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Clinical Implementation of HDR: Afterloader and Applicator Selection

AAPM Meeting 2015

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Disclosures

- I will try avoid mentioning vendor/manufacturer names
- However, I will mention certain models of HDR remote afterloader units (**RAU**s)
- Not recommending one brand over another
- No disclosures

A Little History…

Phys. Med. Biol. **51** (2006) R303–R325 doi:10.1088/0031-9155/51/13/R18

REVIEW

Brachytherapy technology and physics practice since 1950: a half-century of progress

Jeffrey F Williamson

- Late 1970s: Introduction of a single-stepping source RAU using a miniaturized high activity Ir-192 source welded onto the end of a cable (Gauwerky, 1977)

Fast Forward…

- Late 1990s-Early 2000s:
  - HDR replacing LDR in many centers
  - LDR equipment being discontinued by many manufacturers
- 2004: ICRP Publication 97

Prevention of high-dose-rate brachytherapy accidents

ICRP Publication 97

Approved by the Commission in August 2004

  - estimated >1500 units in > 1000 centers across the world
  - ~500,000 treatments/year
- 2015: Where are we at currently with HDR technology?

Learning Objectives

- To become familiar with the different HDR RAUs and applicators available on the market
- To learn how the transition from one RAU to another type of RAU affected a particular institution’s clinical practice (WUSM)
- → To gain an understanding of how to select an HDR afterloader that best fits an institution’s needs

Selecting an HDR RAU

“Where do we go for guidance?”

- Internet, vendor exhibits, colleagues, site visits

- It’s more than just selecting an HDR RAU…
  - Applicators
  - Treatment planning system
  - Treatment Console

- → A remote afterloading (RAL) **system** that safely and accurately integrates the applicators, treatment planning, and treatment delivery

MicroSelectron

- Largest installed base worldwide
- >1500 clinics in > 80 countries
- 3.6 mm active source encapsulated in stainless steel and welded onto the end of a cable (0.9 mm o.d.)
- Height adjustable
- Forward stepping
- Three step sizes: 2.5, 5, 10mm
- 25,000 runs
- Integrates with MOSAIQ and other oncology information systems (OISs)

MicroSelectron

- Scalable afterloading system that can be tailored to a clinic's needs
- start off with 6, scale up to 18, or 30 channels
- i.e., intracavitary (fewer channels) vs. interstitial (more channels)

GammaMedplus iX

- 5th gen in a line of afterloaders
- 3.5 mm source encapsulated into tip of braided cable o.d. of 0.9 mm
- Height adjustable
- Distal to proximal stepping
- 60 dwells per, 1-10 mm, 1 mm increments
- 5000 runs
- Choose 24 or 3 channel system
- Integrates with Aria OIS

GammaMedplus iX

- Multiple safety features
- Treatment Console—unique code for each fraction—must be entered into console prior to initiating treatment
- Built-in treatment length safety feature: Fixed treatment distance (correct TGT + app = 1300 mm)
- Applicator end test to verify app connection integrity **and treatment length**

VariSource iX

- 2 Ir-192 pellets placed in a hole at the end of a Ni-Ti wire & closed by welding a 1mm thick plug → 5 mm active length
- "Thinnest wire": 0.59mm (vs. ~0.9mm)
- Distal to proximal stepping
- 60 dwells, variable step from 2 to 99 mm, 1 mm increments
- **1000 runs (frequency of source exhanges & QA)**
- 20 channels (not scalable)
- Internal CamScale (expedite daily QA)
- Treatment Console—unique code required for each fraction
- Integrates with Aria OIS

Flexitron

- 2 mm Ir-192 pellet with a dimension of Ø 0.8 × 3.5 mm after encapsulation
- Forward stepping
- 400 dwells per channel, 1 mm step size
- 30,000 runs
- 10, 20, 30, or 40 channels
- Integrates with OIS

Flexitron

- Greater emphasis on safety and efficiency.
- Brochure refers to ICRP Publication 97 (2004)
  - "> 500 HDR accidents (including one death) have been reported along the entire chain of procedures from source packing to delivery of dose. Human error has been the prime cause of radiation events"
- To reduce "use errors"
  - Transfer tubes all the same length
  - Reference "0" position at entrance of catheter
    - Uncertainty in catheter tip reconstruction – not a problem
    - No need to account for variable offsets from the tip
    - Dwell position # reflects dwell position distance in mm from "zero"

Summary

Table 4.1 Characteristics of currently used high dose-rate remote afterloaders

Manufacturer				
Afterloader	GammaMed*plus* (iX and 3/24 iX)	VariSource iX	microSelectron	Flexitron
Number of channels	3 or 24	20	18	40
Number of dwell positions per channel	60	60	48	401
Step size	1–10 mm in 1 mm increments	2–99 mm in 1 mm increments	2.5, 5.0, 10.0 mm	1.0 mm
Min. dwell time	0.1 second (s)	0.1 s	0.1 s	0.1 s
Max. dwell time	999.9 s	999.9 s	999.9 s	999.9 s
Direction of travel	Source travels to distal position then steps back	Source travels to distal position then steps back	Forward	Forward
Source travel	71 → 130 cm	70 → 150 cm	150 cm	140 cm
Source mechanical life	5,000 transfers	1,000 transfers	25,000 transfers	30,000 transfers
Safe construction	Tungsten	Tungsten	Tungsten	Tungsten
Maximum source strength	15 Ci	11 Ci	14 Ci	22 Ci
Source active length	3.5 mm	5 mm	3.6 mm	3.5 mm
Source diameter	0.6 mm	0.34 mm	0.6 mm	0.6 mm
Wire/cable diameter	0.9 mm	0.59 mm	0.9 mm	0.85 mm

Intraoperative Irradiation: Techniques and Results, Gunderson et al., 2011
Comprehensive Brachytherapy: Physical and Clinical Aspects, Venselaar et al., 2012

Considerations for Selecting the RAL System

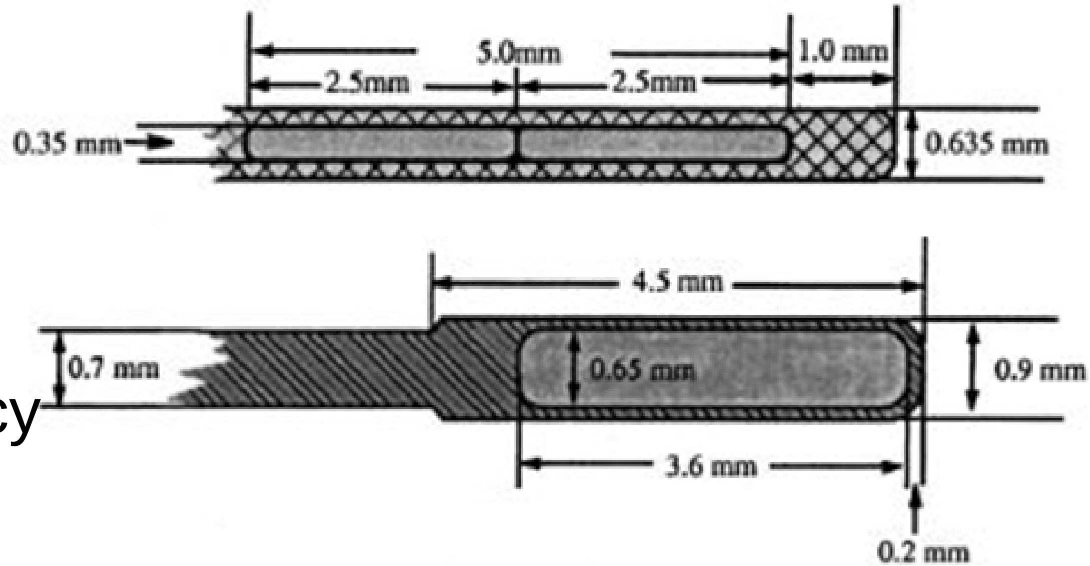
- What sites will be treated?
- How will these sites be implanted?
  - Intracavitary/intraluminary (RAU with few channels) vs. Interstitial/mold (more channels)
- What applicators do we need?
  - Assembly, durable/re-usable, sterilization issues, CT/MRI compatible
- What type of planning do we want to accomplish? Film-based? CT? MRI? 3D capabilities of the TPS?
- How many procedures? Will number of runs be an issue? Require frequent source exchanges?
- What safety features or “extras” does the RAU have?
  - Fixed transfer tube length, camera to check source position, treatment console codes

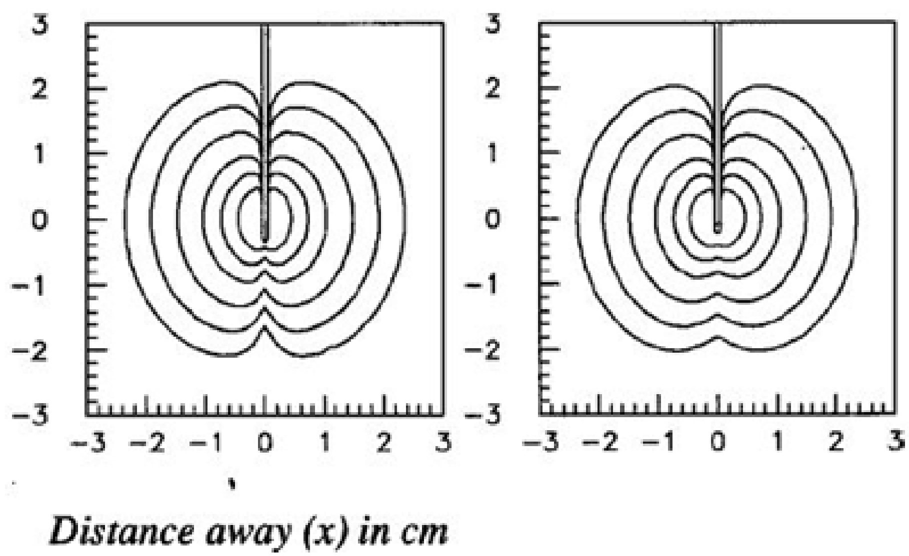
Example: RAL1 → RAL2**

- WUSM transitioned from one RAL system to a different type of RAL system back in 2006
- The following slides are examples of how changing to another new RAL system led to changes in the clinical workflow, QA, procedures that had been performed (for years) with the old system
- **Not intended to be a head-to-head comparison of the features on these two systems, since they have changed over time

Source Characteristics Matter

- RAL2: Thin wire→Concerns over breakage
- Runs limited to 1000 →increased our frequency of source exchange QA
- 0.1 cm thick encapsulation vs. 0.2 mm
- Greater anisotropy → effected weighting in vaginal cylinder plans





Daskalov et al, *Med Phys*, 25(11): 2200-2208.
Angelopoulos et al, *Med Phys*, 27(11): 2521-2527.

Daily QA on RAL2

Mostly similar to before, **except…**

- Replaced positional accuracy check with internal camera instead of film

- Busy→Added checks on number of runs

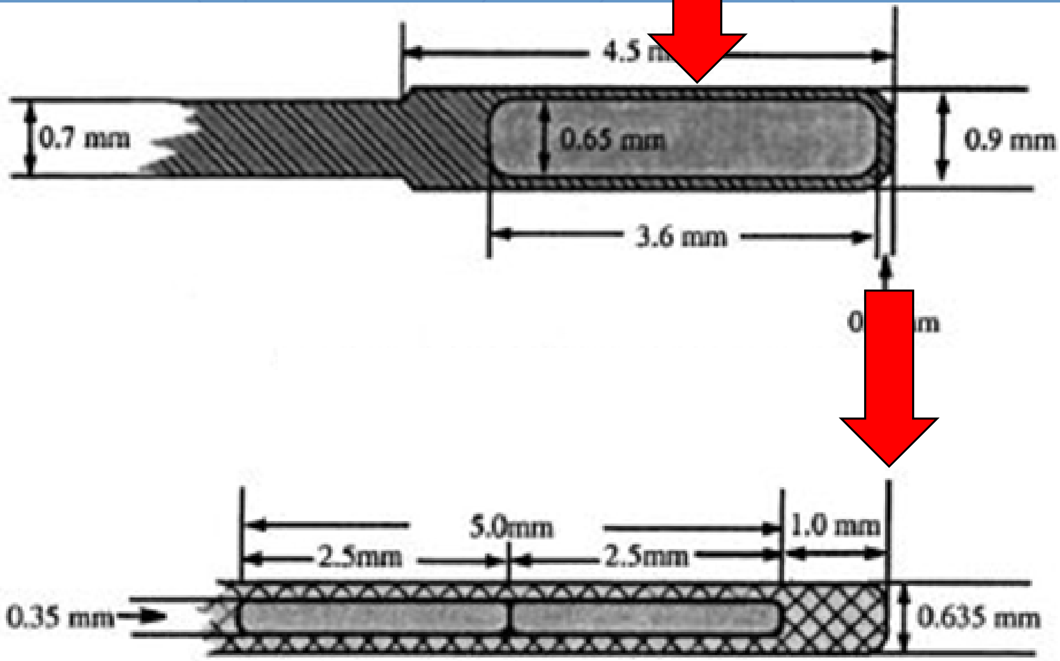
1. Safety Checks		Date:	
Acceptable			
Y	N		
☐	☐	Door Interlock	
☐	☐	Emergency Stop	
☐	☐	Room/Machine indicator lights/Display test	
☐	☐	Visual/Audible Contact	
☐	☐	Emergency Equipment Present	
☐	☐	Instruction Manual Present	
☐	☐	Prime Alert/Backup Battery Function	
☐	☐	TCS Date/Time Correct	
☐	☐	TCS Source Strength Correct	
☐	☐	Survey Meter Present	
☐	☐	Number of source runs ______	(< 1000?)
☐	☐	Number of dummy runs ______	(< 1640?)

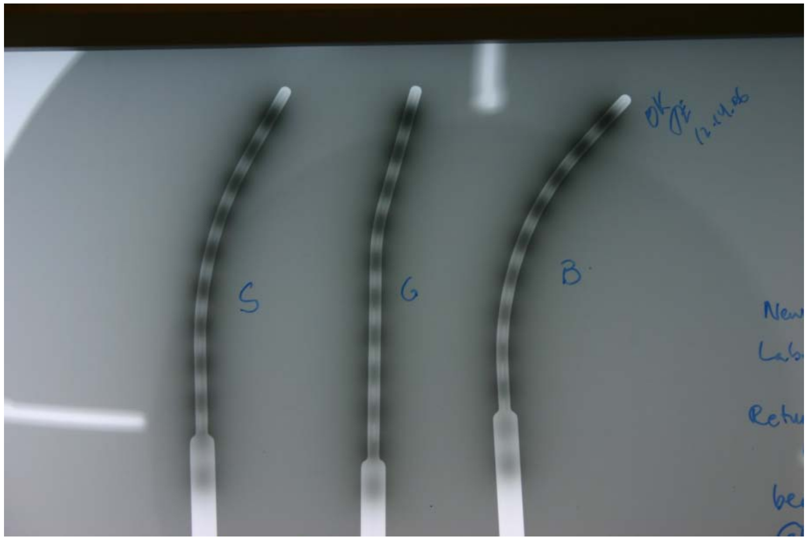
Dwell Position Matters

- How does the RAL system define a dwell position?

- Can vary between units
  - RAL1: Center of the source in mm
  - RAL2: Tip of wire in cm

- RAL2: 0.35cm offset→ e.g., programmed dwell position of 119.5cm means the center of the source falls at 119.15cm





Daskalov et al, *Med Phys*, 25(11): 2200-2208.
Angelopoulos et al, *Med Phys*, 27(11): 2521-2527.

Transfer Guide Tubes (TGTs)

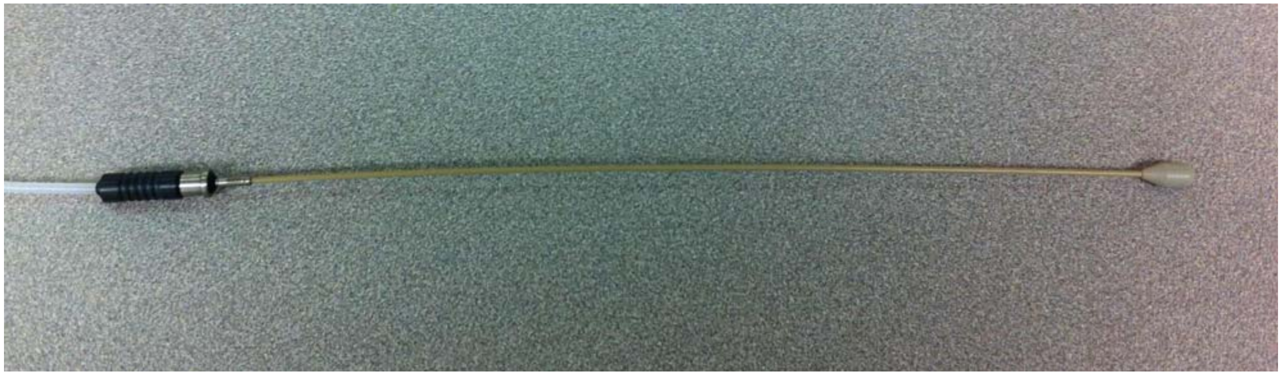
RAL1:

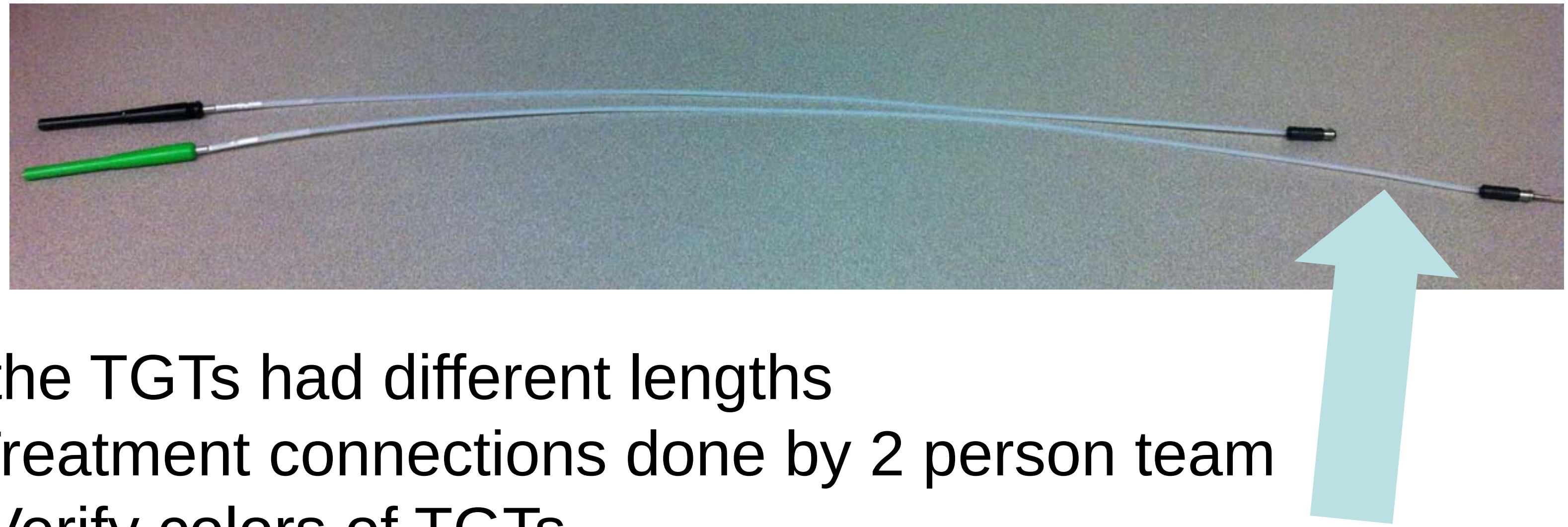
- 1 type of TGTs for all intracavitary GYNs
- 1 type of TGTs for interstitial treatments

RAL2:

- 1 set of TGTs for T&Os
- 1 set of TGTs for ring & VC
- 1 set of TGTs for interstitial
- 1 set of TGTs for Heyman Capsules (HC)
- → so many more TGTs to handle!

Different Lengths: HC TGTs vs. T&O TGTs





And the TGTs had different lengths

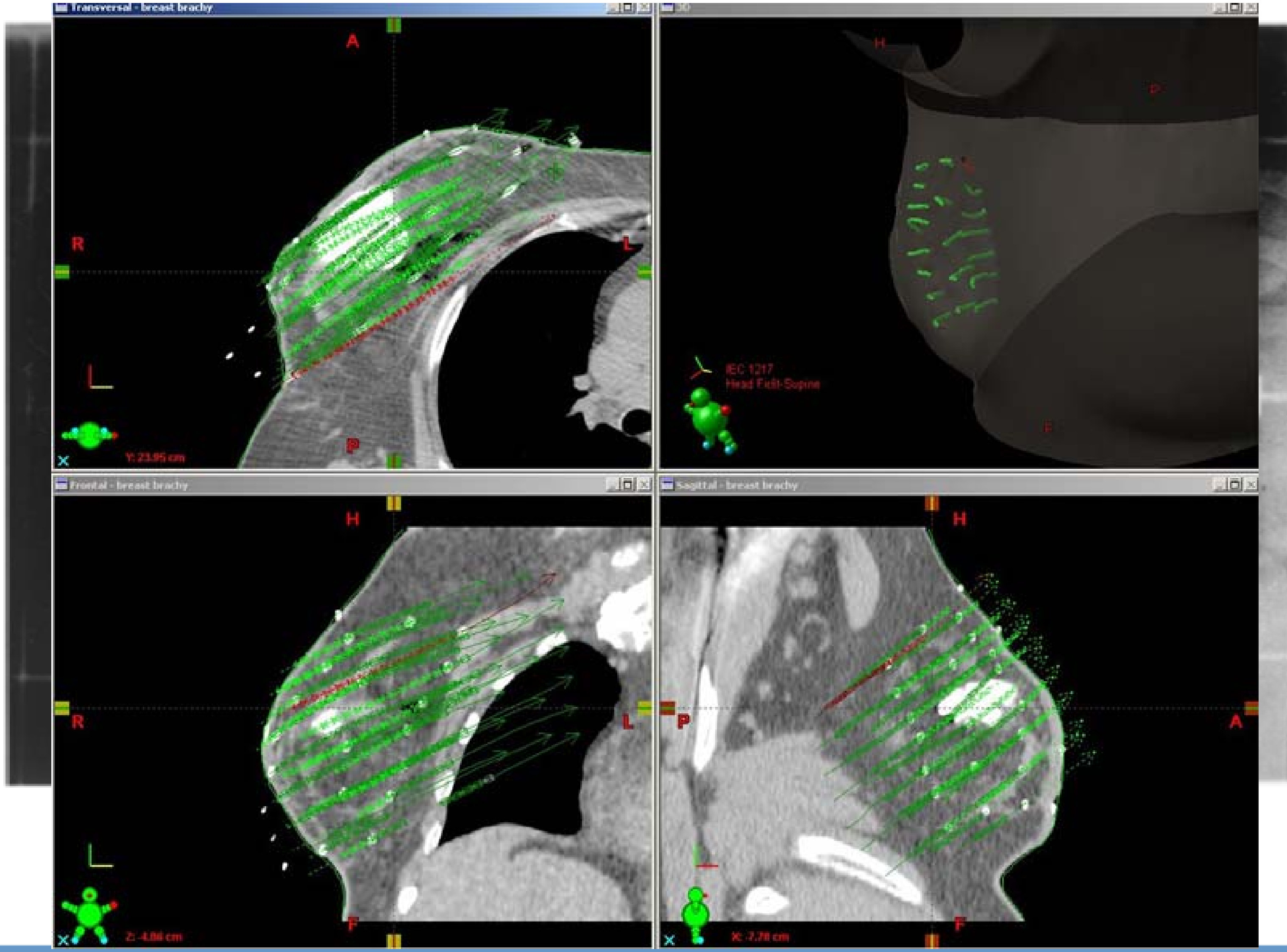
- →Treatment connections done by 2 person team
- → Verify colors of TGTs
- → Measure lengths of TGTs
- → Prior to every treatment

Applicator Differences

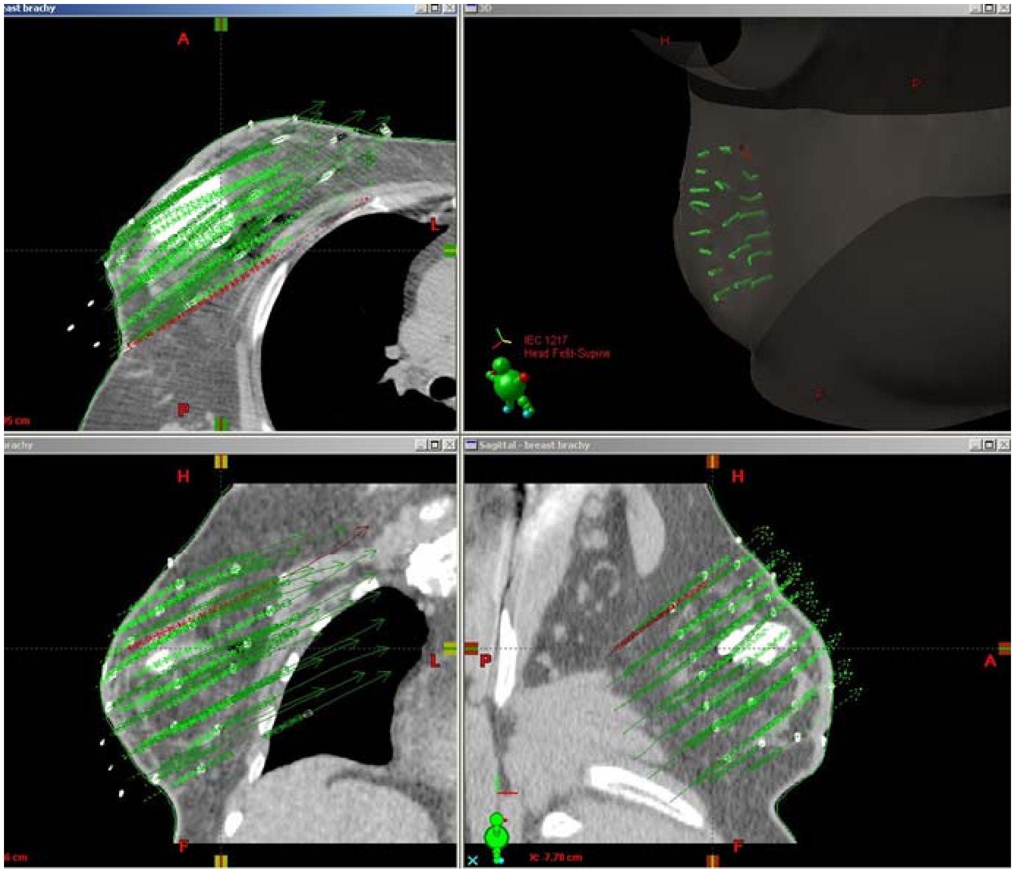
- VC
- More components
- If not assembled correctly → treatment positions are shifted relative to VC → incorrect dose delivery
- → Source guide tube measured prior to insertion and treatment
- → TGT + VC length measured prior to every treatment

Film-based → CT-based Planning

2003



CT-based Planning

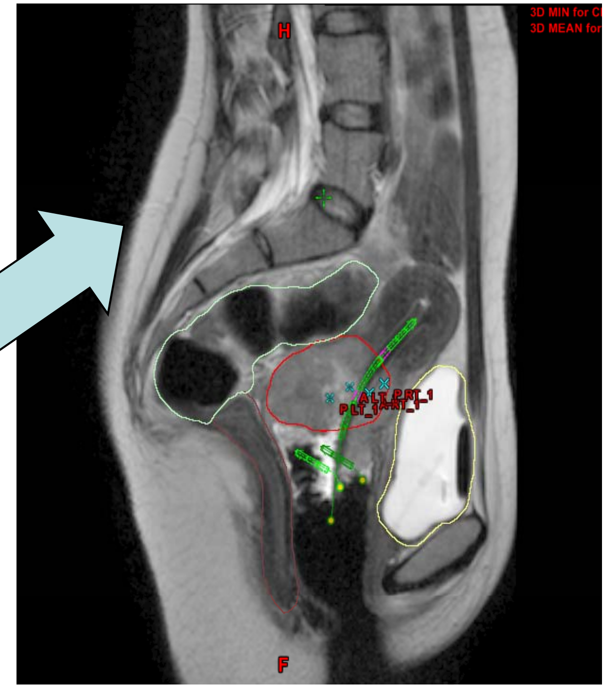


- RAU2:
  - Visualization in multi-planar reconstructed views
  - Ease of contouring
- RAU1: TPS was very limited with 3D visualization and contouring capabilities (at that time)

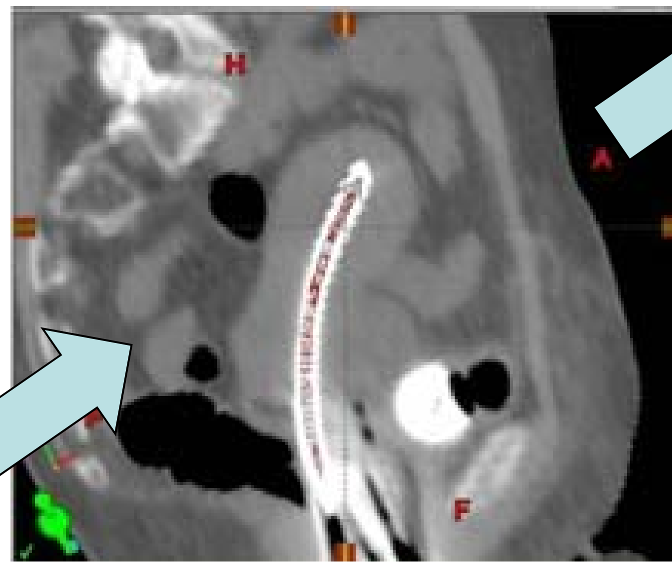
MR-based Planning

- Non-axial MRI acquisitions
- Contour in sagittal views

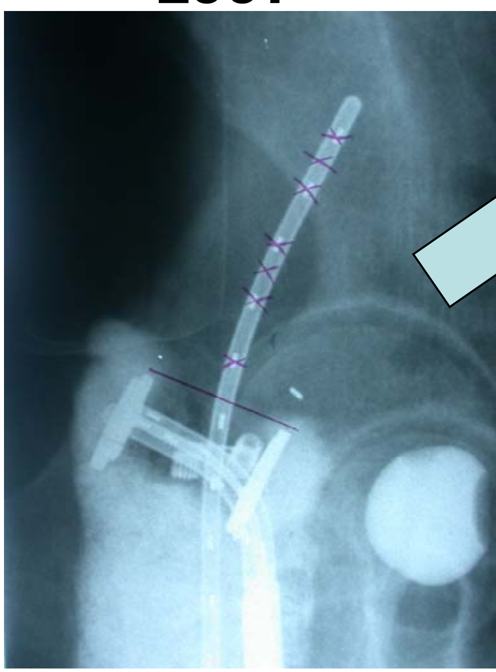
2009



2007



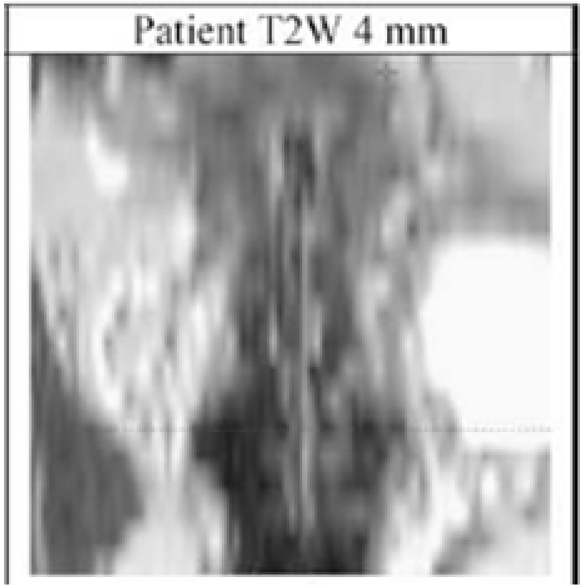
1997

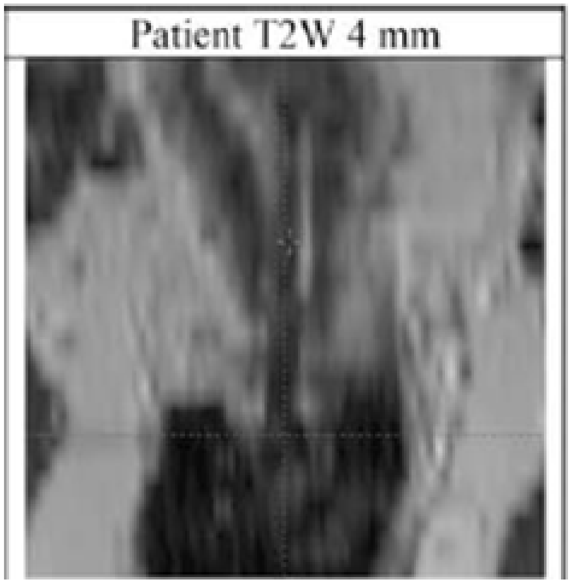


- Image registration (multi-sequence MRI)
- External beam (EB) as well as brachy (BT)
- Plan summation (BT1+BT2+EBRT)

MRI-compatible Applicators

- Plastic (RAU1) or Titanium (RAU2)?
  - Vendor-specific
  - Plastic – weak signal
  - Titanium – susceptibility artifact
  - Use of markers? Probably helpful for plastic, but not for Ti

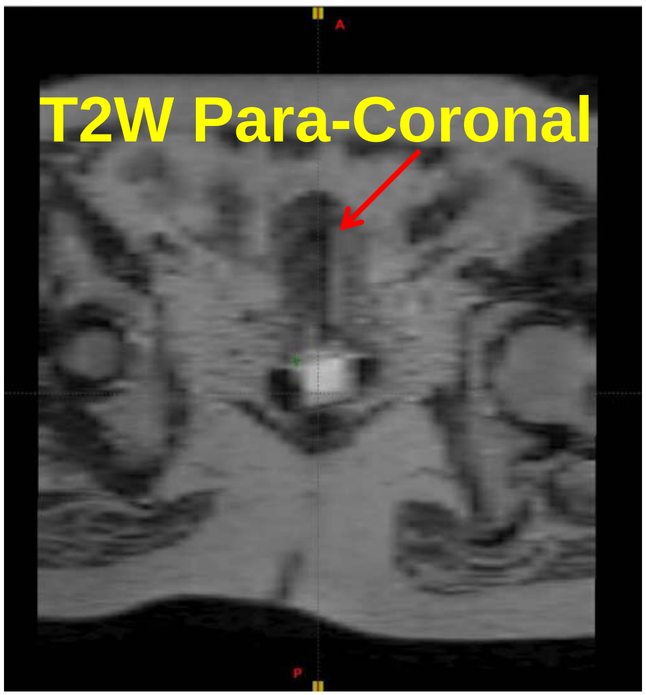


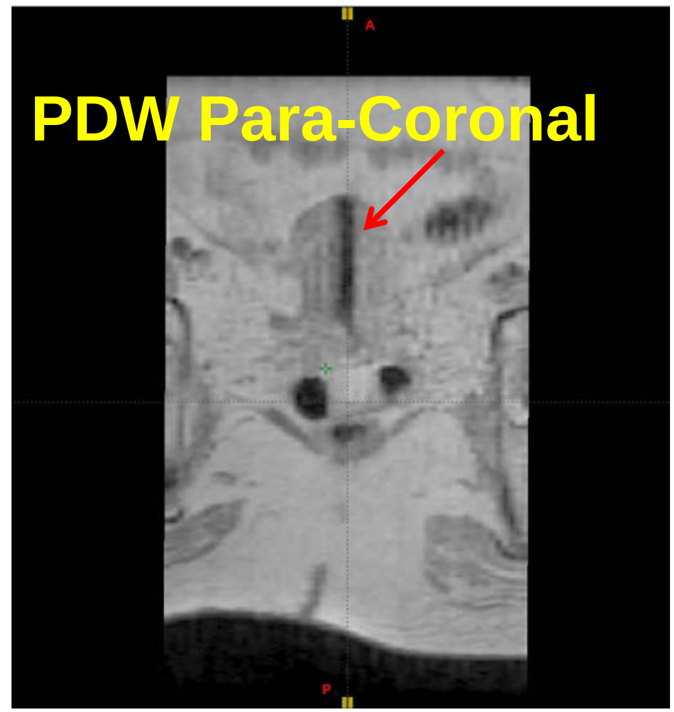


Haack et al, *Radiotherapy and Oncology* 2009;91:187-193.

MRI-compatible Ti Applicators

- For Ti applicator visualization we use multiple MRI sequences to image our GYN patients
  - T2-weighted sequences (“standard”) vs. Proton density-weighted sequences (WUSM)

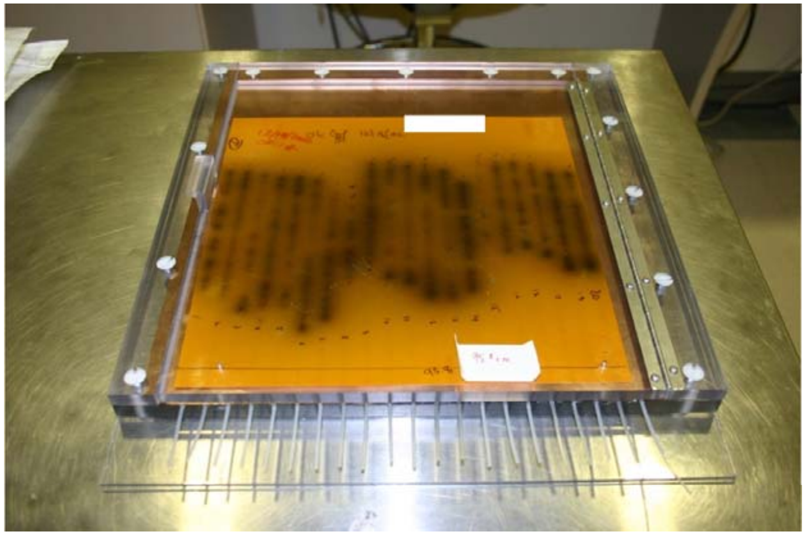




Hu and Esthappan et al, *Radiation Oncology* 2013: 8:16
Dimopoulos et al, *Radiother Oncol.* Apr 2012;103(1):113-122.

Treatment Console Station (TCS)

- Simple operation
- Error codes – meaningful & instructive
- QA mode vs. clinical mode (physics thumbs-up)
- “Autoradiograph mode” (lost this with RAU2)
- Treatment console reports (easy to comprehend and informative)
- Connectivity with OIS (Integrated solutions)
- → Paperless? (if regulatory-wise ok)



Conclusions

- We have described different HDR RAUs and some of the applicators available on the market
- We have described how a RAU and its components (app+TPS + TCS) can affect clinical practice by relating the experience of one institution that transitioned from one RAL to another
- → We have given some perspective as to what considerations should be made by an institution when selecting not just a RAU, but a remote afterloading system