Introduction

• Definition of HDR brachytherapy.
• Rationale for HDR vs. conventional LDR.
• HDR program:
  – Preparation
  – Shielding, licensing
  – Acceptance and commissioning
  – QA – source exchange, daily…
  – Logistical issues
**NRC definition of “High dose-rate remote afterloader”:**

- A brachytherapy device that remotely delivers a dose rate in excess of 12 gray per hour to a point or surface where the dose is prescribed.

10 CFR 35.2

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**Comparison of HDR with Conventional LDR**

**Advantages**
- Reduced exposure to staff.
- Ability to shape dose cloud – dose optimization.
- Outpatient treatments.
- More stable positioning of applicator.
- Increased distance from normal tissue.
- Ability to immediately treat patients after surgery, do not have to order sources.

**Disadvantages**
- Relatively complicated treatment system – more interlocks, more QA.
- Compressed time frame for treatment delivery – could result in serious consequences.
- “Predicted” radiobiological disadvantages.
- Increased need for accurate dosimetric, anatomic and geometric information.
- Potential for VERY high exposure in case of unit malfunction.

Radionuclides that have been available as HDR Sources

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>$E_{\text{aver}}$ (MeV)</th>
<th>$T_{1/2}$</th>
<th>HVL$_{p90}$ (cm)</th>
<th>Specific Activity (Ci/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{60}$Co</td>
<td>1.17, 1.33</td>
<td>5.27 a</td>
<td>1.10</td>
<td>60</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>0.662</td>
<td>30.1 a</td>
<td>0.65</td>
<td>10</td>
</tr>
<tr>
<td>$^{192}$Ir*</td>
<td>0.38 (avg)</td>
<td>73.83 d</td>
<td>0.30</td>
<td>450</td>
</tr>
</tbody>
</table>

*Although $^{192}$Ir’s short half-life would seem to make it a disadvantage for use as an HDR source, this is more than compensated by its HVL and specific activity.

HDR Program Preparation

- Meeting of the key HDR players
  - Equipment purchase
  - Room design
- NRC Licensing
- Room preparation
- Acceptance testing and commissioning
- QA program
- Logistics plan and staff training
**Equipment**

- Involved parties must discuss equipment necessary to run and sustain an HDR practice.
  - HDR unit
  - Applicators
  - Treatment planning computer
  - Ancillary equipment – i.e. digitizer, film scanner
  - Dummy strands
  - Well chamber
  - Survey meter

**Afterloading Units**

- GammaMed Plus
  - Varian
  - 24 Channels
  - (Also available with 5 channels)
- microSelectron HDR
  - Nucletron
  - 18 Channels
- Varisource
  - Varian
  - 20 Channels
Applicators

- Involved parties should discuss expected patient population.
  - Gyn applicators – cylinders, tandem & ovoids, tandem & ring
  - Breast applicators – Mammosite, template
  - Template applicators – prostate and gyn

Gyn Applicators

- Single channel cylinder
- Multi channel cylinder

Varian Medical Systems – www.varian.com
**Gyn Applicators**

- **Tandem and Ovoids**
- **Tandem and Ring**

Varian Medical Systems – [www.varian.com](http://www.varian.com)
Nucletron – [www.nucletron.com](http://www.nucletron.com)

**Breast Applicators**

- **Kuske template.**
- **Interstitial treatment of breast.**
- **Mammosite.**
- **Used to treat lumpectomy site.**

Nucletron – [www.nucletron.com](http://www.nucletron.com)
Mammosite – [www.mammo.com](http://www.mammo.com)
**Template Applicators**

- MUPIT – Martínez Universal Perineal Interstitial Template.
- Used to treat vaginal and rectal cancer.
- Used to treat prostate cancer.

Nucletron – [www.nucletron.com](http://www.nucletron.com)

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**Room Design**

- Clinic must decide where the HDR unit will reside.
  - Linac vault vs. dedicated suite
  - Decision will be dictated by expected HDR load, finances and spatial constraints.
**Room Shielding**

\[ B = \frac{Pd^2}{WT} \]

- \( B \) – barrier transmission factor
- \( P \) – max permissible weekly dose
- \( d \) – distance from source to point of interest
- \( W \) – workload
- \( T \) – occupancy factor

\[ \#HVL = -\ln(B); \#TVL = -\log(B) \]

Dictated by the NCRP, 20 \( \mu \)Gy/hr. Aver # pt’s per week x air kerma rate @ 1 m.

**Calculation of Workload**

\[ W = \Gamma x f x A x t \]

\( \Gamma \) - exposure rate constant, the exposure rate (R/hr) at a point 1 cm from a 1 mCi point source.
\( f \) - roentgen-to-rad or the exposure-to-dose conversion factor
\( A \) – activity
\( t \) – total treatment time per week

Sample Calculation

- Design parameters:
  - Maximum source activity – 15 Ci
  - Weekly treatment time – 10 min/fx x 25 fx/wk = 250 min/wk = 4.17 hr/wk

- Source parameters:
  - $\Gamma_{Ir}$ – 0.469 R/Ci/hr @ 1 m
  - $f$ – 0.971 cGy/h

\[
W = \Gamma \times f \times A \times t = 0.469 \times \frac{R}{Ci \cdot hr} \times 0.971 \times \frac{cGy}{R} \times 15Ci \times 4.17 \frac{h}{wk}
\]

\[
= 28.5 \frac{cGy}{wk}
\]

occupancy factor (T):

<table>
<thead>
<tr>
<th>Location</th>
<th>Occupancy Factor (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full occupancy areas (areas occupied full-time by an individual), e.g., administrative or clerical offices; treatment planning areas, treatment control rooms, nurse stations, receptionist areas, attended waiting rooms, occupied space in nearby building</td>
<td>1</td>
</tr>
<tr>
<td>Adjacent treatment room, patient examination room adjacent to shielded vault</td>
<td>1/2</td>
</tr>
<tr>
<td>Corridors, employee lounges, staff rest rooms</td>
<td>1/3</td>
</tr>
<tr>
<td>Treatment vault doors</td>
<td>1/8</td>
</tr>
<tr>
<td>Public toilets, unattended vending rooms, storage areas, outdoor areas with seating, unattended waiting rooms, patient holding areas, attics, janitors' closets</td>
<td>1/20</td>
</tr>
<tr>
<td>Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), stairways, unattended elevators</td>
<td>1/40</td>
</tr>
</tbody>
</table>
**NRC Licensing**

- Types of license for medical use of byproduct material:
  - Specific license of limited scope
  - Specific license of broad scope


**Specific License of Limited Scope**

- Issued to private or group medical practices.
- Authorized users (AUs), authorized medical physicists (AMPs) must be specifically listed on license.

Specific License of Broad Scope

- Issued to institutions:
  - Experienced success operation under specific license of limited scope.
  - Demonstrate compliance with regulatory agencies.
  - Engaged in medical research and routine use of byproduct materials.


NRC Licensing

- According to 10 CFR 35, the licensee must provide:
  - Facility diagram – including shielding
  - Information regarding equipment
  - Training and experience of the RSO, AUs, and AMPs.
  - Radiation safety precautions and instructions
  - Methodology for measurement of dosage
  - Calibration, maintenance, and repair of instruments and equipment necessary for radiation safety
NUREG 1556

• For details and examples on how to apply or amend an existing license see NUREG 1556.

Room Preparation

• Before an HDR unit can be installed, one must verify:
  – Room shielding
  – Door interlocks are functional
  – Radiation detectors are available and functional
  – Sufficient number of outlets, conduits and power
  – Identified means in which unit, keys, TPS and room are secured
  – Shelves/drawers
Acceptance Testing and Commissioning

- HDR unit and treatment control system (software function, source position, source calibration, safety features, indicators,…)
- Treatment Planning Computer (dose calculation, source decay (if applicable), standard applicators, accessories such as digitizers, film scanners…)
- QA equipment (well chamber/electrometer, survey meters, QA jigs, length checkers, dummy strands,…)  
- Applicators! (parts inventory, assembly, condition, simulation with dummy strands pre-patient…)

Calculation of Total Dose

- Total dose is dependent on the position of source relative to point of interest and dwell times.
- TG-43 dose algorithm (review):

\[ D(r, \theta) = t \cdot S_k \cdot \Lambda \cdot \frac{G_L(r, \theta)}{G_L(r_o, \theta_o)} \cdot g_L(r) \cdot F(r, \theta) \]

\[ D_{\text{Total}} = \sum_{1}^{n} D(r_n, \theta_n) \]

- In planning system, can optimize dose based on distance or volume.

**Monthly QA & Quarterly Source Exchange**

- Source calibration (within 5% of manufacturer)
- Source position accuracy (within 1 mm)
- Safety checks (radiation detectors, interrupt/emergency buttons, battery backup, interlocks, dual x-ray operation, catheter length)
- Timer accuracy/linearity
- Applicator/transfer tube lengths and conditions


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**Daily QA**

- Functionality of safety interlocks
- A/V system
- Emergency equipment
- All Detectors & Survey meters functional
- Camera/intercom
- Timer accuracy
- Correct date, time, decay factor
- Integrity of applicators checked

From TG-59 - Principles of an HDR brachytherapy program design:

“HDR is often hectic since the time the applicator remains in the patient must be minimized, creating an environment in which errors and miscommunications easily occur.”

- Use written documentation.
- Develop formal procedures.
- Exploit redundancy.
- Exploit quality improvement techniques.
Logistics

• Where is equipment kept?
• Applicators: sterilization, need for duplicate applicators vs. time between cases, labeling, inventory
• Treatment planning: simple sim vs. CT planned, where will the TP station live?
• Where does patient stay between sim and treat?
• For subsequent fxs, how to verify applicator placement (resim or port film)
• Scheduling: How to time the treatments so that physicist and physician (therapist?) can all be present?
• What’s the therapists’ roll?
• Who is responsible for billing?

Treatment Specific QA

• Rx – Authorized User defines the target volume or point, selects dose and fractionation scheme and acceptable dose to normal structures. Physics/dosimetry must clarify and confirm intent, ensure that it is properly documented and develop a tx strategy.
• Treatment Planning – Physics/dosimetry will import patient and applicator info via CT scan, films or digitizer into TP computer, along with script info.
• QA of TP phase depends on difficulty of case, type of implant, type of simulation…
**Key to a successful program...**

- Teamwork
- Established flow
- Quality Assurance
- Documentation
- Experience

**Thank you!**