Brachytherapy Facility Design

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REMOTE
AFTERLOADING
TECHNOLOGY
Figure 1. Of 45 articles reporting results for 10 anatomic sites, the percentage of articles by site.
Factors in Facility Design

(a) treatment programs are highly dependent on specific physicians and their interests and skills;
(b) The major goal of HDR brachytherapy remains to achieve, with acceptable complication rates, cure rates equivalent to those achieved with LDR brachytherapy;
(c) business plan projections (conjectures) about potential patient numbers are optimistically high by a factor of two to three;
(d) brachytherapy is, more labor intensive per case than external beam procedures; and
(e) a facility will likely last longer than either the physicist designing it or the radiation oncologist using it.
### Table 1. Dose Equivalents (DE) and Area Designations for Protection against Radiation

<table>
<thead>
<tr>
<th>Member Designation</th>
<th>Dose Equivalent</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Public</td>
<td>1 mSv Annually</td>
<td>5 mSv allowed via prior regulatory authorization with demonstrated need; visitors per authorized user approval</td>
</tr>
<tr>
<td>General Public</td>
<td>0.02 mSv in any one hour</td>
<td>In unrestricted area; <em>not</em> 0.02 mSv per hour</td>
</tr>
<tr>
<td>Embryo/Fetus</td>
<td>5 mSv over gestation period</td>
<td>Avoid substantial variations above uniform monthly exposure rate</td>
</tr>
<tr>
<td>Occupational Adults</td>
<td>50 mSv Annually</td>
<td>Deep DE (DDE) at 1 cm; excludes planned specials</td>
</tr>
<tr>
<td>(External Whole Body)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational Adult</td>
<td>150 mSv Annually</td>
<td>Deep DE (DDE) at 1 cm</td>
</tr>
<tr>
<td>(Eye Lens)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational Adult</td>
<td>500 mSv Annually</td>
<td>Shallow DE at 7 μm over 1 cm²; knees &amp; below; elbows &amp; below</td>
</tr>
<tr>
<td>(Skin &amp; Extremities)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational Minors</td>
<td>0.1 DE allowed adults</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area Designation</th>
<th>Limit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted area</td>
<td>No restriction to access</td>
<td></td>
</tr>
<tr>
<td>Radiation Area</td>
<td>0.05 mSv in one hour at 30 cm from radiation source or surface radiation penetrates</td>
<td>Accessible to individuals; “Caution” signs may be used</td>
</tr>
<tr>
<td>High Radiation Area</td>
<td>1 mSv in one hour at 30 cm from radiation source or surface radiation penetrates</td>
<td>Controlled locked access; alarmed area; “Caution” or “Danger” signs may be used</td>
</tr>
<tr>
<td>Very High Radiation Area</td>
<td>5 Gy (5 Sv) in one hour at 100 cm from radiation source or surface radiation penetrates</td>
<td>Controlled locked access; alarmed area; deliberate entry; “Grave Danger” sign used</td>
</tr>
</tbody>
</table>

*See 10 CFR 20 “Standards for Protection Against Radiation” for complete definitions.  
**Limited comments only; for a full description see 10 CFR 20.*
<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Features</strong></td>
<td>Accessible but reasonably isolated (away from public and employee work areas); large room with solid concrete walls; strong, locked, wide door (to accommodate transportable HDR RAU) (with warnings and emergency contact number postings) with automatic closer</td>
</tr>
<tr>
<td><strong>Communications</strong></td>
<td>Telephone (outside line for immediate vendor contact); computer (and printer); computer jacks; bulletin boards for regulatory postings</td>
</tr>
<tr>
<td><strong>Interior Features</strong></td>
<td>Well lit; water and cleaning supplies, sink with protected drain (mesh screening); workbenches with cabinet drawer storage; adequate electrical outlets above the workbenches; wall pegboards with hooks, bulletin boards; adjustable shelves; seamless tile floor; “Radioactive materials” waste can; film storage in lead bins</td>
</tr>
<tr>
<td><strong>Tools</strong></td>
<td>Conventional shop tools; flashlights, source handling tools, tweezers, forceps, etc.</td>
</tr>
<tr>
<td><strong>Source Storage</strong></td>
<td>Locked lead safe(s) or lead well; lead “L” blocks, lighted magnification lamp; temporary lead “pigs” for source sorting during preparation</td>
</tr>
<tr>
<td><strong>QA Equipment</strong></td>
<td>Area radiation monitor; radiation detection (NaI (Tl), GM) counters, survey meters; wipe test equipment (if needed); well-ionization chamber and electrometer; autoradiography equipment; barometer, thermometer</td>
</tr>
<tr>
<td><strong>Transport Equipment</strong></td>
<td>Shielded source transport containers; carts</td>
</tr>
<tr>
<td><strong>Empty Container Storage</strong></td>
<td>Cabinet, shelves to storage reusable or disposal containers, empty lead “pigs”</td>
</tr>
<tr>
<td><strong>Work Area</strong></td>
<td>Computer area; binders, blank forms, office equipment and supplies, calculators</td>
</tr>
<tr>
<td><strong>Applicator Preparation and Storage</strong></td>
<td>Applicators and accessories (by type) stored in large labeled clear plastic boxes in cabinets or on shelves</td>
</tr>
<tr>
<td><strong>Everything Else</strong></td>
<td>All those favorite “gadgets” that you use in your source room!</td>
</tr>
</tbody>
</table>
Figure 2. (a) A homemade portable bedside shield featuring a slant design and an adjustable step. (b) A commercial radiation shield with adjustable height.
<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Concrete</th>
<th>Steel</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt-60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCRP 40 &amp; 49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.6</td>
<td>6.9</td>
<td>4.0</td>
</tr>
<tr>
<td>IPEM 75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.6</td>
<td>No data given</td>
<td>4.0</td>
</tr>
<tr>
<td>IPSM 46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>No data given</td>
<td>No data given</td>
<td>4.6</td>
</tr>
<tr>
<td>Boutroux-Jaffré</td>
<td>22</td>
<td>6.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Cesium-137</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCRP 40 &amp; 49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.7</td>
<td>5.3</td>
<td>2.1</td>
</tr>
<tr>
<td>IPEM 75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.7</td>
<td>No data given</td>
<td>2.1</td>
</tr>
<tr>
<td>IPSM 46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>No data given</td>
<td>No data given</td>
<td>2.2</td>
</tr>
<tr>
<td>Boutroux-Jaffré</td>
<td>17.5</td>
<td>5</td>
<td>2.2</td>
</tr>
<tr>
<td>Ir-192</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCRP 40 &amp; 49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.7</td>
<td>4.3</td>
<td>2.0</td>
</tr>
<tr>
<td>IPEM 75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.3</td>
<td>No data given</td>
<td>1.5</td>
</tr>
<tr>
<td>IPSM 46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>No data given</td>
<td>No data given</td>
<td>1.2</td>
</tr>
<tr>
<td>Boutroux-Jaffré</td>
<td>14.7</td>
<td>4.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Au-198</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCRP 40 &amp; 49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.5</td>
<td>No data given</td>
<td>1.1</td>
</tr>
<tr>
<td>IPEM 75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.5</td>
<td>No data given</td>
<td>1.1</td>
</tr>
<tr>
<td>IPSM 46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>No data given</td>
<td>No data given</td>
<td>1.0</td>
</tr>
<tr>
<td>Boutroux-Jaffré</td>
<td>No data given</td>
<td>No data given</td>
<td>No data given</td>
</tr>
</tbody>
</table>

<sup>a</sup> Approximate values obtained with large attenuation.

<sup>b</sup> No explicit statement that data is broad beam data.

<sup>c</sup> McKenzie et al. (1986).
<table>
<thead>
<tr>
<th>Patient lateral half-pelvic (r) (cm)</th>
<th>Effective transmission factor K(r) for $^{192}$Ir (Glasgow 2002b)</th>
<th>Effective transmission factor K(r) for $^{137}$Cs (Glasgow 1985)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>12</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>14</td>
<td>0.64</td>
<td>0.62</td>
</tr>
<tr>
<td>16</td>
<td>0.55</td>
<td>0.59</td>
</tr>
<tr>
<td>18</td>
<td>0.50</td>
<td>0.55</td>
</tr>
<tr>
<td>20</td>
<td>0.44</td>
<td>0.50</td>
</tr>
<tr>
<td>22</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>24</td>
<td>0.36</td>
<td>0.41</td>
</tr>
<tr>
<td>25</td>
<td>0.34</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Figure 5a. A small second floor hospital room renovated to house an LDR remote afterloading device for gynecologic treatments. This room features an internal storage closet in which the LDR unit is stored when not in use. A 1.3 cm (1/2 in.) thick lead projection shield beneath the bed shields the area below; a 0.6 cm (1/4 in.) thick lead shield (not shown) is suspended from the ceiling above. Note the compressed air supply, dedicated electric outlet, radiation monitor, remote control and telephone, power-assisted door opener, 1.3 cm (1/2 in.) lead walls shields, and supplemental lights overhead.
Figure 4. A dedicated LDR remote afterloading room with a small maze and viewing window. (Modified from B.M. Wilson et al., Med Phys 13: 608. © 1986, with permission from AAPM. Courtesy J. D. Bourland.)
Figure 5b. Adjacent closet houses the Selectron-LDR, a low dose rate remote afterloading device for gynecologic treatments. Note the emergency source retrieval container.
<table>
<thead>
<tr>
<th>Program</th>
<th>Square Foot Costs</th>
<th>Facility Costs for 600 sq ft&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>New construction costs for medical building without shielded areas, i.e., offices, etc.</td>
<td>$100</td>
<td></td>
</tr>
<tr>
<td>For an HDR suite for minor procedures, i.e., Class B operating room, add $400 per sq ft</td>
<td>$500</td>
<td>$300,000</td>
</tr>
<tr>
<td>For an HDR suite for major procedures, i.e., Class C operating room, add $100 per sq. ft.</td>
<td>$600</td>
<td>$360,000</td>
</tr>
</tbody>
</table>

<sup>a</sup>Calendar Year 2004.

<sup>b</sup>Assume 400 sq ft for treatment area and 200 sq ft console and support areas.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mobile</th>
<th>Low End</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicators</td>
<td>$100K–Dupl</td>
<td>$50K–Basic</td>
<td>$100K–Many</td>
</tr>
<tr>
<td>Table</td>
<td>$35K</td>
<td>$35K</td>
<td>$75K</td>
</tr>
<tr>
<td>Van</td>
<td>$25K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics QA</td>
<td>$25K</td>
<td>$25K</td>
<td>$50K</td>
</tr>
<tr>
<td>Image System</td>
<td>Use Existing</td>
<td>$120K C-Arm</td>
<td>$600K IBU</td>
</tr>
<tr>
<td>Vault</td>
<td>Use Existing</td>
<td>$175K–Sm</td>
<td>$235K–Lg</td>
</tr>
<tr>
<td>Totals</td>
<td>$310K–$460K</td>
<td>$655K–$815K</td>
<td>$1325K–$1525K</td>
</tr>
</tbody>
</table>
### Table 6. Equipment List: Dedicated HDR Remote Afterloading/Minor Procedures Suite

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Location/Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote afterloader storage and treatment location;</td>
<td>Anesthesia area: Medical gases and vacuum; designated location and electrical power for patient monitoring equipment; remote displays</td>
</tr>
<tr>
<td>source guide tubes; in-room radiation detector; check source</td>
<td>Operating room/procedures light</td>
</tr>
<tr>
<td>Remote afterloader control console</td>
<td>Applicator storage and medical and nursing supplies</td>
</tr>
<tr>
<td>Visual communications: 2 systems</td>
<td>Sink/scrub/gown/glove area</td>
</tr>
<tr>
<td>Audio communications</td>
<td>Treatment applicators</td>
</tr>
<tr>
<td>Secure locked door; door interlock</td>
<td>Applicator positioning clamp: Integral with procedures table</td>
</tr>
<tr>
<td>Multiple position patient procedure table; x-ray compatible</td>
<td>Emergency off buttons at console, in maze, and in room</td>
</tr>
<tr>
<td>Overhead track-mounted radiography with X-ray generator and X-ray control console; or,</td>
<td>Emergency lighting; wall or ceiling mounted</td>
</tr>
<tr>
<td>Mobile C-arm x-ray unit with fluoroscopy; fiducial marker device</td>
<td>Emergency power for selected equipment: Audio, video, anesthesia patient monitoring, lighting, radiation detectors and indicators; remote afterloader</td>
</tr>
<tr>
<td>Emergency recovery equipment and container; “Open source” sign, etc.</td>
<td>Patient monitors</td>
</tr>
<tr>
<td>Survey meters</td>
<td>Optional treatment planning workstation</td>
</tr>
<tr>
<td>Optional ultrasound imaging system</td>
<td></td>
</tr>
</tbody>
</table>
Figure 6. Dedicated intraoperative radiotherapy facility at the Regional Cancer Center at Baptist Hospital of Miami. The facility is also used as an HDR suite. [Reprinted from “Design and Implementation of a Program for High Dose Rate Brachytherapy” by P. V. Houdek, G. P. Glasgow, J. G. Schwade, and A. A. Abitbol in High Dose Rate Brachytherapy: A Textbook. S. Nag (ed.). Armonk, NY: Futura Publishing Co., © 1994, with permission from Blackwell Publishing.]
Figure 10. A dedicated “Class B” (minor procedures) HDR suite. (Loyola University Medical Center Outpatient Clinic, 2003)
Figure 11. A pre-fab HDR suite. (Courtesy Rick LeBlanc, NELCO, Woburn, MA.)
Figure 13. “On the road, again!” A movile HDR van. (Courtesy Plato Lee.)
Brachytherapy Facility Design

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Figure 12. An integrated brachytherapy unit.
(Courtesy, E. van ‘t Hooft, Nucletron International B.V.)
Figure 7. Dedicated HDR brachytherapy suite and OR at the U. of Miami’s Sylvester Comprehensive Cancer Center. The suite can be used for intraoperative procedures. [Reprinted from “Design and Implementation of a Program for High Dose Rate Brachytherapy” by P. V. Houdek, G. P. Glasgow, J. G. Schwade, and A. A. Abitbol in High Dose Rate Brachytherapy: A Textbook. S. Nag (ed.). Armonk, NY: Futura Publishing Co., © 1994, with permission from Blackwell Publishing.]