Electronic Brachytherapy (EBT)

Zoubir Ouhib
Lynn Cancer Institute
Speaker for ELEKTA
What is EBT?

- Brachytherapy using miniature X-ray sources
- Energy <100 Kv
- Brought to the market with similar existing dosimetry
- Used for skin, intracavitary sites, intraoperative PBI
- Treatment at short distances
- Requires less room shielding
The use of the word “Brachytherapy” in EBT is still being debated”!
Source design mimics HDR with the advantage of low energy shielding requirement.

**PDD @ 3mm skin**

- 50 KV X-ray
- 70 KV X-ray
- Valencia-HDR
- 2MeV electrons

Depth (mm)

0 5 10 15 20

0.0% 50.0% 100.0% 150.0% 200.0%

Courtesy of Jose Perez-Calatayud
Current EBT systems

- Intrabeam® by Zeiss Surgical
- Xoft® by Icad Inc.
- Esteya® by Elekta
- SRT-100™ by Sensus Healthcare
- Photoelectric Therapy by Xstrahl Ltd
- Papillon (UK only) by Ariane Medical Systems Ltd
Devices

- Xoft (Icad)
- Intrabeam (Zeiss LTD)
- Esteya (ELEKTA)
- P.T. (Xstrahl)
- SRT 100 (Sensus Healthcare)
<table>
<thead>
<tr>
<th>System</th>
<th>Kv</th>
<th>mA</th>
<th>Applicator sizes (cm)</th>
<th>HVL (mm Al)</th>
<th>SSD (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esteya</td>
<td>69.5</td>
<td>0.5; 1.0; 1.6</td>
<td>1; 1.5; 2; 2.5; 3</td>
<td>1.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Xoft</td>
<td>50</td>
<td>0.3</td>
<td>1, 2, 3.5, 5.0</td>
<td>0.5 and 1.6</td>
<td>2-3 (cones)</td>
</tr>
<tr>
<td>Intrabeam</td>
<td>50</td>
<td>0.04</td>
<td>1-6 (Surface); 1.5-5 (Spheres); 2-3.5 (cylinders)</td>
<td>0.1; 0.8-1.3; 1.6-2.1</td>
<td>1-2.6</td>
</tr>
<tr>
<td>SRT</td>
<td>50-100</td>
<td>8-10</td>
<td>1-5</td>
<td>0.5-2.1</td>
<td>15</td>
</tr>
<tr>
<td>P.T.</td>
<td>80</td>
<td>1.3</td>
<td>1-5</td>
<td>2.9</td>
<td>5</td>
</tr>
<tr>
<td>Papillon</td>
<td>50</td>
<td>2.7</td>
<td>2.2-3.0</td>
<td>1.9</td>
<td>2.9-3.8</td>
</tr>
</tbody>
</table>
What is needed for Implementation of an EBT program?
Items for the EBT program

- Room
- Staff
- Equipment
- Regulatory items
- Acceptance testing
- Commissioning
- Policy and procedures
- Staff training
- End to end case with all forms in place
- Reimbursement
- Patient load to support the unit
Room selection (pros and cons)

- Accelerator room (1)
- Sim room (2)
- Exam room (3)
- others
Staff

- Similar to HDR Brachytherapy: therapists, medical physicist, rad. onc., and dosimetrist
- Dermatologists are purchasing these to be used in their offices (potential issues with staffing, Q.A., patient safety)
Equipment

- Delivery system and accessories
- Equipment to perform commissioning
- Survey meter
- Door interlock system
- A/V, intercom
- Emergency buttons installed in the room and outside
- Portable shield
Rules 64E-5.1601 — 64E 5.1604 are effective March 12, 2009 and are designated as Revision 9 (R9).

PART XVI

ELECTRONIC BRACHYTHERAPY
24.12.5.7 The date of calibration.

24.13 Electronic Brachytherapy.

24.13.1 Electronic brachytherapy devices shall be subject to the requirements of 24.13, and shall be exempt for the requirements of 24.7.

24.13.1.1 An electronic brachytherapy device that does not meet the requirements of 24.13 shall not be used for irradiation of patients; and

24.13.1.2 An electronic brachytherapy device shall only be utilized for human use applications specifically approved by the U.S. Food and Drug Administration (FDA) unless participating in a research study approved by the registrant’s Institutional Review Board (IRB).
<table>
<thead>
<tr>
<th>PART XVI</th>
<th>ELECTRONIC BRACHYTHERAPY</th>
</tr>
</thead>
<tbody>
<tr>
<td>R9</td>
<td>64E-5.1601...Definitions.................................................................XVI-1</td>
</tr>
<tr>
<td>R9</td>
<td>64E-5.1602...Administrative Requirements................................................XVI-2</td>
</tr>
<tr>
<td>R9</td>
<td>64E-5.1603...Training and Education........................................................XVI-4</td>
</tr>
<tr>
<td>R9</td>
<td>64E-5.1604 General Technical Requirements For ............................................XVI-7</td>
</tr>
<tr>
<td>R9</td>
<td>Electronic Brachytherapy Facilities................................................................XVI-7</td>
</tr>
</tbody>
</table>
64E-5.1603 Training And Education.

(1) Qualification of Authorized User.

(a) The registrant shall require the authorized user to be a physician who:

1. Is licensed by the department as a medical doctor or doctor of osteopathy;

2. Has completed a manufacturer's device-specific training as specified in subsection 64E-5.1603(5), F.AC.; and

3. Is certified in:
   
   a. Radiation oncology or therapeutic radiology by the American Board of Radiology;
   
   b. Radiation oncology by the American Osteopathic Board of Radiology;
   
   c. Radiology, with specialization in radiotherapy, as a British "Fellow of the Faculty of Radiology" or "Fellow of the Royal College of Radiology"; or
   
   d. Therapeutic radiology by the Canadian Royal College of Physicians and Surgeons.

(b) A physician shall not act as an authorized user for any electronic brachytherapy device until such time as said physician's training has been reviewed and approved by the department.
(2) Qualification of Authorized Medical Physicist.

(a) The registrant shall require the authorized medical physicist to be a person who:

1. Is currently licensed pursuant to Section 483.901, F.S., as a therapeutic radiological physicist; and

2. Has completed a manufacturer’s device-specific training as specified in subsection 64E-5.1603(5), F.A.C.

(b) A medical physicist shall not act as an authorized medical physicist for any electronic brachytherapy device until such time as said physicist’s training has been reviewed and approved by the department.
Technical requirements

- Survey
- Calibration system (Calibrated for the energy to be used).
- Q.A. check measurements
- Q.M. program: W.D.; patient identification (two methods); records of any deviation; review of a sample of patient treated; recordable events, medical events etc...
Authority and responsibilities

- Radiation safety officer
- Authorized User: *physically present at start and during* patient Tx; review patient Tx
- Authorized Medical Physicist: *physically present at start and during patient Tx*; evaluate EBT output; review calc. prior to Tx; assess each Tx for possible M.E.; establish a Q.A. spot checks
Operating procedures and calibration

- Unit is FDA approved
- **Unit is secured when not in use**
- Operating and emergency procedures in close proximity to the EBT.
- Survey meter (dose rate 0.01 to 1000 mrem/hr)
- Calibration: O.F. (**within 2%**); timer accuracy; evaluation of relative dose distribution (5%)
- Source positioning accuracy within 1 mm within the applicator
Spot checks

- Daily spot checks
- AMP to review spot checks within 2 days of completion. Should include indicator lights cables, catheters or parts of the device
- Dosimetry spot checks: O.F (or dose rate) within 3%; validation of radiation area of the intended area within 1 mm
Treatment planning

- Correct source-specific input parameters of the source
- Accuracy of treatment-time time calculations
- Accuracy of isodose plots
Acceptance testing

- Performed with the installer to verify all aspects of the device (Hardware and software)
- Delivery check of all expected items: treatment unit, applicators, software, computer, documentation, QA device, cables, user manual, etc.
- Installation of radiation indicator, door interlock, applicator interlock, emergency stop switch, timer etc.
- Should provide you with some basic training to run the unit for the commissioning
- Provide you with dosimetric data for the unit to compare to: surface dose rate, PDD.
Calibrated chamber for the used energy
What kind of calibration: in air or in water?
For low energy device calibration: in air In the U.S.; in Europe in water (not for all chambers)
Chamber holder in air and in water, 2 D tank for water
Plastic water for film dosimetry
Film dosimetry: appropriate film scanner and film
Items: flatness and symmetry, penumbra, HVL, absolute dose, surface dose rate, virtual source (effective SSD), PDD, timer accuracy etc..
Opportunity to establish daily Q.A. and periodic testing
Both films and chamber were used
Surface dose rate measurements were performed
Absolute dose measurements
PDD measurements (absolute and relative)
Virtual SSD
Dose profiles (F&S, penumbra etc.)
Accuracy of timer
HVL (work in progress)
1. Applicator
2. Surface Applicator
3. Applicator Cap

Available diameters of surface applicators:

- 10
- 15
- 20
- 25
- 30
Source

- The system uses electronically generated X-rays through a small end-window type X-ray source, proprietary design
  - Dose rate: 2.7 Gy / min @ 3mm
  - X-ray source operating range: 69.5 kV
  - Beam current: 1.6 mA (nominal) or 1.0 mA or 0.5 mA (depends on treatment fraction-time)
  - X-ray source maximum temperature: external 33 °C (91.4 °F), internal 41°C (105.8 °F)
  - Cooling system X-ray source: Liquid filled active heat exchanger
  - X-ray radiation, defined by x-ray source; with 69.5 kV and the 1.6 mm Aluminum filter at a Source to Surface Distance (SSD) of 60 mm.
  - Dose profile designed to mimic HDR Valencia
  - Source maintenance interval: 4,000 fractions
The QA Device is attached to the X-ray source of the treatment unit for the required quality check. The QA Device is connected to the treatment unit with a network cable.

A total of 26 sensors measure:
- Dose rate
- Flatness of dose at depth
- Percent dose at depth
Q.A. device (sensors)
26 sensors: 13 on top layer and 13 on bottom layer spaced 0.5 mm
5 cm solid water underneath
Work flow for Esteya

Self test → QA check → Add a new patient

Start treatment → Position on surface → Set up treatment plan
PDD’s for various brachytherapy skin applicators (normalized at 3 mm)
Unique Esteya electronic brachytherapy applicators have an even smaller penumbra than proven HDR Valencia applicators (1.1 mm versus 1.9 mm) and much smaller than teletherapy.

- Healthy tissue outside applicator spared
- Stray radiation is extremely low
Commissioning and periodic tests of Esteya

C. Candela-Juan\textsuperscript{1}, J. Perez-Calatayud\textsuperscript{1}, F. Ballester\textsuperscript{2}, Z. Ouhib\textsuperscript{3}, Y. Niatsetski\textsuperscript{4}

\textsuperscript{1} Radiation Oncology Department, \textit{La Fe University and Polytechnic Hospital, Valencia, Spain}
\textsuperscript{2} Atomic, Molecular and Nuclear Physics Department, \textit{University of Valencia, Burjassot, Spain}
\textsuperscript{3} \textit{Lynn Cancer Institute of Boca Raton Regional Hospital, Boca Raton, Florida, USA}
\textsuperscript{4} Research and Development Department, \textit{Elekta Brachytherapy, Veenendaal, The Netherlands}
LCI Commissioning
Dose Profiles using film dosimetry for all applicators
Profiles (3mm depth): Flatness, symmetry, and penumbra

<table>
<thead>
<tr>
<th>Property</th>
<th>Mid horizontal</th>
<th>Center vertical</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field width</td>
<td>30.4 mm</td>
<td>31.8 mm</td>
<td>31.1 mm</td>
</tr>
<tr>
<td>Offset to isocenter</td>
<td>0.5 mm</td>
<td>0.2 mm</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>Flatness</td>
<td>1.0 %</td>
<td>0.8 %</td>
<td>0.9 %</td>
</tr>
<tr>
<td>Flattened area</td>
<td>24.3 mm</td>
<td>25.4 mm</td>
<td>24.9 mm</td>
</tr>
<tr>
<td>Flatness max CAJ</td>
<td>101.6 %</td>
<td>101.2 %</td>
<td>101.4 %</td>
</tr>
<tr>
<td>Symmetry</td>
<td>0.7 %</td>
<td>0.1 %</td>
<td>0.4 %</td>
</tr>
<tr>
<td>Symmetry area</td>
<td>24.3 mm</td>
<td>25.4 mm</td>
<td>24.9 mm</td>
</tr>
<tr>
<td>Penumbra left</td>
<td>0.8 mm</td>
<td>0.8 mm</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Penumbra right</td>
<td>0.2 mm</td>
<td>0.2 mm</td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Penumbra distano</td>
<td>96.8 %</td>
<td>96.8 %</td>
<td>96.8 %</td>
</tr>
</tbody>
</table>
Surface dose rate $D_w$ in water with measurements performed in water and in air:

$$
\dot{D}_w = \frac{M_Q N_{D_{w;Q}} k_{Q;Q_0}}{t} \left( \frac{SSD + d_c}{SSD} \right)^2
$$

$$
\dot{D}_w = \frac{M_Q N_K B_w P_{stem,air}}{t} \left[ \left( \frac{\mu_{en}}{\rho} \right)^w_{air} \right] \left( \frac{SSD + d_c}{SSD} \right)^2
$$
Surface dose rate in water

- $M_Q$: reading at depth corrected for $T$, $P$, and $E_c$.
- $K_{Q_0}$: chamber-specific factor to correct for differences between beam quality $Q$ during measurements and reference beam quality $Q_0$ at time of calibration.
- $N_{D_{w,Q_0}}$: calibration factor in terms of absorbed dose to water for reference quality $Q_0$.
- $t$: radiation time.

$D_w(t) = \frac{M_Q N_{D_{w,Q_0}} k_{Q,Q_0}}{t} \left( \frac{SSD + d_c}{SSD} \right)^2$
Surface dose rate (in air)

- NK is the air-kerma calibration factor for the beam quality used in the measurements.
- Bw is the backscatter factor which accounts for the effect of the phantom scatter. Varies with SSD, field size (collimator diameter), and HVL (Table V from TG-61).
- Pstem,air is the stem correction factor, which accounts for the change in photon scatter from the chamber stem between the calibration and measurement (mainly due to the change in field size).
- \( \left( \frac{\mu_{en}}{\rho} \right)^w_{air} \) is the mass energy-absorption coefficient ratio of water-to-air

\[
\dot{D}_w = \frac{M_Q N_K B_w P_{stem,air}}{t} \left[ \left( \frac{\mu_{en}}{\rho} \right)^w_{air} \right] \left( \frac{SSD + d_c}{SSD} \right)^2
\]
S.I. A20 Chamber

- collecting volume is 0.0738 cm³
- collector diameter is 1.93 mm
- entrance window of 50.8 μm and
- effective point of measurement is at \( dc = 1.80 \) mm depth from the entrance surface
Measurements performed in air

- Chamber used: Standard Imaging Exradin A20 (calibrated for beam quality UW80-L at U.W.)

- Two different geometries:
  - 
  - vs.

- Different results
# Results

<table>
<thead>
<tr>
<th>Applicator Size (cm)</th>
<th>Planned Dose Rate (Gy/min)</th>
<th>Measured Dose Rate (Gy/min)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>3.330</td>
<td>3.412</td>
<td>2.462</td>
</tr>
<tr>
<td>2.5</td>
<td>3.330</td>
<td>3.439</td>
<td>3.256</td>
</tr>
<tr>
<td>2.0</td>
<td>3.248</td>
<td>3.308</td>
<td>1.845</td>
</tr>
<tr>
<td>1.5</td>
<td>3.179</td>
<td>3.227</td>
<td>1.500</td>
</tr>
<tr>
<td>1.0</td>
<td>3.109</td>
<td>3.093</td>
<td>-0.502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planned Dose Rate (Gy/min)</th>
<th>Measured Dose Rate (Gy/min)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.330</td>
<td>3.434</td>
<td>3.129</td>
</tr>
<tr>
<td>3.289</td>
<td>3.450</td>
<td>4.871</td>
</tr>
<tr>
<td>3.248</td>
<td>3.348</td>
<td>3.084</td>
</tr>
<tr>
<td>3.179</td>
<td>3.247</td>
<td>2.127</td>
</tr>
<tr>
<td>3.109</td>
<td>3.103</td>
<td>-0.174</td>
</tr>
</tbody>
</table>
PDD measurements in water and with film

- With Exradin A20 in a 2D tank
- Film using plastic water.
- Dose calibration curve for film measurement was created (0, 1, 3, 5, 7, 8, 10 Gy)
- Scanner: Epson 11000XL with Epson Twain drivers
- Software: Film QA PRO2015 from Ashland
- Films: GafChromic EBT2 and EBT3 radiochromic
Measurements of PDD in water (advantages of linac couch for setup)
PDD (Film): 2.5 cm applicator
PDD comparison for 3.0 cm applicator

Esteya (S/N 87654321) 3.0 cm Applicator PDD Comparison
(Normalized to 3mm)

Percent Depth Dose (PDD)

Depth (mm)
PDD comparison for 2.5 cm applicator

Esteya (S/N 87654321) 2.5 cm Applicator PDD Comparison
(Normalized to 3mm)

Percent Depth Dose (PDD)

Depth (mm)

- Film (EBT3)
- A20
- TM34013*
- Internal
PDD comparison for 2.0 cm applicator

Esteya (S/N 87654321) 2.0 cm Applicator PDD Comparison
(Normalized to 3mm)
PDD comparison for 1.5 cm applicator

Esteya (S/N 87654321) 1.5 cm Applicator PDD Comparison
(Normalized to 3mm)
PDD comparison for 1.0 cm Applicator

Esteya (S/N 87654321) 1.0 cm Applicator PDD Comparison (Normalized to 3mm)
\[ \sqrt{\frac{X_0}{X_g}} = 1 + \frac{g}{(SSD + d_c)} \]

Esteya (S/N 87654321) Virtual SSD 3cm Applicator

SSD = 5.855 cm
Accuracy for all measurements

- Film positioning vs. applicator
- Calibration curve
- Chamber positioning
- Others
Q.A for EBT

- Establish a method of verification for Tx time
- Which data to use: own or internal?
- Daily Tx verification
- Compliance form (presence of AU and AMP)
- Have a template for sim and Tx
- Pacemaker verification
- Others
Independent calculation for EBT (Esteya) procedure

Patient: ___________________ Date: ____________
Treatment Area: ___________ Fields: ____________
Radiation Oncologist: _______ Physician: __________
Applicator identification (please circle appropriate size):

10 mm  15 mm  20 mm  25 mm  30 mm

Hand calculation for treatment time

Use the equation below, the dose per fraction, measured dose rate (Table 1), and measured PDD (Table 2) to determine the calculated treatment time.

Calc. Time = \( \frac{\text{Fraction Dose (Gy)}}{\text{Measured Dose Rate (Gy/min) \times Measured PDD}} \) = Min

Treatment planning time (from ESTEYA) = Min
Treatment planning time calculated time x 100=(
Acceptable (ratio less than 3%): Y N
Calculated by: _______ Date: ____________

**Table 1. Measured dose rate for ESTEYA S/N 87654321**

<table>
<thead>
<tr>
<th>Applicator diameter (mm)</th>
<th>Dose rate (Gy/min) at 0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3.109</td>
</tr>
<tr>
<td>15</td>
<td>3.179</td>
</tr>
<tr>
<td>20</td>
<td>3.248</td>
</tr>
<tr>
<td>25</td>
<td>3.330</td>
</tr>
<tr>
<td>30</td>
<td>3.330</td>
</tr>
</tbody>
</table>

**Table 2. Measured PDD for ESTEYA S/N 8765321 normalized at 0 mm**

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>3</th>
<th>2.5</th>
<th>2.0</th>
<th>1.5</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>0.5</td>
<td>0.959</td>
<td>0.958</td>
<td>0.958</td>
<td>0.968</td>
<td>0.974</td>
</tr>
<tr>
<td>1.0</td>
<td>0.923</td>
<td>0.941</td>
<td>0.914</td>
<td>0.930</td>
<td>0.932</td>
</tr>
<tr>
<td>1.5</td>
<td>0.870</td>
<td>0.911</td>
<td>0.876</td>
<td>0.890</td>
<td>0.892</td>
</tr>
<tr>
<td>2.0</td>
<td>0.859</td>
<td>0.879</td>
<td>0.849</td>
<td>0.855</td>
<td>0.856</td>
</tr>
<tr>
<td>2.5</td>
<td>0.835</td>
<td>0.850</td>
<td>0.818</td>
<td>0.829</td>
<td>0.814</td>
</tr>
<tr>
<td>3.0</td>
<td>0.811</td>
<td>0.825</td>
<td>0.791</td>
<td>0.808</td>
<td>0.786</td>
</tr>
</tbody>
</table>

**Example:**
Dose/fraction: 7 Gy at depth of 3 mm
Applicator size: 30 mm  Used current: 1.6 mA
Esteya calculated time: 2:36.3 which is equivalent to 2.57 min
Calculated time: Dose/ (Measured Dose Rate x measured PDD)
7/(0.811 x 0.811) = 2:35.5 (MIN 5:55) which is 2.59 min
(Calculated - Esteya)/calculated x 100 = -0.8%
## Dose rate vs. mA

### Dose rate for Esteya

#### 1) Current: 1.6 mA

<table>
<thead>
<tr>
<th>Applicator Size (mm)</th>
<th>Dose in Gy</th>
<th>Time (min: sec: ms)</th>
<th>Dose rate at surface (Gy/min)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Actual</td>
<td>Initial</td>
<td>Actual</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>2.151</td>
<td>2.151</td>
<td>2.408</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>2.111</td>
<td>2.111</td>
<td>2.194</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
<td>2.093</td>
<td>2.093</td>
<td>2.205</td>
</tr>
<tr>
<td>25</td>
<td>7</td>
<td>2.085</td>
<td>2.085</td>
<td>2.208</td>
</tr>
<tr>
<td>30</td>
<td>7</td>
<td>2.082</td>
<td>2.082</td>
<td>2.208</td>
</tr>
</tbody>
</table>

Average: 2.2%

#### 2) Current: 0.5 mA

<table>
<thead>
<tr>
<th>Applicator Size (mm)</th>
<th>Dose in Gy</th>
<th>Time (min: sec: ms)</th>
<th>Dose rate at surface (Gy/min)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Actual</td>
<td>Initial</td>
<td>Actual</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0.031</td>
<td>0.031</td>
<td>0.225</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>0.032</td>
<td>0.032</td>
<td>0.227</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>0.038</td>
<td>0.038</td>
<td>0.246</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>0.035</td>
<td>0.035</td>
<td>0.236</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>0.031</td>
<td>0.031</td>
<td>0.234</td>
</tr>
</tbody>
</table>

Average: 2.9%

#### 3) Current: 1.0 mA

<table>
<thead>
<tr>
<th>Applicator Size (mm)</th>
<th>Dose in Gy</th>
<th>Time (min: sec: ms)</th>
<th>Dose rate at surface (Gy/min)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Actual</td>
<td>Initial</td>
<td>Actual</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>2.073</td>
<td>2.073</td>
<td>2.945</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>2.073</td>
<td>2.073</td>
<td>2.945</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>2.078</td>
<td>2.078</td>
<td>3.032</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>2.082</td>
<td>2.082</td>
<td>3.032</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>2.082</td>
<td>2.082</td>
<td>3.032</td>
</tr>
</tbody>
</table>

Average: 2.1%
## Esteya time vs. calculated time

### 7 Gy at 3 mm depth

<table>
<thead>
<tr>
<th>Applicator Diameter (cm)</th>
<th>Actual Treatment Time (min)</th>
<th>Calculated Treatment Time (min)</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>2.572</td>
<td>2.56</td>
<td>-0.466563</td>
</tr>
<tr>
<td>2.5</td>
<td>2.61</td>
<td>2.57</td>
<td>-1.532567</td>
</tr>
<tr>
<td>2.0</td>
<td>2.653</td>
<td>2.714</td>
<td>2.29928383</td>
</tr>
<tr>
<td>1.5</td>
<td>2.725</td>
<td>2.692</td>
<td>-1.2110092</td>
</tr>
<tr>
<td>1.0</td>
<td>2.8033</td>
<td>2.894</td>
<td>3.23547248</td>
</tr>
</tbody>
</table>

7 Gy @ 3mm
## Esteya vs. calculated time
### 7 Gy at 2mm depth

<table>
<thead>
<tr>
<th>Applicator Diameter (cm)</th>
<th>Actual Treatment Time (min)</th>
<th>Calculated Treatment Time (min)</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>2.403</td>
<td>2.397</td>
<td>-0.2496879</td>
</tr>
<tr>
<td>2.5</td>
<td>2.44</td>
<td>2.41</td>
<td>-1.2295082</td>
</tr>
<tr>
<td>2.0</td>
<td>2.48</td>
<td>2.52</td>
<td>1.61290323</td>
</tr>
<tr>
<td>1.5</td>
<td>2.537</td>
<td>2.52</td>
<td>-0.6700828</td>
</tr>
<tr>
<td>1.0</td>
<td>2.6</td>
<td>2.66</td>
<td>2.30769231</td>
</tr>
</tbody>
</table>

7 Gy @ 2mm
<table>
<thead>
<tr>
<th>Applicator Diameter (cm)</th>
<th>Actual Treatment Time (min)</th>
<th>Calculated Treatment Time (min)</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>2.248</td>
<td>2.243</td>
<td>-0.2224199</td>
</tr>
<tr>
<td>2.5</td>
<td>2.277</td>
<td>2.258</td>
<td>-0.8344313</td>
</tr>
<tr>
<td>2.0</td>
<td>2.308</td>
<td>2.33</td>
<td>0.95320624</td>
</tr>
<tr>
<td>1.5</td>
<td>2.363</td>
<td>2.355</td>
<td>-0.3385527</td>
</tr>
<tr>
<td>1.0</td>
<td>2.42</td>
<td>2.45</td>
<td>1.23966942</td>
</tr>
</tbody>
</table>

7 Gy @ 1 mm
Daily verification

Lynn Cancer Institute

Daily Treatment Q.A. for Estey Skin Brachytherapy

Patient Name:
Physician:
Applicator selection (circle appropriate applicator):

10  15  20  25  30

<table>
<thead>
<tr>
<th></th>
<th>Fraction #1</th>
<th>Fraction #2</th>
<th>Fraction #3</th>
<th>Fraction #4</th>
<th>Fraction #5</th>
<th>Fraction #6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Clinical Application: useful beam
Simulation
Treatment
Treatment field verification (new design on the way!)
Special thanks to:
Casey Curley*** (FAU student)
Resat Aydin (Ashland)
Regina Fulkerson (Standard Imaging)