Low Dose Rate and Pulsed Dose Rate Afterloaders
UT MDACC Perspective

John Horton, Ann Lawyer, Firas Mourtada
Collaborators

• Patricia Eifel, MD
• Anuja Jhingran, MD
• Paula Berner, BS, CMD
• Mandy Cunningham, BS
• Teresa Bruno, BS, CMD
• Mitch Price, MS
• Kent Gifford, PhD
Conflicts of Interest

- Nucletron sponsored research agreement supports a portion of this research
- Transpire sponsored research agreement supports a portion of this research
Course Objectives

• After this lecture, the participant should be able to discuss
  - LDR and PDR remote afterloading units
  - Issues to address when changing to a new radioisotopes, e.g., $^{137}\text{Cs}$ to $^{192}\text{Ir}$, to treat a disease
  - Issues to address when changing afterloading techniques, e.g., manual to LDR or LDR to PDR
LDR Afterloaders

- UTMDACC – 4 Selectron LDR $^{137}$Cs afterloaders for gynecological cases
- Average 3 cases per week
- Principal replacement for $^{226}$Ra
- Manually afterloaded $^{137}$Cs sources for small number of cases
Selectron LDR Afterloader

- 4 channels
  - 1 for tandem
  - 1 for each ovoid
  - 1 spare
- 48 pellets, 2.5 mm dia.
- 20 active
  - 5mgRaeq (36.135 U) nominal
  - $^{137}$Cs on surface of 1.5mm ceramic (borosilicate) bead, 0.5mm SS encapsulation
- 28 inactive pellets
  - Ferromagnetic, 304 stainless steel
Selectron LDR Afterloaders

- 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
Radium to Cesium

- $^{226}$Ra tube sources, 22 mm PL, 14 mm AL
  - Sources spaced “uniformly” tip to flange
  - 3 mm spacers used, if required
  - Loadings w/o spacers, “sources” loading
  - Loadings w spacers, “inches” loading

- $^{137}$Cs tube sources, 20 mm PL, 13.5 mm AL
  - 2 mm spacers, “sources” loading
  - 5 mm spacers, “inches” loading
  - No spacers, “short sources” loading
Radium Tube Sources to Cesium Selectron Pellets in the Tandem

Note: each active pellet has a nominal activity of 5 mgRaeq
$^{226}$Ra to Selectron LDR Afterloaders

- $^{226}$Ra treatment plans historical tandem and ovoids treatments
- Selectron loadings for “same” dose distribution
- Tables translate $^{226}$Ra to Selectron, “sources” and “inches” tandem loadings
- MDACC ovoids - 33mm
LDR Afterloader Advantages

- Reduction of radiation exposure to personnel
- Reduction in rectal dose
- "Optimization" – variable geometry of active/inactive pellets
LDR Afterloaders Disadvantages

- Machine failure during pellet transfer
  - Air pressure
  - Power sags and surges
  - “out of round” pellets
- Visitors interrupt treatment, increase time patient in hospital
Facility Considerations

• Shielding
  - Maximum air kerma strength per hour
  - Maximum total air kerma strength per week
  - Uncontrolled areas - 1.0 mSv per year, no more than .02 mSv in any one hour, $T = 1$
  - Radiation workers, .05 Sv per year

• Location
  - Multiple shielded rooms adjacent
  - Near nurses’ station, surveillance
Facility Considerations

• Ancillary services
  - Emergency power
  - Compressed air
  - Door interlock
  - Area radiation monitors
  - Emergency equipment, bail out pig
  - Radiation signs, instructions

• Audio-visual communications

• Equipment arrangement in room and outside
  - Afterloader, TCS, nurses’ console, etc.
Licensing Issues

• Licensed by USNRC or State Agency
• Registry of Sealed Sources and Devices
  – Verify vendor registration before purchase of unit
• “Say what you mean, do what you say”
  – Whatever you state you will do in license, you must do
  – You can always do more, but never less
License Application

- Description of source and registry number
- Manufacturer and model # of afterloader
- Authorized users and qualifications
- Authorized medical physicist and qualifications
- Planned use of device
- Location of planned use
License Application

- Adequacy of shielding
- Floor plan
- Area radiation monitors
- Radiation detection devices – survey meters
- Audiovisual equipment
- Machine operation indicators
- Security of the area and the sources
- Maximum activity of specified isotope in the facility at any time
License Application

• Training of operators
• Personnel monitoring
• Details of Quality Control Program
  - Calibration techniques and frequency
  - Routine QC procedures and frequency
  - Leak tests procedures and frequency
  - Qualifications of individuals performing procedures
License Application

- Emergency procedures, location
- Manuals, location
- Disposal of decayed sources
- Records
- Fee for application
- Signature of executive level administrator
Training

• Physicists/dosimetrists – operation, programming, emergency procedures, radiation safety
• Nursing staff – start/stop, emergency procedures, radiation safety
• Physicians – emergency procedures, radiation safety
Afterloader Commissioning

- Source calibration
- Source positioning
- Timer accuracy
- Room and treatment unit surveys
- Interlock & indicator light checks
- Audiovisual device checks
- Accuracy of printouts
- Applicator tests
Treatment Planning System Commissioning

- Data input devices
- Data output devices
- Image reconstruction algorithms
- Dose calculation algorithms
Afterloader Quality Control

• Interlock checks
• Audiovisual device checks
• Area radiation monitor
• Accuracy of printouts
• Printer paper supply
• Door lights
• Indicator lights & audible alarms
Afterloader Quality Control

- Warning signs
- Manuals
- Air compressors
- Emergency power
- Timer accuracy
- Room and treatment unit surveys
Afterloader Quality Control

- Source calibration
- Source positioning
- Applicator tests
Problem

• Desire an intracavitary LDR brachytherapy program with remote afterloader.
• After 2009 Nucletron will not support the Selectron LDR remote afterloader.
• Manual $^{137}$Cs sources are more difficult to obtain.
• PDR remote afterloader, potential solution
Nucletron PDR Afterloader

- Physical construction identical to Nucletron unit (mHDRv2)
- $^{192}$Ir stepping source
- Source activity 18.5 – 74 GBq at installation
- Treatment Control Station software specific for PDR
PDR Remote Afterloader

- Simulates LDR with higher activity source exposed a fraction of each hour
- PDR source steps through the implant during irradiation pulse
PDR Afterloader Advantages

- Radiobiological models and measurements indicate PDR provides capability to simulate LDR
- Nursing care provided between pulses
- Patient has more certainty when treatment finishes
- Visitors between pulses
- Computerized optimization
  - 3D imaging, planning, volumetric information required for true optimization
PDR Afterloader Disadvantages

- Potential for failure to retract source
  - Low probability, never occurred
- AMC – Amsterdam
  - 5117 delivered pulses
    - 272 obstruction during check cable insertion
    - 5 obstruction during active source insertion
  - 417 treatments
    - 5 (1.2%) required adjustment
    - 5 (1.2%) discontinued, medical reasons
AMC – Amsterdam PDR
Conclusions

• Errors occur and on rare occasion require treatment adjustment
• Errors don’t always occur on first pulse
  - Flexible catheters more problem than rigid applicators
• Check cable proven effective system to prevent problems with active source
Questions

- When do treatment interruptions that require treatment adjustment become a reportable event in US?
  - Patient intervention – No
  - Catheter kinked during treatment - depends???
    - If can adjust to original prescription - perhaps???
    - If can’t adjust to original prescription - probably???
  - If reportable, to whom ???
    - FDA for machine - ???
    - NRC/State for dosage - ???
Facility Considerations

- **Shielding**
  - Maximum air kerma strength per hour
  - Maximum total air kerma strength per week
  - Uncontrolled areas - 1.0 mSv per year, no more than .02 mSv in any one hour, T = 1
  - Radiation workers, .05 Sv per year
  - Shielding adequate for $^{137}$Cs LDR, should be adequate for same (cGy in any one hour) treatments with $^{192}$Ir PDR

- **Location**
  - Multiple shielded rooms adjacent
  - Near nurses’ station, surveillance
Facility Considerations

• Ancillary services
  - Emergency power
  - Door interlock
  - Area radiation monitors
  - Emergency equipment, bail out pig
  - Radiation signs, instructions

• Audio-visual communications

• Equipment arrangement in room and outside
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License Application

• Description of source and registry number
• Manufacturer and model # of afterloader
• Authorized users and qualifications
• Authorized medical physicist and qualifications
• Planned use of Device
• Location of planned use
License Application

- Adequacy of shielding
- Floor plan
- Radiation area monitors
- Radiation detection devices
- Audiovisual equipment
- Security of the area and the sources
- Maximum activity of specified isotope in the facility at any time
License Application

• Training of operators
• Personnel monitoring
• Details of Quality Control Program
  - Calibration techniques and frequency
  - Routine QC procedures and frequency
  - Leak tests procedures and frequency
  - Qualifications of individuals performing procedures
License Application

- Emergency procedures, location
- Manuals, location
- Disposal of decayed sources
- Records
- Fee for application
- Signature of executive level administrator
TRAINING

• Higher activity source – training even more important
• Physicists/dosimetrists – operation, programming, emergency procedures, radiation safety
• Nursing staff – operation, emergency procedures, radiation safety, nurses “buy-in” essential
• Physicians – emergency procedures, radiation safety
Afterloader Commissioning

• Source calibration
• Source positioning
• Room and treatment head surveys
• Interlock checks
• Audiovisual device checks
• Accuracy of printouts
• Applicator tests
Afterloader Commissioning

- Transit dose, high number of source transfers
- Machine reliability, number of transfers
  - Nucletron specs 25,000, tested to 100,000
- Transfer tubes, what radius of curvature results in failure
Treatment Planning System Commissioning

• Data input devices
• Data output devices
• Data transfer from TPS to Treatment Control Station
• Image reconstruction algorithms
• Dose calculation algorithms
Afterloader Quality Control

- Interlock checks
- Audiovisual device checks
- Area radiation monitor
- Accuracy of printouts
- Printer paper supply
- Door lights
- Indicator lights & audible alarms
Afterloader Quality Control

- Warning signs
- Manuals
- Emergency power
- Timer accuracy
- Source positioning
- Source calibrations
- Room and treatment unit surveys
LDR to PDR
Prescriptions

Geometry based
Point A dose
3D planning
LDR to PDR
Dose Distribution

Radial dose function
\(^{137}\text{Cs} vs. ^{192}\text{Ir}\)

Anisotropy effect

Ovoid shielding

Cs-137 vs. Ir-192 \(g(r)\) comparison

\(g(r)\) for \(^{137}\text{Cs}, ^{192}\text{Ir}\), ratio

Radial dose function

Radial distance (cm)
LDR to PDR
Activity Distribution

- Tube sources, fixed geometry, fixed activity
- Selectron pellets, fixed activity, variable geometry active/inactive pellets
- PDR stepping source, variable geometry, variable dwell times

MCNPX2.5.e calculation
Selectron LDR
Fletcher-Suit-Delclos Ovoids

- **small ovoids** - one ovoid with medium cap
- **mini ovoids**
- **large cap**
- **medium cap**
- **30 degree “short” small ovoid**
- **ovoid - 33 mm long “short” ovoid - 28 mm long**
- **15 degree small ovoid**
- **“short” large cap**
- **15 degree mini ovoid**
- **30 degree small ovoid**
FSD Selectron Ovoid

Gifford
Fletcher Williamson
Tandem and Ovoids

Polysulfone ovoid body

bladder shield

solid on laterally

cavity for shields medially

set screw

Nucletron catalogue
2 cm dia.
Ovoid cap

Rectal shield

Screw inside cap

Bladder shield

Fletcher Williamson Ovoid

Moritz display of ovoid geometry
LDR to PDR
Ovoid Comparison

% Difference map

Small ovoid – PDR
Fletcher Williamson
compared to LDR FSD

20 mgRaeq, same active
dwell positions for FW
and FSD

Dwell time same at each
dwell position

MCNPX2.5.e calculation
# Rectal Shield Geometry

<table>
<thead>
<tr>
<th></th>
<th>Rectal FW</th>
<th>Rectal FSD</th>
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<tbody>
<tr>
<td><strong>ID, mm</strong></td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td><strong>OD, mm</strong></td>
<td>18</td>
<td>18</td>
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<tr>
<td><strong>Thickness, mm</strong></td>
<td>2.1</td>
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<tr>
<td><strong>Total surface, mm^2</strong></td>
<td>344</td>
<td>458</td>
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<tr>
<td><strong>Largest face surface, mm^2</strong></td>
<td>191</td>
<td>102</td>
</tr>
<tr>
<td><strong>Total shield volume, mm^3</strong></td>
<td>254</td>
<td>510</td>
</tr>
</tbody>
</table>

Shield material for both FW and FSD is Densimet 17 (17 g/cm^3)
Percent difference isodose maps (FW-FSD)/FSD
with 20 mgRaeq loading in center of each ovoid
XY Plane is 1-cm from posterior ovoid surface

MCNPX2.5.e calculation  Price, et al., AAPM Annual Meeting, 2005, TU-D-T-617-1
LDR to PDR
UTMDACC Schedule

• First treatment in mid-October 05
• 18.5 GBq (0.5 Ci) source
• Change source every two months
• No weekend treatments
• Evaluate program in January 06
end
## Bladder Shield Geometry

<table>
<thead>
<tr>
<th></th>
<th>FW</th>
<th>FSD</th>
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<tbody>
<tr>
<td>Height, mm</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>OD, mm</td>
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<td>18</td>
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<tr>
<td>thickness, mm</td>
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<tr>
<td>Total surface, mm$^2$</td>
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<td>296</td>
</tr>
<tr>
<td>largest face surface, mm$^2$</td>
<td>91</td>
<td>58</td>
</tr>
<tr>
<td>total shield volume, mm$^3$</td>
<td>191</td>
<td>288</td>
</tr>
</tbody>
</table>

* Material for both FW and FSD is Densimet 17 (17 g/cm$^3$)