciting things...