Radiation Protection in Brachytherapy in the Next Decade

SESSION 4
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International Conference on RADIATION PROTECTION IN MEDICINE
Setting the Scene for the Next Decade
3-7 December 2012
Bonn, Germany
IAEA - WHO
Radiation Protection in Brachytherapy

• CASE FOR BRACHYTHERAPY
• PATIENT CONSIDERATIONS
• STAFF CONSIDERATIONS
• PUBLIC CONSIDERATIONS
• CONCLUSIONS
Radiation Protection in Brachytherapy
Worldwide Cancer Rates Continue to Rise

- 7.6 Million (13%) deaths in 2008 (WHO).
- Lung, stomach, liver, colon, breast, cervical ...
- ~70% of all cancer deaths in 2008 were in low- and middle-income countries.
- Cancer expected to continue to rise up to ~26.4 Million cases (IARC), 13.1 Million deaths in 2030.
- Radiotherapy plays an important role in cancer management.
- Advances of last 10 y shifting goals from life preservation to cure with increased quality of life.
Brachytherapy Advantages

Placing a radiation source internally, either into or immediately next to the tumor, or externally on the tumor.

100+ year history.

14,000+ publications in the last 50 y.

- **Precision** – delivery of highly targeted, individualized dose.
- **Conformity** – targeted, shaped dose.
- **Efficacy** – cure rates comparable to surgery and EBRT, and enhanced in combination.
- **Optimized** – effective tumor dose with sparing of surrounding tissue, reduced side effects/toxicity/2nd Ca.
- **Shorter Times** – of ~1-5 d.
- **Cost Effective** – < $, outpatient.
Typical Brachytherapy Treatment Locations

Female:
- Breast
- Uterus, cervix, vagina, vulva
- Skin
- Other soft tissues

Male:
- Brain, eye, lip, mouth, tongue, nasopharynx, oropharynx
- Trachea, bronchi, lung
- Esophagus, gall bladder, bile ducts, rectum, anus
- Bladder, urethra
- Skin
- Prostate, penis
Worldwide Brachytherapy Pattern of Use

- >400,000 treatments in 2007 (UNSCEAR).
- >500,000 HDR alone now (ICRP).
- 50% increase in patients per center in some regions.
- >0.12 treatments per 1,000 population.
- Gynecological > Genitourinary > Prostate > Breast > Head and Neck > Others.
- US – >90% cervical Ca with EBRT + brachytherapy.
- Palliative care needed in 50% of inoperable Ca cases.
- Growth over the last decade. (see Guedea’s work).
- Appropriateness Criteria would support increases.

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Infrastructure Needs for Next Decade

- + Studies of Current Patterns of Use
- + Studies of Future Patterns of Need
- + Patient access and adherence
- + Facilities
- + Innovation
- + Equipment
- + Staff
- + Training
- + Safety
- - Disparities
Radiation Protection in Brachytherapy

PATIENT CONSIDERATIONS
### Brachytherapy Source Selection

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Photon Avg MeV</th>
<th>Half-Life</th>
<th>First HVL mm lead</th>
<th>μGy m² GBq h</th>
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</thead>
<tbody>
<tr>
<td>Co-60</td>
<td>1.25</td>
<td>5.26 y</td>
<td>12</td>
<td>309</td>
</tr>
<tr>
<td>Cs-137</td>
<td>0.66</td>
<td>30.0 y</td>
<td>6.5</td>
<td>79</td>
</tr>
<tr>
<td>Au-198</td>
<td>0.41</td>
<td>2.7 d</td>
<td>3</td>
<td>55</td>
</tr>
<tr>
<td>Ir-192</td>
<td>0.38</td>
<td>73.8 d</td>
<td>6</td>
<td>116</td>
</tr>
<tr>
<td>I-125</td>
<td>0.028</td>
<td>60 d</td>
<td>0.02</td>
<td>34</td>
</tr>
<tr>
<td>Pd-103</td>
<td>0.021</td>
<td>17 d</td>
<td>0.01</td>
<td>35</td>
</tr>
<tr>
<td>Ra-226 (0.5 mm Pt)</td>
<td>0.83</td>
<td>1600 y</td>
<td>16</td>
<td>234</td>
</tr>
</tbody>
</table>

Alternatively –
High Energy Beta sources, e.g. P-32, Sr-90, Ru-106, etc.
Neutron sources, e.g. Cf-252
## Brachytherapy Optimization

### Source Placement
- **Target** = tumor and local surrounding.
- **Applicators** (catheters or needles or seeds).
- **Contact or Interstitial**
- ** Temporary – timed.**
- **Permanent – seeds, microspheres.**

### Dose Rate
- **LDR – Low 0.4-2 Gy/h**
  - Sources, wires, ribbons, seeds, plaques, spheres
- **HDR – High > 12 Gy/h**
  - Source tip, catheters
- **PDR – Pulsed**
  - Gynecological or head and neck

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Rapid Changes in Dosimetric Approach

Pre-Treatment Planning

- 2D, radiography based
- 3D, volume based
  - CT
  - MRI
  - PET

Image-Guided Real-Time

- Ultrasound.
- Fluoroscopy.*
- O-Arm CT.*
- Intraoperative optimized planning.
- 4D (3D+time) approaches.
- In-vivo dosimeters...

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<table>
<thead>
<tr>
<th>Types</th>
<th>Causes?</th>
</tr>
</thead>
</table>
| - HDR (~34%), rate 0.03%  
  - >500 accidents and  
    > 1 death per ICRP.  
- LDR (~32%), rate 0.30%  
  - notably implants  
- Incorrect source strengths.  
- Dose calculation errors.  
- Misplacements.  
- Dislodgements. | - Human  
- HDR 1.6-5 Gy/min!  
- Afterloader complex technology.  
- Incorrect source strength/calibration.  
- Prostate visualization?  
- Equipment. |
When looking at Why...

First reaction is often to...

*BLAME SOMEONE!*
Brachytherapy Medical Error Event
Brachytherapy Medical Error Event
Quality Management Guidelines Exist... Implemented??

- Kubo, et al. AAPM Report No. 59, HDR.
- Podgorsak. IAEA. Radiation Oncology Physics.
- IAEA-QUATRO, Comprehensive Audits Tool.
- IAEA-Setting up a radiotherapy program: clinical, medical physics, radiation protection and safety.
- Venselaar, et al. ESTRO Booklet No. 8.
- EC-Guidelines on education and training in radiation protection for medical exposures.
- ASTRO-Safety is no Accident. ...and others...

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STAFF CONSIDERATIONS

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**LDR Staff Dose Potential**

**Manipulating**
- Contamination from leaking or cut sources.
  - Wipe tests.
- Unshielded sources.
  - Shield, control, monitor.
- Lost sources.
  - Inventory cradle to grave.
- ALARA precautions not followed.

**Seed / Spheres**
- Prostate Implantation (Schwartz 2003)
  - Fluoro Time.
  - 100 \( \mu \text{Sv} \)/case DDE.
  - 700 \( \mu \text{Sv} \)/case SDE extrem.
- Spheres –
  - Fluoro Time.
  - Contamination.
  - Beta doses.

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HDR Techniques Lower Staff Dose *IF*:

- Quality Management is implemented.
- Facility is carefully designed/shielded.
- Radiation monitoring is present.
- Equipment is tested and has preventive maintenance regularly.
- Packaged and shipped accordingly.
- Wipe tests for contamination.
- Labeled appropriately.
- Care when changing sources...

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Blurring of Brachytherapy Boundaries

Radiation Oncology

Fluoro-Guided

Medical Physics

Nuclear Medicine

Radiology

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## Optimizing Radiation Protection

<table>
<thead>
<tr>
<th>“Tried and True”</th>
<th>“Newer and Developing”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined Rad Prot</td>
<td>Need to define Rad Prot</td>
</tr>
</tbody>
</table>

- **Time**
- **Distance**
- **Shielding**
- **Planning**
- **Training**
- **Quality Management**

- **Conformal Balloons.**
- **Intraoperative (again).**
  - Electronic Brachy.
  - μSpheres.
  - P-32 flexible plaque for dura of spine and brain.
- **Pre-operative**
  - Rad Seed localizations.

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PUBLIC CONSIDERATIONS
Low Public Exposures

HDR ~ No dose.

LDR ~ Permanent

Low energy photon or short-range beta results in low public exposure potential. Less restrictive instructions

Temporary

Time, Distance, Shielding and Planning lowers public exposure potential.

I-125 at 30 cm 90% ≤10 μGy/h

Pd-103 at 30 cm 90% ≤4 μGy/h

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ICRP-98 on Permanent Implants

- Use is increasing.
- No adverse effects to medical staff and/or patient’s family reported.
- Annual dose from patients to family or household members remains << 1 mSv.
- Expulsion of sources is rare.

Radiation safety aspects of brachytherapy for prostate cancer using permanently implanted sources
ICRP Publication 98

- Cremation can be allowed if 12 months have elapsed or special measures may be needed.
- Patient needs specific recommendations.
  - see Dauer et al 2010 for followup.

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Security and Safeguards

Several thousand facilities worldwide.

10,000+ Source Shipments/y.

Need for more equipment and sources in next decade must consider safeguards.
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CONCLUSIONS

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Conclusions

- **Brachytherapy:**
  - Continues be an important radiotherapeutic option.
  - Should increase in next decade - recognized as ‘high value’.
- **Emphasis on basic radiation safety principles needed as current methods mature and newer techniques are developed.**
- **Significant opportunities for improvement exist in implementing Quality Management.**
- **Infrastructure is lacking:**
  - Equipment resources and availability.
  - Human resources and training.
  - Safeguards for sources.

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