Regulatory Guidelines and Computational Methods for Safe Release of Radioactive Patients

II. Brachytherapy

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Disclosures

• None
Talk Objectives

• Describe General Sealed Source Brachytherapy Applications
• Summarize NRC Rulings
• Describe Release Methods for LDR sources
Talk Objectives

• Describe General Sealed Source Brachytherapy Applications
• Summarize NRC Rulings
• Describe Release Methods for LDR sources
Introduction

Brachy : short

Brachytherapy: Therapy at a short distance

Brachytherapy refers to radiation therapy that involves the application of radioactive material directly into or immediately adjacent to the tumor.

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Brachytherapy Treatments

- Low Dose Rate vs. High Dose Rate
- Techniques
  - Intracavitary
  - Interstitial
  - Intraluminal
  - Surface (topical)
- Definitive vs. Boost
  - Example of definitive treatment - prostate implant
  - Example of boost treatment - cervical implant
Dose Rate in Brachytherapy

• Low Dose Rate (LDR):
  – Range of 0.4 to 2.0 Gy/hr (per ICRU #38)
  – Time to deliver prescription is days

• High Dose Rate (HDR)
  – Dose rate > 12 Gy/hr (per ICRU #38)
  – Time to deliver prescription is minutes

• Note: Medium Dose Rate (MDR)
  – Dose rate between LDR and HDR
  – Not as common in the USA

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From Multiple Sources/Manual Loading to a Single Source/Afterloading

Ra-226 Tubes → Cs-137 Tubes/Manual Loading → Cs-137 Pellet LDR → Ir-192 PDR/HDR

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Manual LDR Sources (MDACC)

Cesium Pellet  |  Cesium Walstram  |  Cesium Tube Source
Iridium Wire  |  Gold (Au) Seeds  |  Iodine Seeds

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Selectron LDR Afterloaders

- $^{137}$Cs Pellets sorted magnetically
- Active pellets stored in radiation protection safe
- Program active and inactive pellets in each channel
- Programmed pellets, in intermediate safe
- Compressed air transfer of pellets

MD Anderson, Houston, Tx

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Radium Tubes Sources to Cesium Selectron Pellets in the Tandem

25.0 mm = Ra-226 tube source with 3mm spacer

22.0 mm = Ra-226 tube

2.5 mm

Center of 1st tube source

2.5 mm

Note: each pellet has a nominal activity of 5 mgRaeq.

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HDR/PDR Remote Afterloader

HDR: 10 Ci
PDR: 1-2 Ci

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High-Energy Brachytherapy Sources-examples

Figure 1. Schematic drawing of the Nucletron ‘Classic’ $^{192}$Ir HDR brachytherapy source.

Figure 2. Schematic drawing of the Nucletron ‘V2’ $^{192}$Ir HDR brachytherapy source.
Low-Energy Brachytherapy Sources - examples

Amerham Health model 6702 source

Amersham-Health model 6711 source

Best model 2301 source

IsoRay model CS-1 Rev2

Mentor Prostaseed

Theragenics model 200 source

DraxImage LS-1

Amerham 6733

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From MJ Rivard
# Most Common Radionuclides in Brachytherapy (LDR/HDR)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>( T_{1/2} )</th>
<th>( E_{avg}(\text{KeV}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{226}\text{Ra})</td>
<td>1,622 y</td>
<td>830</td>
</tr>
<tr>
<td>(^{60}\text{Co})</td>
<td>5.26 y</td>
<td>1,250</td>
</tr>
<tr>
<td>(^{137}\text{Cs})</td>
<td>30 y</td>
<td>662</td>
</tr>
<tr>
<td>(^{192}\text{Ir})</td>
<td>74.1 d</td>
<td>380</td>
</tr>
<tr>
<td>(^{198}\text{Au})</td>
<td>2.7 d</td>
<td>410</td>
</tr>
<tr>
<td>(^{131}\text{Cs})</td>
<td>~10 d</td>
<td>29</td>
</tr>
<tr>
<td>(^{125}\text{I})</td>
<td>~60 d</td>
<td>28</td>
</tr>
<tr>
<td>(^{103}\text{Pd})</td>
<td>~17 d</td>
<td>22</td>
</tr>
</tbody>
</table>

- Low E (<50 keV)

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ICBT- Gynecology

- Intracavitary: Places radioactive sources within a body cavity (cervical cancer)
- LDR (temporary, 48hrs) or HDR (temporary, minutes)
**Characteristics of Cervical Cancer Treatment**

Total doses to reference points (LDR+EBRT)) - MDACC

<table>
<thead>
<tr>
<th>Reference point</th>
<th>Dose ± S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td>87 ± 8 Gy</td>
</tr>
<tr>
<td>Bladder</td>
<td>70 ± 9 Gy</td>
</tr>
<tr>
<td>Rectum</td>
<td>70 ± 8 Gy</td>
</tr>
<tr>
<td>Vaginal surface</td>
<td>125 ± 15 Gy</td>
</tr>
</tbody>
</table>

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Intraluminal

Intraluminal: Places the source of radiation within body “tubes” such as esophagus, trachea, bronchus and rectum.

Temporary (HDR, minutes)
Surface (Topical)

- Places the radioactive sources on top of the area to be treated (choroidal melanoma)
- Temporary: ~72hrs (LDR)

A custom-made radiation plaque. On the left is the inside of a plaque with the radiation seeds. On the right is the gold coating on the outside of the plaque.

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Interstitial Examples

- **Interstitial**
  - Temporary
    - Sarcoma - muscle
      - Iridium seeds or wire, LDR
    - GI - rectum
      - Iridium seeds or wire, LDR
    - H&N - BOT, FOM nasal septum
      - Iridium seed or wire, LDR
  - Prostate
    - Iridium, HDR
Interstitial Examples

• Interstitial
  – Permanent

  • GU - prostate
    (I-125, Pd-103, Cs-131)
  • GYN - pelvic side wall
    (Au-198)
  • GI - rectum (Au-198)
Trans Rectal Ultrasound (TRUS) for Prostate Implants

- 1990’s - Advancements of the Ultrasound Guided Transperineal Brachytherapy Procedure

- Advancements made with the TRUS
  - pre-operatively plans the placement and number of seeds
  - Calculate 3-D radiation dose distribution for prostate, rectum, urethra, and bladder
  - adjust variables for dose escalation and normal tissue sparing
Prostate Implant OR Procedure
## Prostate Implant Typical LDR Prescriptions

<table>
<thead>
<tr>
<th>Source</th>
<th>$T_{1/2}$ (days)</th>
<th>Energy (median, KeV)</th>
<th>90% Dose delivered (days)</th>
<th>Monotherapy (Gy)</th>
<th>Boost (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-125</td>
<td>~60</td>
<td>~28</td>
<td>204</td>
<td>145</td>
<td>100-110</td>
</tr>
<tr>
<td>Pd-103</td>
<td>~17</td>
<td>~22</td>
<td>58</td>
<td>120 or 125</td>
<td>90-100</td>
</tr>
<tr>
<td>Cs-131</td>
<td>~10</td>
<td>~30</td>
<td>33</td>
<td>115</td>
<td>85</td>
</tr>
</tbody>
</table>

AAPM Task Group 43


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TG-43 Updates

Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations

Medical Physics, Vol. 31, No. 3, March 2004

Recommendations of the American Association of Physicists in Medicine regarding the Impact of Implementing the 2004 Task Group 43 Report on Dose Specification for $^{103}$Pd and $^{125}$I Interstitial Brachytherapy

Medical Physics, Vol. 32, No. 5, May 2005

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Task Group 43-updated

\[
\dot{D}(r, \theta) = S_K \cdot \Lambda \cdot \frac{G_L(r, \theta)}{G_L(r_0, \theta_0)} \cdot g_L(r) \cdot F(r, \theta)
\]
Source Strength (Activity)

1 Ci (curie): $3.7 \times 10^{10}$ disintegration/sec

1 Bq (becquerel): 1 disintegration/sec

1 Ci = 37 GBq

mg-Ra-eq is the mass of radium required to produce the same exposure rate at 1cm from the substitute source

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Source Strength (Air Kerma)

• Product of air kerma rate times distance squared, usually 1 m, to point of specification.
• $S_k = (dK(r)/dt)\cdot r^2$, units are in U
  $1U = 1 \mu\text{Gy} - \text{m}^2/\text{hr}$ or $1\text{cGy}-\text{cm}^2/\text{hr}$
• AAPM TG-43 protocol specifies air kerma strength on perpendicular bisector of source at 1cm

\[ S_K = \dot{K}_\delta(d)\cdot d^2 \]

*Updated – 5 keV cutoff

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TG 43-updated Dose Rate Constants

\[ D(r, \theta) = S_K \cdot \Lambda \cdot \frac{G_L(r, \theta)}{G_L(r_0, \theta_0)} \cdot g_L(r) \cdot F(r, \theta) \]

TABLE I. NIST standard WAFAC calibration dates for air kerma strength for each manufacturer, and dose rate constant values. Note that for a given source type, the % change in \( \Lambda \) from the 1999 value is not necessarily equal to the average % change in air-kerma strength due the 1999 NIST WAFAC anomaly because some of the \( \Lambda \) values were calculated based on air-kerma strength measurements of a single seed.

<table>
<thead>
<tr>
<th>Manufacturer and source type</th>
<th>NIST date used by ADCL and NIST as standard</th>
<th>( c_{\text{CN/}}^\Lambda ) [cGy\cdot h^{-1}\cdot U^{-1}]</th>
<th>% difference in ( \Lambda ) from 1999 value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amersham 6702</td>
<td>( ^{125}\text{I} ) April 15, 1998</td>
<td>1.036</td>
<td>N/A</td>
</tr>
<tr>
<td>Amersham 6711</td>
<td>( ^{125}\text{I} ) April 15, 1998</td>
<td>0.965</td>
<td>N/A</td>
</tr>
<tr>
<td>Best Industries 2301</td>
<td>( ^{125}\text{I} ) August 18, 2000</td>
<td>1.018</td>
<td>+3.3%</td>
</tr>
<tr>
<td>NASI MED3631-A/M</td>
<td>( ^{125}\text{I} ) June 30, 2001</td>
<td>1.036</td>
<td>+1.0%</td>
</tr>
<tr>
<td>Bebig/Theragenics I25 S06</td>
<td>( ^{125}\text{I} ) January 27, 2001</td>
<td>1.012</td>
<td>+2.2%</td>
</tr>
<tr>
<td>Imagyn IS-12501</td>
<td>( ^{125}\text{I} ) October 21, 2000</td>
<td>0.940</td>
<td>+3.5%</td>
</tr>
<tr>
<td>Theragenics 200</td>
<td>( ^{103}\text{Pd} ) July 8, 2000</td>
<td>0.686</td>
<td>+4.0%</td>
</tr>
<tr>
<td>NASI MED3633</td>
<td>( ^{103}\text{Pd} ) April 23, 2001</td>
<td>0.688</td>
<td>+4.3%</td>
</tr>
</tbody>
</table>
Per ICRU 38, LDR sources used for brachytherapy have dose rate range at prescription depth

0%  1. 0.4 to 2.0 Gy per hr

0%  2. 0.4 to 4.0 Gy per hr

0%  3. Over 12 Gy per hr

0%  4. Less than 12 Gy per hr but more than 2.0 Gy per hr

0%  5. Less than 12 Gy per hr but more than 3.0 Gy per hr
Per ICRU 38, LDR sources used for brachytherapy have dose rate range at prescription depth

- **0%** 1. **0.4 to 2.0 Gy per hr**
- **0%** 2. **0.4 to 4.0 Gy per hr**
- **0%** 3. **Over 12 Gy per hr**
- **0%** 4. **Less than 12 Gy per hr but more than 2.0 Gy per hr**
- **0%** 5. **Less than 12 Gy per hr but more than 3.0 Gy per hr**

ICRU 38: Dose and Volume Specifications for Reporting Intracavitary Therapy in Gynecology, 1985
For I-125 prostate implant, 90% of absorbed dose is delivered in days?

0%  1. In the first day after implant
0%  2. In less than 30 days since implant
0%  3. In about 60 days since implant
0%  4. In about 30 days since implant
0%  5. In about 200 days since implant
For I-125 prostate implant, 90% of absorbed dose is delivered in days?

0% 1. In the first day after implant
0% 2. In less than 30 days since implant
0% 3. In about 60 days since implant
0% 4. In about 30 days since implant
0% 5. **In about 200 days since implant**

*Rivard et al. Brachytherapy, 6: 34-37, 2007*
Talk Objectives

• Describe General Sealed Source Brachytherapy Applications
• **Summarize NRC Rulings**
• Describe Release Methods for LDR sources
PART 35—MEDICAL USE OF BYPRODUCT MATERIAL

Subpart A—General Information
35.1 Purpose and scope.
35.2 Definitions.
35.3 Maintenance of records.
35.4 Provisions for the protection of human research subjects.
35.5 FDA, other Federal, and State requirements.
35.8 Information collection requirements: OMB approval.
35.10 Implementation.
35.11 License required.
35.12 Application for license, amendment, or renewal.
35.13 License amendments.
35.14 Notifications.
35.15 Exemptions regarding Type A specific licenses of broad applicability.
35.16 License issuance.
35.19 Specific exemptions.

Subpart B—General Administrative Requirements
35.24 Authority and responsibilities for the radiation protection program.
35.26 Radiation protection program changes.
35.27 Supervision.

Subpart C—General Technical Requirements
35.60 Possession, use, and calibration of instruments used to measure the activity of unsealed byproduct material.
35.61 Calibration of survey instruments.
35.63 Determination of dosages of unsealed byproduct material for medical use.
35.65 Authorization for calibration, transmission, and reference sources.
35.67 Requirements for possession of sealed sources and brachytherapy sources.
35.69 Labeling of vials and syringes.
35.70 Surveys of ambient radiation exposure rate.
35.75 Release of individuals containing unsealed byproduct material or implants containing byproduct material.
35.80 Provision of mobile medical service.
35.92 Decay-in-storage.
§ 35.75 Release of individuals containing unsealed byproduct material or implants containing byproduct material.

(a) A licensee may authorize the release from its control of any individual who has been administered unsealed byproduct material or implants containing byproduct material if the total effective dose equivalent to any other individual from exposure to the released individual is not likely to exceed 5 mSv (0.5 rem).\(^1\)

(b) A licensee shall provide the released individual, or the individual’s parent or guardian, with instructions, including written instructions, on actions recommended to maintain doses to other individuals as low as is reasonably achievable if the total effective dose equivalent to any other individual is likely to exceed 1 mSv (0.1 rem). If the total effective dose equivalent to a nursing infant or child could exceed 1 mSv (0.1 rem) assuming there were no interruption of breast-feeding, the instructions must also include—

(1) Guidance on the interruption or discontinuation of breast-feeding; and

(2) Information on the potential consequences, if any, of failure to follow the guidance.

(c) A licensee shall maintain a record of the basis for authorizing the release of an individual in accordance with § 35.2075(a).

(d) The licensee shall maintain a record of instructions provided to a breast-feeding female in accordance with § 35.2075(b).


\(^1\) The current revision of NUREG-1556, Vol. 9, “Consolidated Guidance About Materials Licenses: Program-Specific Guidance About Medical Licenses” describes methods for calculating doses to other individuals and contains tables of activities not likely to cause doses exceeding 5 mSv (0.5 rem).
10 CFR 35.75

“Release of individuals containing unsealed byproduct material or implants containing byproduct material”
10 CFR 35.75
Release Dose Limit

A licensee may authorize the release from its control of any individual who has been administered unsealed byproduct material or implants containing byproduct material if the total effective dose equivalent (TEDE) to any other individual from exposure to the released individual is not likely to exceed 5 mSv (500 mrem).*

*NUREG–1556, Vol. 9, "Consolidated Guidance About Materials Licenses: Program-Specific Guidance About Medical Licenses"
A licensee shall provide the released individual, or the individual's parent or guardian, with instructions:

including written instructions, on actions recommended to maintain doses to other individuals as low as is reasonably achievable if the TEDE to any other individual is likely to exceed 1 mSv (100 mrem).
10 CFR 35.75
Nursing Infant or Child Ruling

If TEDE to a nursing infant or child could exceed 1 mSv (100 mrem) assuming there were no interruption of breast-feeding, the instructions must also include:

(1) Guidance on the interruption or discontinuation of breast-feeding; and

(2) Information on the potential consequences, if any, of failure to follow the guidance.

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A licensee shall maintain a record of the basis for authorizing the release of an individual in accordance with § 35.2075(a).

The licensee shall maintain a record of instructions provided to a breast-feeding female in accordance with § 35.2075(b).
Talk Objectives

• Describe General Sealed Source Brachytherapy Applications
• Summarize NRC Rulings
• Describe Release Methods for LDR sources for permanent implants (prostate)
Calculation of release limits following implant brachytherapy

Consolidated Guidance About Materials Licenses

Program-Specific Guidance About Medical Use Licenses

Final Report

Date Completed: January 2008
Date Published: January 2008

Prepared by
D. B. Howe, M. Beardsley, S. R. Bakhsh

Office of Federal and State Materials and Environmental Management Programs
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
APPENDIX U

Model Procedure for Release of Patients or Human Research Subjects Administered Radioactive Materials
Release Equation

The activity at which patients could be released was calculated by using, as a starting point, the method discussed in the National Council on Radiation Protection and Measurements (NCRP) Report No. 37, “Precautions in the Management of Patients Who Have Received Therapeutic Amounts of Radionuclides.” This report uses the following equation to calculate the exposure until time \( t \) at a distance \( r \) from the patient:

Equation U.1:

\[
D(t) = \frac{34.6 \Gamma Q_0 T_p (1 - e^{-0.693t/T_p})}{r^2}
\]

where:
- \( D(t) \) = Accumulated exposure at time \( t \), in roentgens
- \( 34.6 \) = Conversion factor of 24 hrs/day times the total integration of decay (1.44)
- \( \Gamma \) = Specific gamma ray constant for a point source, R/mCi·hr at 1 cm
- \( Q_0 \) = Initial activity of the point source in millicuries, at the time of the release
- \( T_p \) = Physical half-life in days
- \( r \) = Distance from the point source to the point of interest, in centimeters
- \( t \) = Exposure time in days.

*The dose to an individual likely to receive the highest dose from exposure to the patient is taken to be the dose to total decay \( (1 - e^{-0.693t/T_p}) \) is set equal to 1.
*It is assumed that 1 R is equal to 10 mSv (1 rem).
Implants with radionuclides with a physical half-life greater than 1 day: Use Equation U.2

\[ D(\infty) = \frac{34.6 \ Gamma \ Q_0 \ T_p \ (0.25)}{(100 \ cm)^2} \]

Eq. (U2)

It is assumed that the individual likely to receive the highest dose from exposure to the patient would receive a dose of 25% of the dose to total decay (0.25 in Equation U.2), at a distance of 1 meter.*

*Selection of 25% of the dose to total decay at 1 meter for estimating the dose is based on measurements discussed in the supporting regulatory analysis that indicate the dose calculated using an occupancy factor, \( E \), of 25% at 1 meter is conservative in most normal situations.
### Table U.5 Half-Lives and Exposure Rate Constants of Radionuclides Used in Medicine

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Physical Half-Life (days)</th>
<th>Exposure Rate Constant (R/mCi-h at 1 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag-111</td>
<td>7.45</td>
<td>0.15</td>
</tr>
<tr>
<td>Au-198</td>
<td>2.696</td>
<td>2.3</td>
</tr>
<tr>
<td>Cr-51</td>
<td>27.704</td>
<td>0.16</td>
</tr>
<tr>
<td>Cu-64</td>
<td>0.529</td>
<td>1.2</td>
</tr>
<tr>
<td>Cu-67</td>
<td>2.578</td>
<td>0.58</td>
</tr>
<tr>
<td>Ga-67</td>
<td>3.261</td>
<td>0.753</td>
</tr>
<tr>
<td>I-123</td>
<td>0.55</td>
<td>1.61</td>
</tr>
<tr>
<td>I-125</td>
<td>60.14</td>
<td>1.42</td>
</tr>
<tr>
<td>I-125 implant</td>
<td>60.14</td>
<td>1.114</td>
</tr>
<tr>
<td>I-131</td>
<td>8.04</td>
<td>2.2</td>
</tr>
<tr>
<td>In-111</td>
<td>2.83</td>
<td>3.21</td>
</tr>
<tr>
<td>Ir-192 implant</td>
<td>74.02</td>
<td>4.594</td>
</tr>
<tr>
<td>P-32</td>
<td>14.29</td>
<td>NA^2</td>
</tr>
<tr>
<td>Pd-103 implant</td>
<td>16.96</td>
<td>0.865</td>
</tr>
<tr>
<td>Re-186</td>
<td>3.777</td>
<td>0.2</td>
</tr>
<tr>
<td>Re-188</td>
<td>0.708</td>
<td>0.26</td>
</tr>
<tr>
<td>Se-47</td>
<td>3.351</td>
<td>0.56</td>
</tr>
<tr>
<td>Se-75</td>
<td>119.8</td>
<td>2</td>
</tr>
<tr>
<td>Sn-117m</td>
<td>13.61</td>
<td>1.48</td>
</tr>
<tr>
<td>Sr-89</td>
<td>50.5</td>
<td>NA^2</td>
</tr>
<tr>
<td>Tc-99m</td>
<td>0.251</td>
<td>0.756</td>
</tr>
<tr>
<td>Tl-201</td>
<td>3.044</td>
<td>0.447</td>
</tr>
<tr>
<td>Yb-169</td>
<td>32.01</td>
<td>1.83</td>
</tr>
<tr>
<td>Yb-169</td>
<td>32.01</td>
<td>1.83</td>
</tr>
</tbody>
</table>

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**Footnotes for Table U.5**


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\[ X = \Gamma_{\text{isotope}} A \frac{1}{d^2} \]

\[ S_k = X \cdot d^2 \cdot \frac{W}{e} \]
• For brachy implants use max dose rate method to release
• Assumed physical half life only
• Occupancy factor of 0.25 at 1 meter for physical half-lives greater than 1 day
• No shielding by tissue assumed

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>COLUMN 1 Activity At or Below Which Patients May Be Released (GBq)</th>
<th>COLUMN 1 Activity At or Below Which Patients May Be Released (mCi)</th>
<th>COLUMN 2 Dose Rate at 1 Meter At or Below Which Patients May Be Released (mSv/hr)</th>
<th>COLUMN 2 Dose Rate at 1 Meter At or Below Which Patients May Be Released (mrem/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag-111</td>
<td>19</td>
<td>520</td>
<td>0.08</td>
<td>8</td>
</tr>
<tr>
<td>Au-198</td>
<td>3.5</td>
<td>93</td>
<td>0.21</td>
<td>21</td>
</tr>
<tr>
<td>Cs-137</td>
<td>4.8</td>
<td>130</td>
<td>0.02</td>
<td>2</td>
</tr>
<tr>
<td>Cu-64</td>
<td>8.4</td>
<td>230</td>
<td>0.27</td>
<td>27</td>
</tr>
<tr>
<td>Cu-67</td>
<td>14</td>
<td>390</td>
<td>0.22</td>
<td>22</td>
</tr>
<tr>
<td>Ga-67</td>
<td>8.7</td>
<td>240</td>
<td>0.18</td>
<td>18</td>
</tr>
<tr>
<td>I-123</td>
<td>6</td>
<td>160</td>
<td>0.26</td>
<td>26</td>
</tr>
<tr>
<td>I-125</td>
<td>0.25</td>
<td>7</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>I-125 implant</td>
<td>0.33</td>
<td>9</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>I-131</td>
<td>1.2</td>
<td>33</td>
<td>0.07</td>
<td>7</td>
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<tr>
<td>In-111</td>
<td>2.4</td>
<td>64</td>
<td>0.2</td>
<td>20</td>
</tr>
<tr>
<td>Ir-192 implant</td>
<td>0.074</td>
<td>2</td>
<td>0.008</td>
<td>0.8</td>
</tr>
<tr>
<td>P-32</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Pd-103 implant</td>
<td>1.5</td>
<td>40</td>
<td>0.03</td>
<td>3</td>
</tr>
<tr>
<td>Re-186</td>
<td>28</td>
<td>770</td>
<td>0.15</td>
<td>15</td>
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<tr>
<td>Re-188</td>
<td>29</td>
<td>790</td>
<td>0.2</td>
<td>20</td>
</tr>
<tr>
<td>Sc-47</td>
<td>11</td>
<td>310</td>
<td>0.17</td>
<td>17</td>
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<tr>
<td>Se-75</td>
<td>0.089</td>
<td>2</td>
<td>0.005</td>
<td>0.5</td>
</tr>
<tr>
<td>Sm-153</td>
<td>26</td>
<td>700</td>
<td>0.3</td>
<td>30</td>
</tr>
<tr>
<td>Sn-117m</td>
<td>1.1</td>
<td>29</td>
<td>0.04</td>
<td>4</td>
</tr>
<tr>
<td>Sr-89</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Te-99m</td>
<td>28</td>
<td>760</td>
<td>0.58</td>
<td>58</td>
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<tr>
<td>Tl-201</td>
<td>16</td>
<td>430</td>
<td>0.19</td>
<td>19</td>
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<tr>
<td>Y-90</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Yb-169</td>
<td>0.37</td>
<td>10</td>
<td>0.02</td>
<td>2</td>
</tr>
</tbody>
</table>

Footnotes for Table U-1

† The activity values were computed based on 5 millisieverts (0.5 rem) total effective dose equivalent.
* If the release is based on the dose rate at 1 meter in Column 2, the licensee must maintain a record as required by 10 CFR 35.75(c), because the measurement includes shielding by tissue. See Item U.3.1, “Records of Release,” for information on records.
Cs-131 is not in Table U1

**Cs–131**: $T_{1/2} = 9.7$ days, $E = 0.25$

\[
D(\infty) = 0.5 \text{rem}(5 \text{mSv}): X_{1m} = \frac{D(\infty)}{34.6 \times 9.7 \text{ days} \times 0.25} = 6 \text{ mrem/hr (0.06 mSv/hr)}
\]

Where,
\[
X_{1m} = \Gamma Q (1 \text{cm/100cm})^2
\]
A person receiving the highest dose due to exposure from a permanent prostate implant patient is assumed in equation U.1 (Release Equation) to be the dose to total decay when

0% 1. $1 - e^{-0.693t/T_p}$ is set equal to 0
0% 2. $1 - e^{-0.693t/T_p}$ is set equal to 1
0% 3. $1 - e^{-0.693t/T_p}$ is set equal to 10
0% 4. $1 - e^{-0.693t/T_p}$ is set equal to 100
0% 5. $1 - e^{-0.693t/T_p}$ is set equal to -1
A person receiving the highest dose due to exposure from a permanent prostate implant patient is assumed in equation U.1 (Release Equation) to be the dose to total decay when

0% 1. $1-e^{(-0.693t/Tp)}$ is set equal to 0
0% 2. $1-e^{(-0.693t/Tp)}$ is set equal to 1
0% 3. $1-e^{(-0.693t/Tp)}$ is set equal to 10
0% 4. $1-e^{(-0.693t/Tp)}$ is set equal to 100
0% 5. $1-e^{(-0.693t/Tp)}$ is set equal to -1

Reference NUREG 1556, App U, p U-2
The standard occupancy factor for the most exposed person's being in the presence of an I-125 prostate implant patient at a distance of one meter is

0% 1. 0.125 (3 hours a day)
0% 2. 0.25 (6 hours a day)
0% 3. 0.42 (10 hours a day)
0% 4. 0.75 (18 hours a day)
0% 5. 1.0 (24 hours a day)
The standard occupancy factor for the most exposed person's being in the presence of an I-125 prostate implant patient at a distance of one meter is

0%  1. 0.125 (3 hours a day)
0%  2. 0.25 (6 hours a day)  **bold**
0%  3. 0.42 (10 hours a day)
0%  4. 0.75 (18 hours a day)
0%  5. 1.0 (24 hours a day)

Reference NUREG 1556, App U, p U-3
Release Criteria for Brachytherapy

- Release of patients based on measured dose rate
- 10 CFR 35.75(c) requires a record because the release is based on considering shielding by tissue
- Use dose rate limits in Table U2 to determine when instructions must be given.
Note: NRC does not intend to enforce patient compliance with the instructions nor is it the licensee’s responsibility to do so.
Content of Instructions

• Be specific to the type of treatment given
  – such as permanent implants

• Include the name of a knowledgeable contact person.

A small radioactive source has been placed (implanted) inside your body. The source is actually many small metallic pellets or seeds, which are each about 1/3 to 1/4 of an inch long, similar in size and shape to a grain of rice. To minimize exposure to radiation to others from the source inside your body, you should do the following for _______ days.

• Stay at a distance of _____ feet from _____.
• Maintain separate sleeping arrangements.
• Minimize time with children and pregnant women.
• Do not hold or cuddle children.
• Avoid public transportation.
• Examine any bandages or linens that come into contact with the implant site for any pellets or seeds that may have come out of the implant site.
• If you find a seed or pellet that falls out:
  — Do not handle it with your fingers. Use something like a spoon or tweezers to place it in a jar or other container that you can close with a lid.
  — Place the container with the seed or pellet in a location away from people.
  — Notify __________________________ at telephone number ________________.

F. Mourtada, Ph.D.
Records of Release

• For Immediate Release of a Patient Based on Measured Dose Rate:
  – The results of the measurement, the specific survey instrument used, and the name of the individual performing the survey.

F. Mourtada, Ph.D.
## Table U.4 Summary of Release Criteria, Required Instructions to Patients, and Records to Be Maintained

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients, including patients who are breast-feeding an infant or child</td>
<td>Administered activity</td>
<td>Administered activity ≤ Column 1 of Table U.1</td>
<td>Yes – if administered activity &gt; Column 1 of Table U.2</td>
<td>No</td>
</tr>
<tr>
<td>Retained activity</td>
<td>Retained activity ≤ Column 1 of Table U.1</td>
<td>Yes – if retained activity &gt; Column 1 of Table U.2</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Measured dose rate</td>
<td>Measured dose rate ≤ Column 2 of Table U.1</td>
<td>Yes – if dose rate &gt; Column 2 of Table U.2</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Patient-specific calculations</td>
<td>Calculated dose ≤ 5 mSv (0.5 rem)</td>
<td>Yes – if calculated dose &gt; 1 mSv (0.1 rem)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Patients who are breast-feeding an infant or child</td>
<td>All the above bases for release</td>
<td>Additional instructions required if: Administered activity &gt; Column 1 of Table U.3 or Licensee calculated dose from breast-feeding &gt; 1 mSv (0.1 rem) to the infant or child</td>
<td>Records that instructions were provided are required if: Administered activity &gt; Column 2 of Table U.3 or Licensee calculated dose from continued breast-feeding &gt; 5 mSv (0.5 rem) to the infant or child</td>
<td></td>
</tr>
</tbody>
</table>
• NUREG1556 is overly conservative in its assumption in the case of the common LDR sources ($^{131}$Cs, $^{125}$I, and $^{103}$Pd).

• The low mean energies cause the measured exposure rate (R/hr) to greatly exceed the “actual” effective dose equivalent rate (Sv/hr) due to tissue shielding of exposed individual.

• The effective dose equivalent rate may also be reduced by self-shielding by the patients themselves.

F. Mourtada, Ph.D.
PATIENT RELEASE CRITERIA FOR LOW DOSE RATE BRACHYTHERAPY IMPLANTS

Dale E. Boyce* and Michael A. Sheetz†

• I-125 mesh implant along chest wall special case could exceed limits in NUREG 1556 Table U1

• Section U1.3 of NUREG 1556 permits patient-specific dose calculations

• See details in paper

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F. Mourtada, Ph.D.
Remember

• Determination of release rests with the authorized user physician.
• Communicating the radiation safety dose reduction instructions to the patient rests with the authorized user physician.
• Records of the basis for authorizing patient release shall be maintained for a minimum of 3 years.
• Records that dose reduction and/or breast-feeding discontinuation instructions were provided where applicable shall also be maintained.
What is the minimum information need to be recorded in the release record for prostate implant patient?

0% 1. The specific survey instrument used, and the name of the individual performing the survey
0% 2. The results of the measurement, and the name of the individual performing the survey
0% 3. The results of the measurement, the specific survey instrument used, and the name of the individual performing the survey.
0% 4. The results of the measurement, the specific survey instrument used, and the name of the OR nurse
0% 5. The results of the measurement, the specific survey instrument used, and the name of the authorized user that performed the procedure.
What is the minimum information need to be recorded in the release record for prostate implant patient?

1. The specific survey instrument used, and the name of the individual performing the survey
2. The results of the measurement, and the name of the individual performing the survey
3. The results of the measurement, the specific survey instrument used, and the name of the individual performing the survey.
4. The results of the measurement, the specific survey instrument used, and the name of the OR nurse
5. The results of the measurement, the specific survey instrument used, and the name of the authorized user that performed the procedure.

Reference NUREG 1556, App U, p U-13