Implementation and Clinical Use of Electronic Brachytherapy (EB)

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Conflict of Interest Statement:

- Partial financial support was provided by Xoft, Inc.

Outline:

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

Brachytherapy:

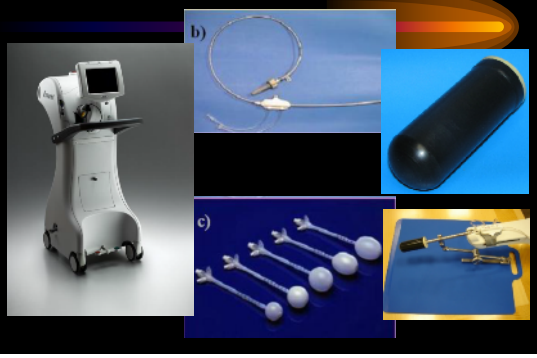
- Internal radiation therapy that involves placing radioactive sources inside the patient close to or in the tumor.

Electronic Brachytherapy:

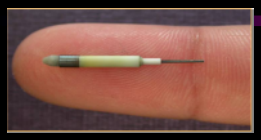
- Internal radiation therapy that involves placing a miniature x-ray source inside the patient close to or in the tumor.

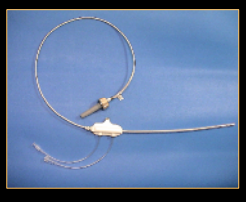
Axxent:

System Components:



X-ray Source

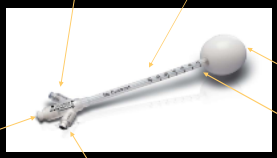




- Tube diameter = 2.25 mm
- Requires a cooling catheter
  - Assembly diameter = 5.4 mm
- Nominal dose rate:
  - 0.6 Gy/min at 3 cm in water

Axxent Controller:

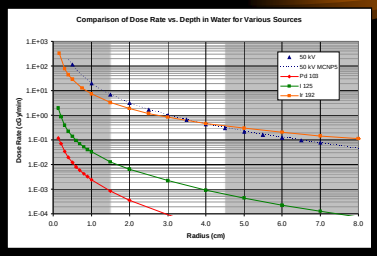
Breast Applicator:



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

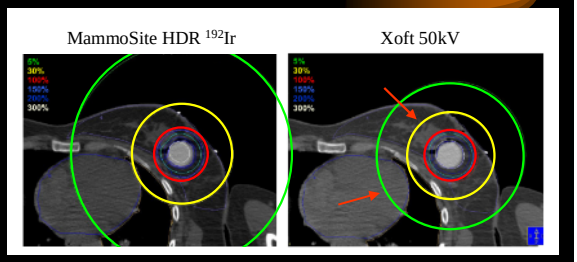
Source Characteristics:



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

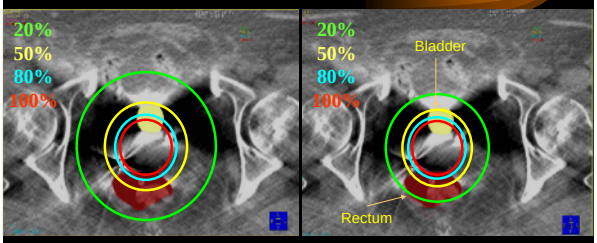
Graph courtesy of Xoft

Intracavity APBI:



Dickler et al. *Brachytherapy*, 2007

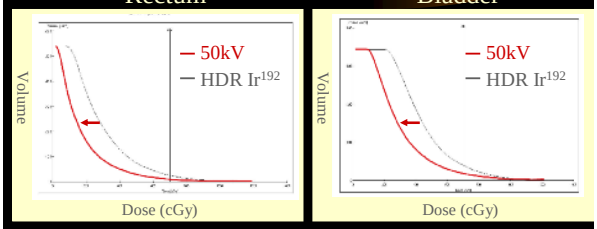
Vaginal Cylinder:



HDR Ir^{192} 50kV EBT

Vaginal Cylinder DVH:

Rectum Bladder



Acceptance and Commissioning:

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

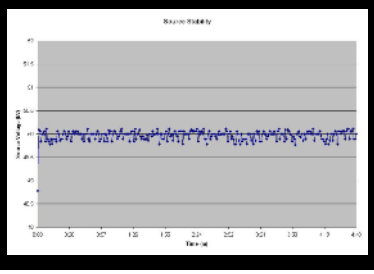
Well-chamber Constancy:

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

Well Chamber Constancy Check				
RIH Unit	Mean Reading (pA):	41.90	SD:	0.02
Xoft Unit	Mean Reading (pA):	41.96	SD:	0.02
% Difference in Readings:				0.14%

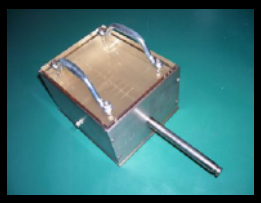
Beam Stability:

- Simulated treatment data extracted from controller and plotted.



Source Positional Accuracy :

QA Test Fixture



(Provided by Xoft)

GAFCHROMIC EBT Film

Source Positional Accuracy :

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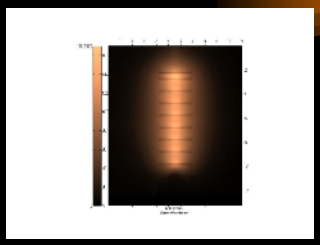
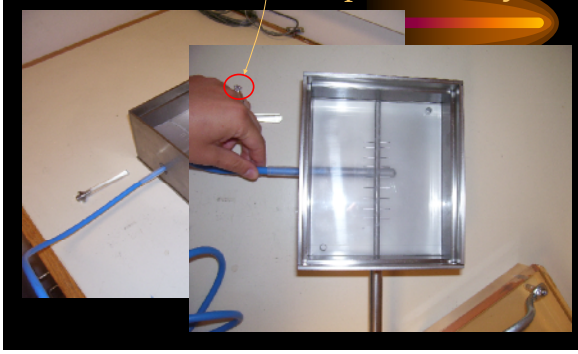


Digitized image of film positioned w/in fixture during exposure

Output Stability :

DAYS UNTIL WEDDING:
16

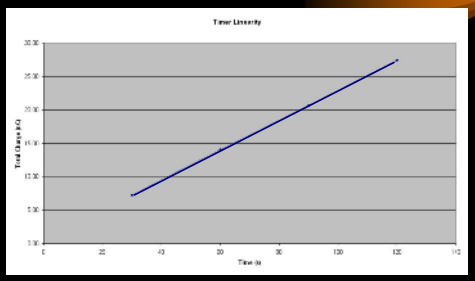
Output Stability :



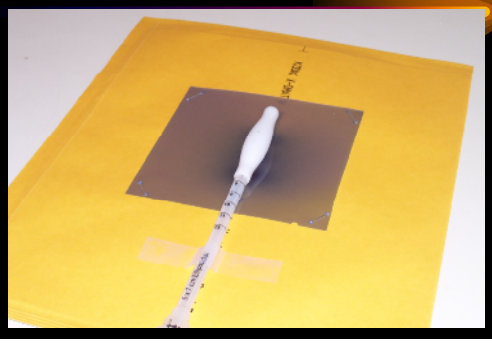
Output Stability :

Source Stability Measurements								
Rate (nA)	Trial Number							
Dwell Position (cm)	1	2	3	4	5	Ave.	SD	Rel. SD
24.5	0.006	0.006	0.006	0.006	0.006	0.006	0.000	0.00
23.5	0.022	0.022	0.022	0.022	0.022	0.022	0.000	0.00
22.5	0.110	0.112	0.111	0.111	0.111	0.111	0.001	0.01
21.5	0.190	0.199	0.199	0.200	0.199	0.197	0.004	0.02
20.5	0.077	0.079	0.080	0.080	0.080	0.079	0.001	0.02
Total Rate (nA)	0.405	0.418	0.418	0.418	0.418	0.416	0.006	0.01

Timer Linearity:



Marker/Source Position Coincidence:



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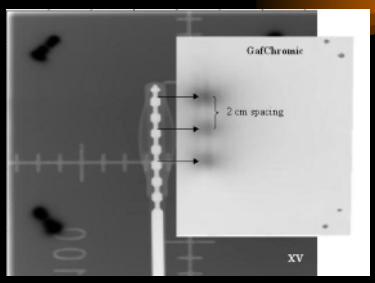
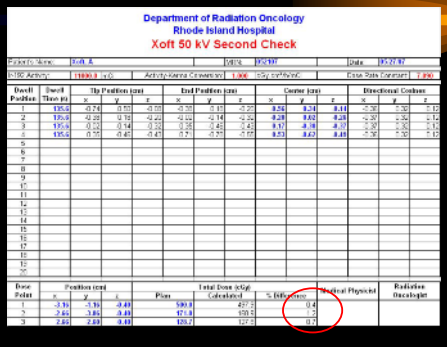


Controller Functionality and Safety Interlocks:

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

Treatment Planning Data Verification:



Department of Radiation Oncology
Rhode Island Hospital
Xoft 50 kV Second Check

Dwell Position	Dwell Time (s)	Tip Position (cm)			End Position (cm)			Center (cm)			Directional Cosines		
		x	y	z	x	y	z	x	y	z	x	y	z
1	135.0	-0.74	0.10	-0.03	-0.32	-0.11	-0.22	0.24	0.24	0.11	-0.30	0.30	0.12
2	135.0	-0.20	0.16	-0.22	-0.32	-0.14	-0.36	0.28	0.02	0.28	-0.30	0.30	0.12
3	135.0	0.02	0.14	0.33	0.36	0.48	0.43	0.17	0.19	0.17	-0.30	0.30	0.12
4	135.0	0.55	0.46	0.47	0.7	0.55	0.55	0.53	0.47	0.49	-0.30	0.30	0.12
5													
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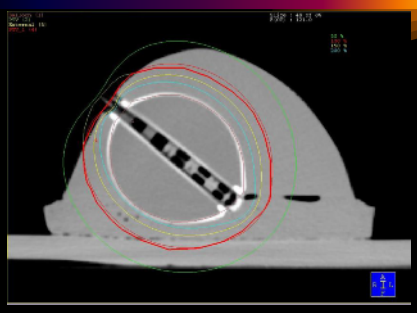
Dose Point	Position (cm)			Total Dose (cGy)				
	x	y	z	Plan	Calculated	% Difference	Medical Physicist	Radiation Oncologist
1	-3.16	-3.16	-3.49	500.0	497.2	0.4		
2	2.66	-3.86	3.49	171.0	169.5	-1.2		
3	2.66	2.89	3.49	133.7	127.5	0.7		

Treatment Planning Data Verification:



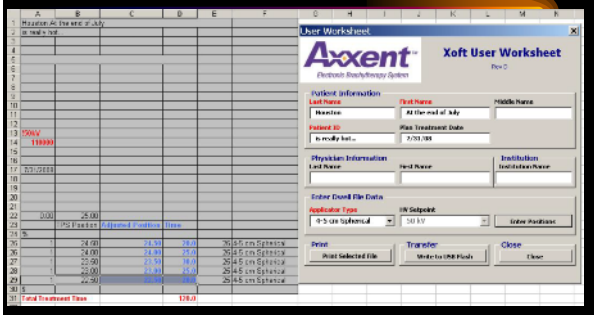
Treatment Planning:

- TG-43 parameters entered into brachytherapy planning system
  - Described by Rivard *et al*., Dosimetry parameters for the Xoft Axxent X-Ray Source," Med. Phys. 33, 4020-4032 (2006).
- ~ 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.

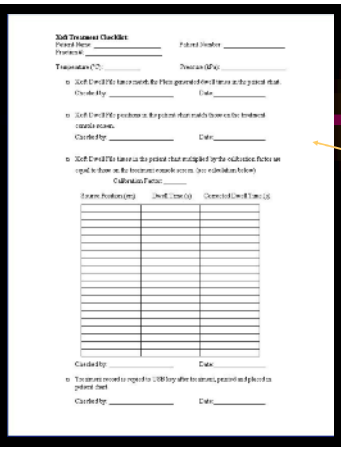
Treatment Planning:



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:



Treatment Checklist

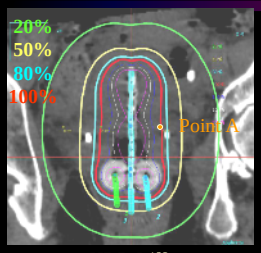
Conclusion: EBT

- 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

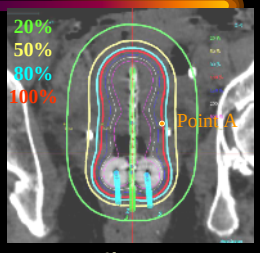
Any questions?

Future Directions of EBT

Tandem and Ovoid:



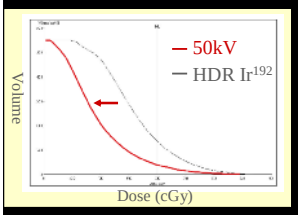
HDR Ir^{192}



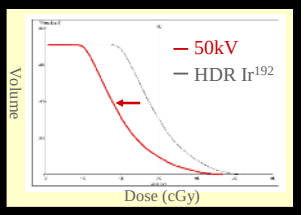
50kV EBT

T&O DVH:

Rectum

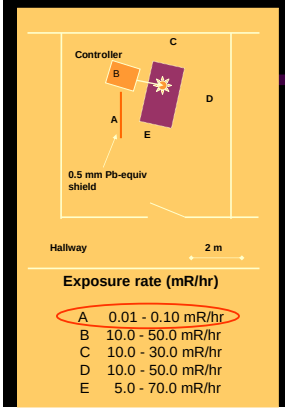


Bladder



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

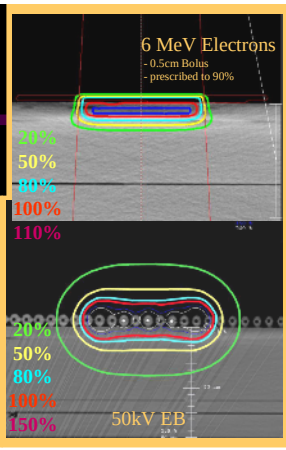


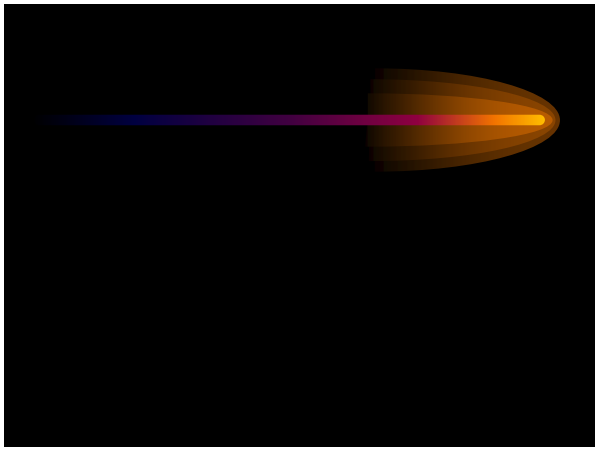
Shielding:

- 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:

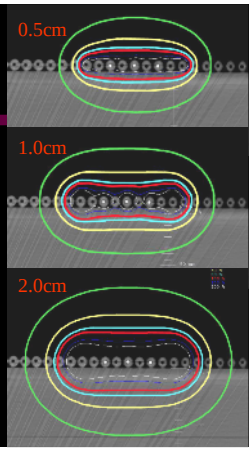
- 50kV EBT approaches electron distribution in an ideal homogenous surface contour





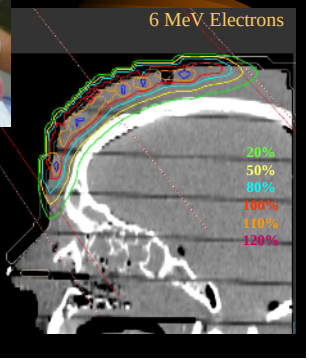
Intra-op Planning:

- 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.



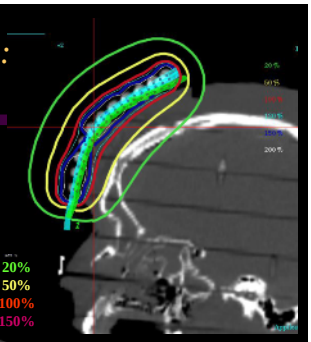
Skin Malignancy:

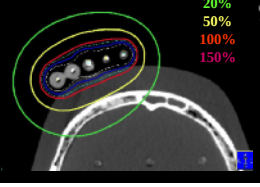
- Electron beam limitations
  - Inhomogeneous dose with irregular surface contour.
  - Requires wide margin due to penumbra and isodose constriction at depth.
    - May be difficult to exclude critical structures such as the eye.
  - Relative surface sparing at low energy



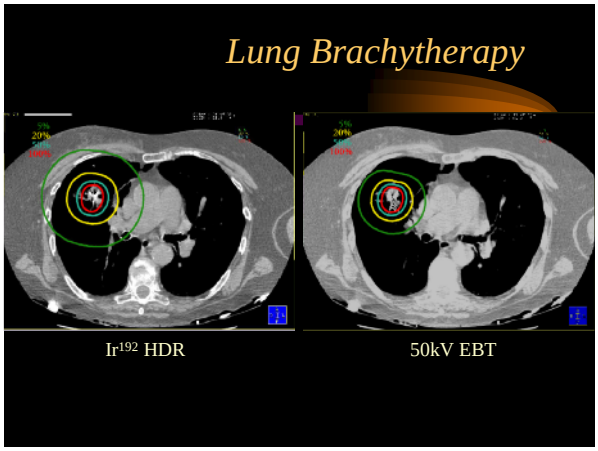
EBT for Skin:

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





50kV EBT


Lung Brachytherapy
Ir192 HDR
50kV EBT