Review of Head and Neck Brachytherapy

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Purpose

• Review of sources and dosimetry techniques relevant to head and neck brachytherapy
• Review of common needle insertion techniques for head and neck brachytherapy
• Review of treatment complications and considerations in their minimization
• Specific treatment techniques and dosimetry
Outline

- Sources and Dosimetry Techniques
- Target Delineation and Implant Techniques
- Treatment Complications and Pretreatment Dental Evaluation
- Clinical Sites
- Summary
Heck and Neck Cancers

- Oral Cavity: base of tongue, oral tongue, floor of mouth, lip, and buccal mucosa
- Oropharynx
- Nasopharynx
- Nasal vestibule
Cs-137 Sources

- Cs-137 tubes and needles
  - Cs-137 needles no longer commercially available in the United States
  - IPL Cs-137 tubes available - reference quality data set not available
  - Large inventory in clinics
Cs-137 Tubes and Needles

- Published dosimetry dataset available for many source designs
- Needles available in various linear strengths and lengths
Ir-192 LDR Sources

- Ir-192 seeds in ribbons
  - Available from Best Medical and Alpha-Omega in the United States
  - Dosimetry data for Best source in TG43 report
  - Monte Carlo data for Alpha-Omega source by Ballester et al. (2004) in comparison with Best Medical seeds

### Dose Rate Constant (cGy-hr⁻¹-U⁻¹)
Comparison of Ir-192 Seeds

<table>
<thead>
<tr>
<th></th>
<th>TG43 Best</th>
<th>Ballester Best</th>
<th>Ballester Alpha-Omega</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose Rate Constant</td>
<td>1.12</td>
<td>1.112</td>
<td>1.111</td>
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</table>
Best (stainless steel) vs. Alpha-Omega (platinum) Ir-192 Seeds
Best vs. Alpha-Omega Ir-192 Seeds: Comparison of Radial Dose Function and Anisotropy Factors (Ballester et al)

**Table V.** Radial dose function for the Alpha-Omega (AO) and steel-clad (BI) seeds.

<table>
<thead>
<tr>
<th>Distance $r$ (cm)</th>
<th>$g_1(r)$ AO$^a$</th>
<th>$g_1(r)$ BI$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.999</td>
<td>0.988</td>
</tr>
<tr>
<td>0.5</td>
<td>0.998</td>
<td>0.995</td>
</tr>
<tr>
<td>0.75</td>
<td>1.000</td>
<td>0.997</td>
</tr>
<tr>
<td>1</td>
<td>1.000</td>
<td>1.000</td>
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<tr>
<td>1.5</td>
<td>1.004</td>
<td>1.004</td>
</tr>
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<td>2</td>
<td>1.006</td>
<td>1.008</td>
</tr>
<tr>
<td>3</td>
<td>1.007</td>
<td>1.010</td>
</tr>
<tr>
<td>4</td>
<td>1.004</td>
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<td>1.000</td>
<td>1.005</td>
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<tr>
<td>6</td>
<td>0.993</td>
<td>0.999</td>
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<tr>
<td>7</td>
<td>0.983</td>
<td>0.990</td>
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<tr>
<td>8</td>
<td>0.970</td>
<td>0.977</td>
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<tr>
<td>10</td>
<td>0.938</td>
<td>0.945</td>
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<td>12</td>
<td>0.896</td>
<td>0.904</td>
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<tr>
<td>15</td>
<td>0.823</td>
<td>0.834</td>
</tr>
<tr>
<td>20</td>
<td>0.691</td>
<td>0.697</td>
</tr>
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</table>

**Table VI.** Anisotropy factors $\phi_{ar}(r)$ for the Alpha-Omega and steel-clad seeds.

<table>
<thead>
<tr>
<th>Distance $r$ (cm)</th>
<th>$\phi_{ar}(r)$ AO$^a$</th>
<th>$\phi_{ar}(r)$ BI$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.134</td>
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<td>0.5</td>
<td>1.005</td>
<td>1.027</td>
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<tr>
<td>0.75</td>
<td>0.982</td>
<td>1.005</td>
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<td>0.974</td>
<td>0.997</td>
</tr>
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<td>0.969</td>
<td>0.991</td>
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<td>0.967</td>
<td>0.988</td>
</tr>
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<td>0.968</td>
<td>0.988</td>
</tr>
<tr>
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<td>0.970</td>
<td>0.989</td>
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<td>5</td>
<td>0.970</td>
<td>0.991</td>
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<td>0.971</td>
<td>0.991</td>
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<td>7</td>
<td>0.972</td>
<td>0.991</td>
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<td>8</td>
<td>0.973</td>
<td>0.991</td>
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<tr>
<td>10</td>
<td>0.974</td>
<td>0.992</td>
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<tr>
<td>12</td>
<td>0.976</td>
<td>0.993</td>
</tr>
<tr>
<td>15</td>
<td>0.979</td>
<td>0.991</td>
</tr>
<tr>
<td>20</td>
<td>0.979</td>
<td>0.994</td>
</tr>
</tbody>
</table>
Dose Distribution Differences of Best vs. Alpha-Omega Ir-192 Seeds (Ballester et al)
Ir-192 HDR/PDR Sources

- Ir-192 HDR/PDR sources
Other Sources

• I-125 seeds: AAPM TG43-U1 (Rivard et al, 2004)

Best Medical Au-198 seeds
Dosimetry Systems

- Manchester, Quimby, and Paris systems typically used for preplanning
- Paris system for Ir-192 hairpins or looping catheters most applicable to H&N brachytherapy
  - Standard Paris system limits hotspots by using no larger than 2.2 cm catheter spacing
  - Catheter spacing larger than 1.4 cm has been shown to increase complications
Paris System for Ir-192 Hairpins or Looping Technique

- Tx’ed Length = 0.8 X active length
- Tx’ed thickness = 1.55 x leg spacing of hairpins
- Tx’ed width = Distance between distal-most hairpins + 0.5 x leg spacing of hairpins
H&N Brachytherapy Dose Prescription and Target Definition

• Typically delivered in combination with external beam radiotherapy
  – Total dose ~ 70 Gy

• Dose rate
  – Standard Manchester system @ 45 cGy/hr
  – Paterson (1952): Modify total Rx dose based on dose rates
  – Pierquin et al (1973, 1997) and Parsons (1994): No Rx dose change for dose rates between 30 to 80 cGy/hr
  – Pernot et al (1997): Dose rates higher than 70 cGy/hr related to high incidence of soft tissue and bone necrosis

• Target definition: CTV + up to 1 cm margin
Implant Techniques – Standard Through-and-Through

Entrance and exit sides need to be selected carefully for ease of access and catheter care.
Implant Techniques – Looping

- Looping over superficial tumor.
- Need access for removal of 1st needle.
Implant Techniques – Looping with Wire

Use a wire to pull catheter through tissue following removal of 1st needle
Implant Techniques – Non-looping
Implant Techniques – Non-looping
Implant Techniques – Non-looping for HDR

Diagram:
- Button
- Rubber spacer
- Silk suture
- Catheter

Diagram (b):
- Tumor
- Tongue surface
Treatment Complications

• Soft tissue and bone necrosis
  – Soft tissue necrosis: Up to 20% (Parsons et al, 1994)
  – Bone necrosis: Up to 6% (Mendenhall, 2004)
  – Rate of necrosis increases with increased dose
    » Steep increase at ≥ 66 Gy (Jereczek-Fossa and Orecchia, 2002)
    » High bone necrosis at ≥ 60 Gy and larger than 55 cGy/hr (Fujita et al, 1996)
  – Rate of necrosis increases with ≥ 12 cm² treated surface area (Pernot et al, 1997)

• Rate of necrosis can be reduced by
  – Use of spacers between target and normal tissue
  – Use of lead shields between implant and gingiva
Treatment Complications

• Skin fibrosis
  – Limit skin dose to less than prescription dose

• Pretreatment dental evaluation
  – Teeth in poor health correlates with increased rate of soft tissue and bone necrosis
  – Pretreatment dental evaluation necessary
    » Teeth in poor health extracted at 14 – 21 days prior to treatment
Specific Sites - Nasopharynx

- Intracavitary treatment using commercial or custom applicators
- Levendag (1997) technique: Recommended by ABS. 3Gy/fx BID. # fx and EBRT based on stage
Levendag Technique for Nasopharynx
Oral Cavity

- Use of template when applicable
- Lead shielding to mandibles

**Table 2a.** HDR brachytherapy as sole treatment for oral cavity cancers

<table>
<thead>
<tr>
<th>EBRT</th>
<th>Fx Size (Gy)</th>
<th># fx</th>
<th>Equiv. dose (Gy)</th>
<th># pts.</th>
<th>L.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>20</td>
<td>65</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>0</td>
<td>6.5</td>
<td>7</td>
<td>63</td>
<td>27</td>
<td>53%</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>10</td>
<td>80</td>
<td>14</td>
<td>100%</td>
</tr>
<tr>
<td>0</td>
<td>4.5–5</td>
<td>10</td>
<td>54–63</td>
<td>13</td>
<td>90%</td>
</tr>
<tr>
<td>0</td>
<td>5.5–6</td>
<td>10</td>
<td>71–80</td>
<td>13</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 2b.** HDR brachytherapy as boost treatment for oral cavity cancers

<table>
<thead>
<tr>
<th>EBRT dose (Gy)</th>
<th>HDR dose/fx (Gy)</th>
<th># fx</th>
<th>Equiv. dose* (Gy)</th>
<th># Pts.</th>
<th>L. C.</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2.7</td>
<td>6</td>
<td>67</td>
<td>12</td>
<td>79%</td>
<td>45%</td>
</tr>
<tr>
<td>40–48</td>
<td>3</td>
<td>7</td>
<td>63–71</td>
<td>18</td>
<td>80%</td>
<td></td>
</tr>
</tbody>
</table>

*Abbreviations: Fx = fractions; equiv. = equivalent; Pts. = patients; L. C. = local control; HDR = high dose rate; EBRT = external beam radiation therapy.*
Use of templates to improve accuracy
Use of Templates
Lip

- Cross needles often necessary for LDR implants
- Use lead shield for gingiva
- LDR: 35 Gy @ 5 mm brachytherapy + 30 Gy EBRT (Million et al., 1994)
- HDR: 5 – 5.5 Gy/fx BID X 8 – 10 fx’s, totaling 40.5 -45 Gy brachytherapy alone (Guinot et al, 2003)
Nasal Vestibule

- 55 – 75 Gy brachytherapy alone
- Does not follow Manchester system
- Potentially high dose rate (~ 80 cGy/hr)
Summary

• Classical implant systems commonly used for H&N brachytherapy
  – May need smaller spacing for Paris system
• High dose rate may correlate with increased soft tissue and bone necrosis rates
  – Limit dose rate
  – Use spacers and shielding for normal tissue
• Select appropriate implant technique and use of templates