Implementation and Clinical Use of Electronic Brachytherapy (EB)

Jessica Hiatt MS
Rhode Island Hospital
Brown Medical School
AAPM July 31, 2008

Conflict of Interest Statement:

• Partial financial support was provided by Xoft, Inc.

Outline:

• Overview and intro to EB
• Dose characteristics
• Acceptance and commissioning

Brachytherapy:

• Internal radiation therapy that involves placing radioactive sources inside the patient close to or in the tumor.
Electronic Brachytherapy:

- Internal radiation therapy that involves placing a miniature x-ray source inside the patient close to or in the tumor.

Axxent:

- Revolutionary new technology will change the way radiation therapy is delivered

System Components:

X-ray Source

- Tube diameter = 2.25 mm
- Requires a cooling catheter
  - Assembly diameter = 5.4 mm
- Nominal dose rate:
  - 0.6 Gy/min at 3 cm in water
**Axxent Controller:**
- Touch Screen Display
- Barcode Reader
- Controller Pullback Arm
- SI Max 4000 Electrometer

**Breast Applicator:**
- Balloon Inflation Valve
- Multi-lumen Flexible Shaft
- Radiation Source Lumen
- Drainage Holes
- Drainage Port Valves

**Vaginal Applicator Set:**
- FDA clearance received in May 2008 for a set of reusable vaginal applicators
- Available in four diameters – 20, 25, 30 and 35 mm
- Each set contains four vaginal cylinders, four source channels and a board & clamp assembly
- Enhanced visibility with CT and fluoroscopic imaging

**Source Characteristics:**
- Comparison of Dose Rate vs. Depth in Water for Various Sources

Dose rate curve is quite similar to 192Ir over region of interest

Graph courtesy of Xoft
Intracavity APBI:

MammoSite HDR $^{192}$Ir vs. Xoft 50kV

Dickler et al. *Brachytherapy*, 2007

Vaginal Cylinder:

Volume

Rectum

50kV

HDR $^{192}$Ir

Volume

Bladder

50kV EBT

Vaginal Cylinder DVH:

Acceptance and Commissioning:

Volume

Dose (cGy)

50kV

HDR $^{192}$Ir

Volume

Dose (cGy)

50kV

HDR $^{192}$Ir
Acceptance and Commissioning:

- Well-chamber constancy
- Beam stability
- Source positional accuracy
- Output stability
- Timer linearity
- Marker/source position coincidence
- Controller functionality/safety interlocks
- Treatment planning data verification

Well-chamber Constancy:

- Intercomparison - Well-chamber/Electrometer
  - SI HDR Plus Well Chamber
  - SI Max 4000 electrometer
  - 4 mg Ra-eq Cs-137 source

<table>
<thead>
<tr>
<th>Well Chamber Constancy Check</th>
<th>RH Unit</th>
<th>Mean Reading (pA): 41.90</th>
<th>SD: 0.02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xoft Unit</td>
<td>Mean Reading (pA): 41.96</td>
<td>SD: 0.02</td>
<td></td>
</tr>
</tbody>
</table>

% Difference in Readings: 0.14%

Beam Stability:

- Simulated treatment data extracted from controller and plotted.

Source Positional Accuracy:

QA Test Fixture

GAFCHROMIC EBT Film

(Provided by Xoft)
**Source Positional Accuracy:**

Digitized image of film positioned w/ fixture during exposure

**Output Stability:**

DAYS UNTIL WEDDING: 16
### Output Stability:

<table>
<thead>
<tr>
<th>Dwell Position (cm)</th>
<th>Trial Number</th>
<th>Rate (nA)</th>
<th>SD</th>
<th>Rel. SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.5</td>
<td>1</td>
<td>0.096</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.096</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.096</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.096</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.096</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>23.5</td>
<td>1</td>
<td>0.022</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.022</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.022</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.022</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.022</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td>22.5</td>
<td>1</td>
<td>0.111</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.111</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.111</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.111</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.111</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>21.5</td>
<td>1</td>
<td>0.199</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.199</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.199</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.199</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.199</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td>20.5</td>
<td>1</td>
<td>0.077</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.077</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.077</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.077</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.077</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td>Total Rate (nA)</td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.418</td>
<td>0.018</td>
<td>0.018</td>
</tr>
</tbody>
</table>

### Timer Linearity:

![Timer Linearity Graph]

### Marker/Source Position Coincidence:

![Marker/Source Position Coincidence Image]
Controller Functionality and Safety Interlocks:

- Setup and delivery
- Status indicator light
- Emergency-off
- Treatment recovery
- Applicator symmetry
- Pullback force error
- No travel through bent applicator

Treatment Planning Data Verification:

- TG-43 parameters entered into brachytherapy planning system
  - Mammosite tx planning: define catheter, determine balloon center, tx w/ multiple dwell positions, prescribe to 1 cm beyond balloon
Treatment Planning:

- Plan is printed and manually entered into an Excel creating a dwell file.

Treatment Planning:

- Dwell file saved to USB key and then physically transferred to Axxent controller.
- At controller, dwell times are scaled from tx planning dwell times based on pre-treatment source calibration.

Treatment Planning:
Conclusion: EBT

- Revolutionary (not evolutionary)
- A remarkable advance in brachytherapy technology
- Simple to implement clinically
- It offers the potential to profoundly impact brachytherapy practice
- With imagination and creativity, it can expand the boundaries of brachytherapy into the management of a much broader array of clinical circumstances

Any questions?

Future Directions of EBT

Tandem and Ovoid:
**T&O DVH:**

Rectum | Bladder
--- | ---

- **50kV** HDR Ir192
- **50kV** HDR Ir192

---

**Intra-Operative EBT:**

- kV EBT applicator is potentially ideal for intra-op treatment for close or positive margins.
  - **Practical Considerations**
    - Allows for wide spread use.
      - No need for dedicated OR Linac
      - Shielding advantages
    - **Dosimetric Considerations**

---

**Shielding:**

- No OR room shielding is required.
- No transport required.
- Anesthesia can be present during treatment
  - Dose falls rapidly with distance
  - Lead Shield (reduced exposure rate by 100-1000x)
  - Lead apron (reduced exposure rate by 1100x)

---

**Intra-Operative:**

- 50kV EBT approaches electron distribution in an ideal homogenous surface contour
**Intra-op Planning:**

- Pre-determined plans for given applicator size and depth of prescription can be developed.
- Intra-op planning can be eliminated by prescribing from standardized tables.

**Skin Malignancy:**

- Electron beam limitations
  - Inhomogeneous dose with irregular surface contour.
  - Requires wide margin due to penumbra and isodose constriction at depth.
  - May be difficult to exclude critical structures such as the eye.
  - Relative surface sparing at low energy

**EBT for Skin:**

- Advantages similar to orthovoltage
  - Tighter margins
  - Custom shielding
  - No surface sparing
  - Rapid dose fall off.
Lung Brachytherapy

\[^{192}\text{Ir}\] HDR  
50kV EBT