

# **Image based Brachytherapy- HDR applications in Gynecological Tumors**

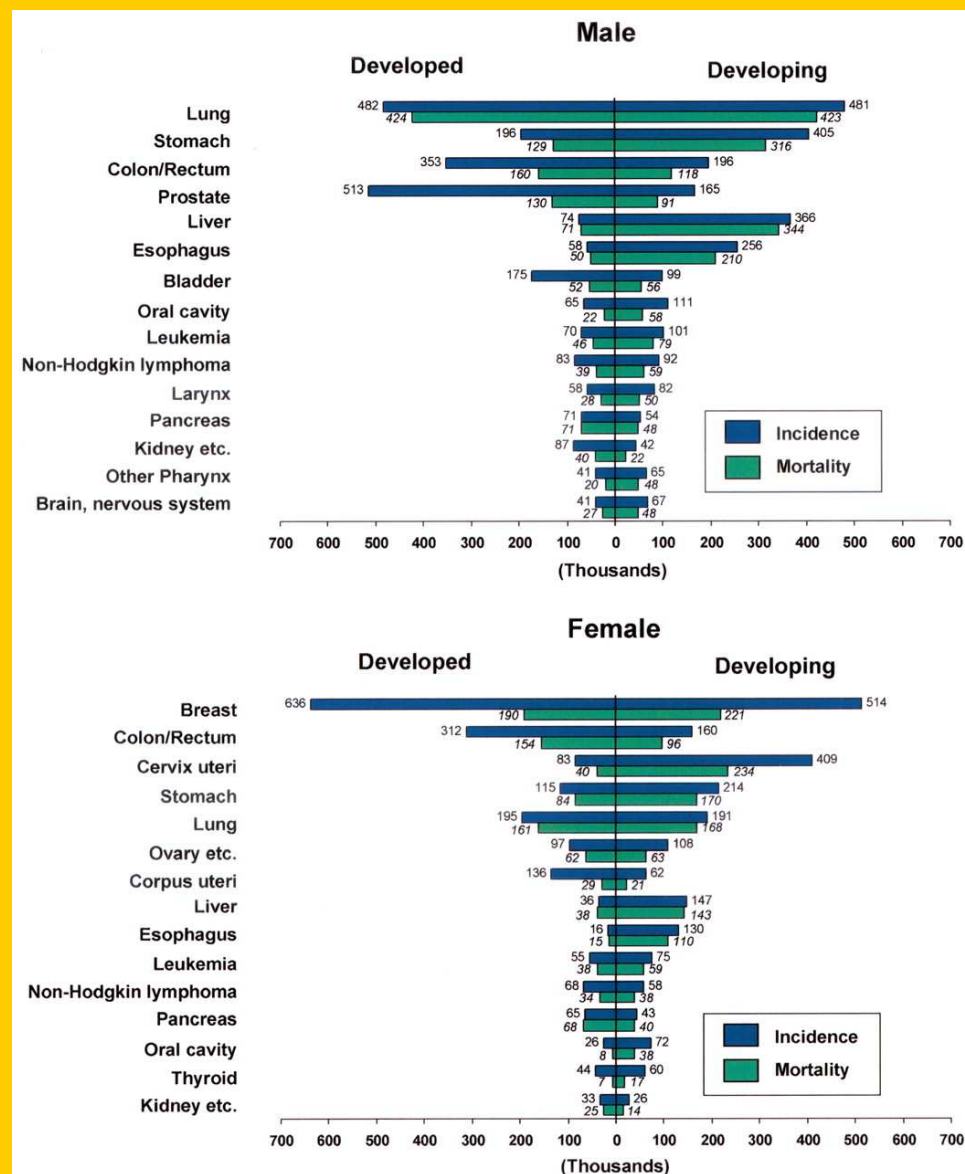
**Yakov Pipman, D. Sc.  
North Shore LIJ Health System**



# **Sites amenable to treatment with HDR Brachytherapy**

- **GYN**
- **Breast**
- **Prostate**
- **Head and Neck**
- **Extremities**
- **Superficial lesions**

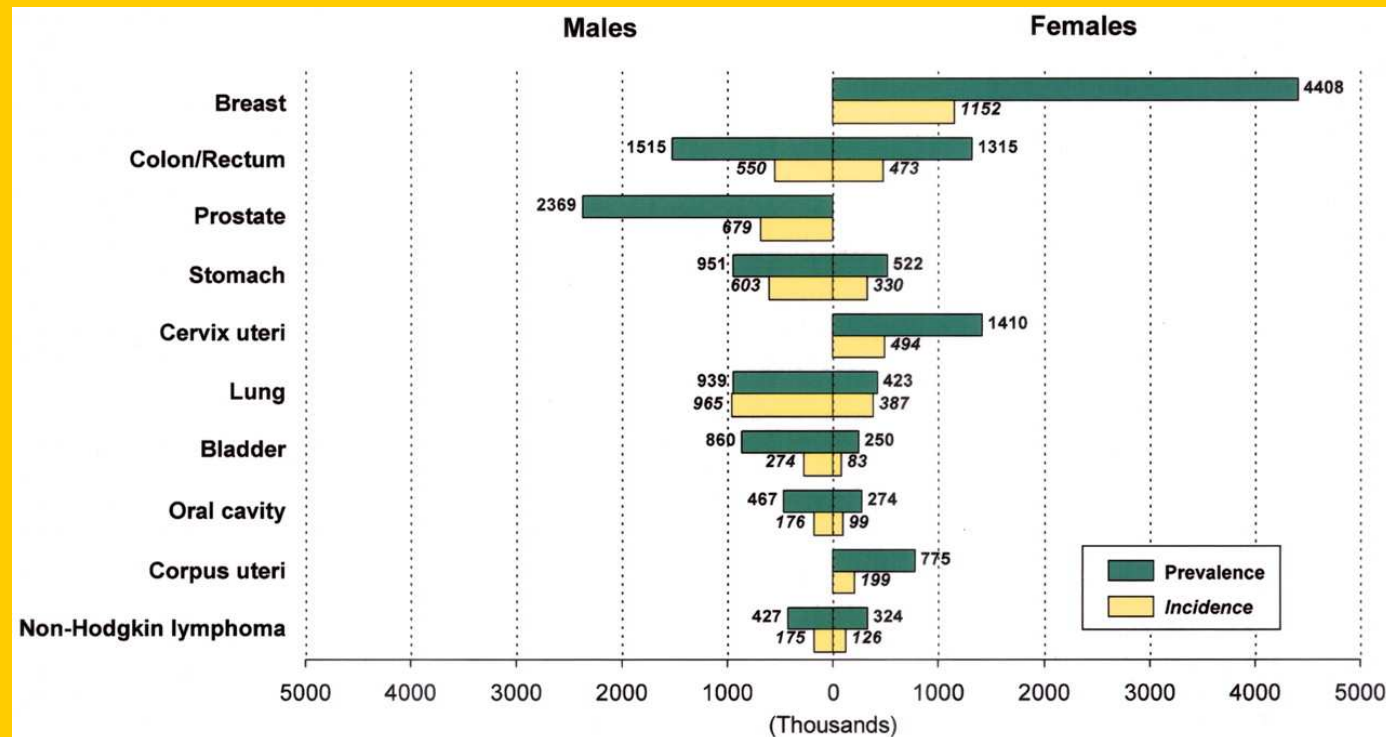
**FIGURE 2 Estimated Numbers of New Cancer Cases (Incidence) and Deaths (Mortality) in 2002**



From Parkin, D. M. et al.  
CA Cancer J Clin 2005;55:74-108.

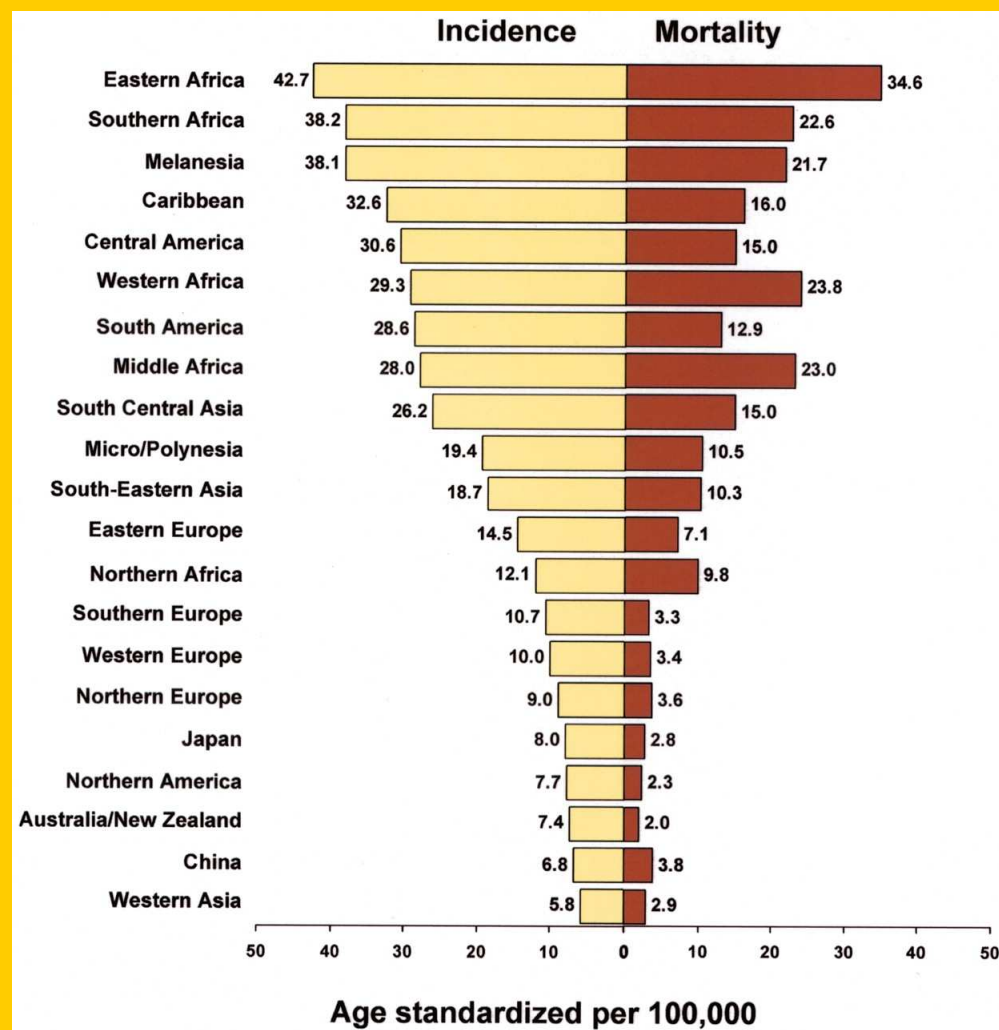
Copyright ©2005 American Cancer Society

**FIGURE 3 Estimated Numbers of New Cancer Cases (Incidence) and Prevalent Cases (Five-year Survival) in 2002**



From Parkin, D. M. et al.  
CA Cancer J Clin 2005;55:74-108.

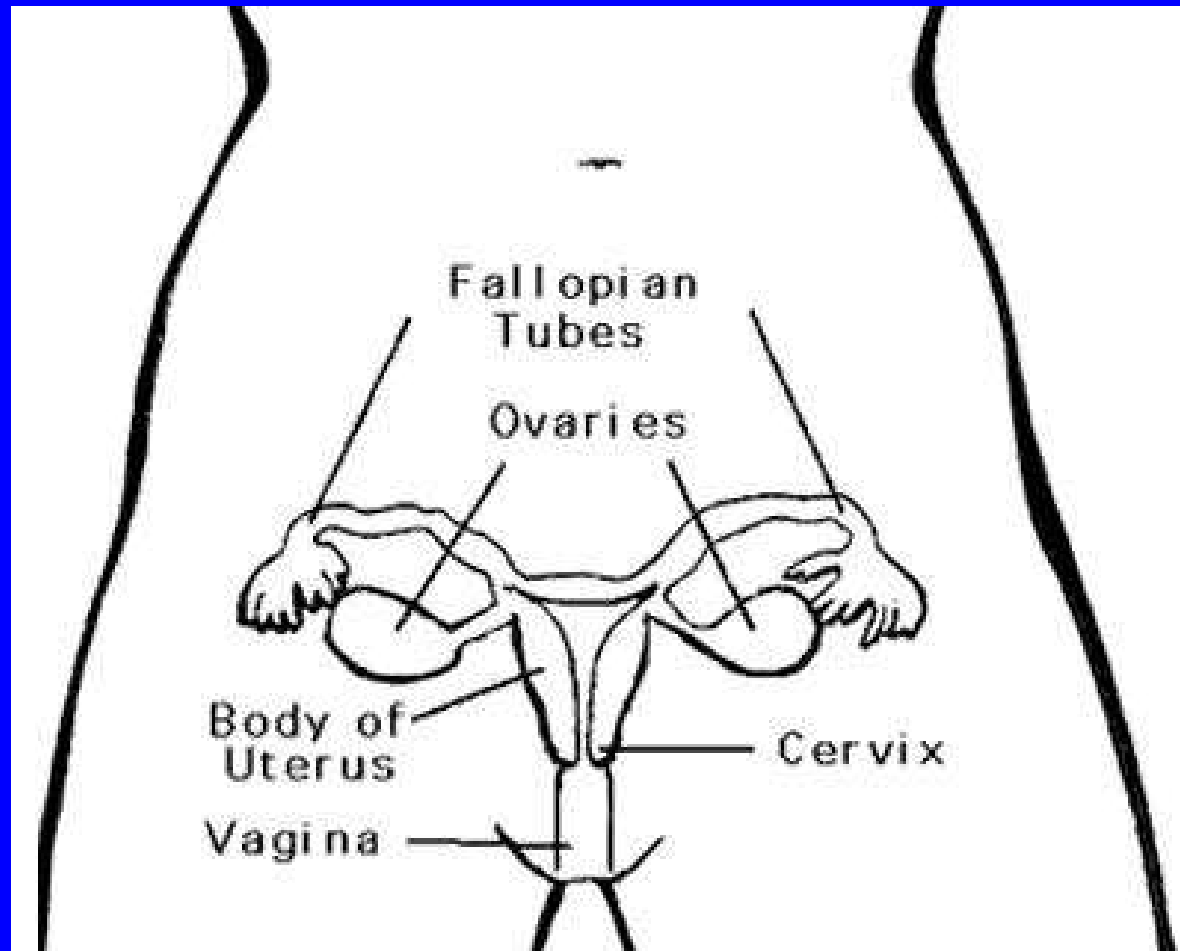
**FIGURE 11 Age-standardized Incidence and Mortality Rates for Cervix Uteri Cancer**



From Parkin, D. M. et al.  
CA Cancer J Clin 2005;55:74-108.

# US statistics on Cervix

Stage	5-year survival
IA	Above 95% (updated August 2006)
IB1	Around 90%
IB2	Around 80%-85%
IIA/B	Around 75%-78%
IIIA/B	Around 47%-50%
IV	Around 20%-30%



# **BRACHYTHERAPY** **can be highly CONFORMAL**

Conforms **(high)** dose to the target  
volume for improved tumor control

Conforms **(low)** dose to sensitive  
structures to reduce  
complications

But where is the  
target





# Staging of Cervix Ca.

- **Stage 0: Carcinoma in situ. Very superficial, in the layer of cells lining the cervix, and has not invaded the cervix.**
- **Stage I: Invaded the cervix, but it has not spread anywhere else.**
  - Stage IA: Earliest form of stage I. Small and seen only under microscope.
    - Stage IA1: Invasion less than 3 mm deep and 7 mm wide.
    - Stage IA2: Invasion between 3 mm and 5 mm deep and less than 7 mm wide.
  - Stage IB: Can be seen without a microscope. Also includes cancers that have spread deeper than 5 mm into connective tissue of the cervix or are wider than 7 mm and can only be seen using a microscope.
    - Stage IB1: Visible but no larger than 4 cm
    - Stage IB2: Visible and larger than 4 cm.
- **Stage II: Spread beyond the cervix to nearby areas, but it is still inside the pelvic area.**
  - Stage IIA: Spread beyond the cervix to the upper part of the vagina but not in the lower third of the vagina.
  - Stage IIB: Spread to the tissue next to the cervix (parametrial tissue).
- **Stage III: Spread to the lower vagina or pelvic wall. May be blocking the ureters.**
  - Stage IIIA: Spread to the lower third of the vagina but not to the pelvic wall.
  - Stage IIIB: Extends to the pelvic wall and/or blocks urine flow to the bladder. [Note: In AJCC alternate staging system is defined by spread to pelvic lymph nodes].
- **Stage IV: Spread to nearby organs or other parts of the body.**
  - Stage IVA: Spread to the bladder or rectum, which are organs close to the cervix.
  - Stage IVB: Spread to distant organs beyond the pelvic area, such as the lungs.

# US statistics on Cervix Ca.

Stage	5-year survival
IA	Above 95%
IB1	Around 90%
IB2	Around 80%-
IIA/B	Around 75%-
IIIA/B	Around 47%-
IV	Around 20%-
	30%



## ***HDR unit and source cable***



# Clinical Considerations

- **Post Hysterectomy**
- **Intact Cervix**
- **Unresected Uterus with wide involvement**
- **Significant Lateral involvement of**

# RTOG 97-08

- **A PHASE II STUDY OF ADJUVANT POSTOPERATIVE IRRADIATION COMBINED WITH CISPLATIN/TAXOLCHEMOTHERAPY FOLLOWING TAH/BSO FOR PATIENTS WITH HIGH-RISK ENDOMETRIAL CANCER**

# RTOG 97-08

- **External Radiotherapy**

Pelvic radiation to 45 Gy, 1.8 Gy per day, five days per week (*25 fractions*).

- **Intracavitary RT boost**

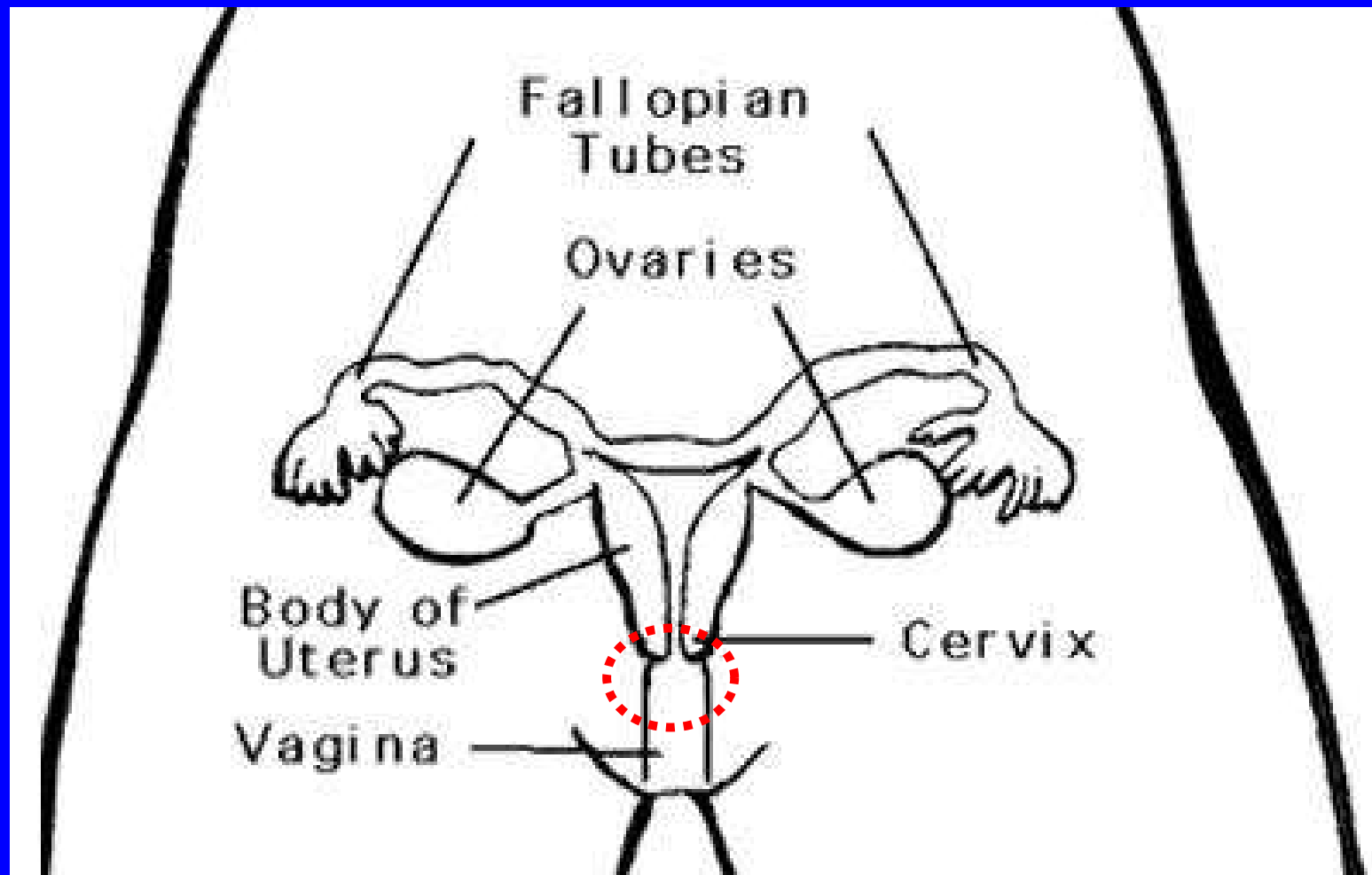
Within two weeks after completion of external beam.

Intracavitary insertions will be given with either a single low dose rate (*LDR*) application of 20 Gy to the vaginal surface or

three high dose rate (*HDR*) applications to deliver an additional 18 Gy to the vaginal surface. If HDR brachytherapy is used, the three insertions should be completed before day 56. More than one insertion may be given per week.

# **RTOG 9708-Endometrium**

- **Intracavitary Radiotherapy Technique and Dose Specifications**
- **Iridium OR Cesium sources are to be used for intracavitary application(s) with vaginal applicators for after-loading applicator system.**
- **Preferable to treat the vaginal cuff only (*treatment of the entire length of the vagina is discouraged and may increase morbidity*).**
- **Not more than 2/3 of the vagina should be included in the treatment volume.**
- **Colpostats/ovoids or cylinders may be used.**





# **RTOG 9708-Endometrium**

- **For HDR applications:**
- **Three applications of 6 Gy each prescribed to the vaginal surface.**
- **This will give a total of 18 Gy prescribed at the vaginal surface.**
- **A report of dose to rectum and bladder and vaginal surface is mandatory.**



## **RTOG 9708-Endometrium**

- **Bladder dose calculated at a proximal reference point on a Foley catheter. Balloon filled with 7cm<sup>3</sup> of radio-opaque fluid.**

On the lateral radiograph, the reference point is obtained on an AP line drawn through the center of the balloon, at the posterior surface of the balloon

On the AP radiograph, the reference point is taken at the center of the balloon.

Rectal dose calculated by

Introducing contrast material in the rectum and marking a point on the rectal wall adjacent to the applicator system or

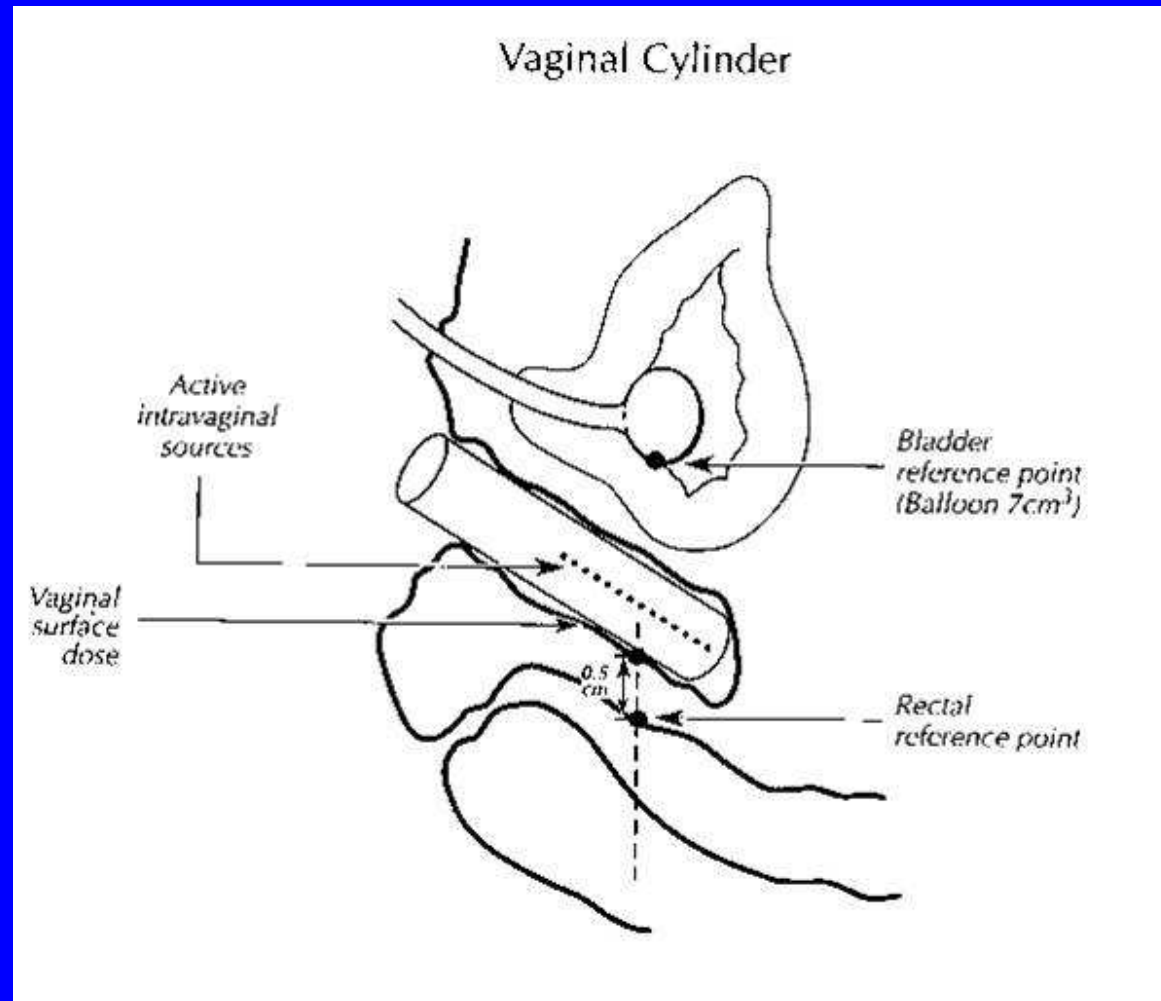
At a point 0.5 cm posterior to the vaginal ovoids or vaginal packing in the lateral projection.

Vaginal surface dose calculated at

the vaginal surface lateral to the midpoint of the surface of the ovoid or cylinder.



**RTOG 9708-**  
**Endometrium**  
**protocol**  
**APPENDIX VI**  
**Definition of**  
**Bladder and**  
**Rectal Points**



# A vaginal cylinder applicator set



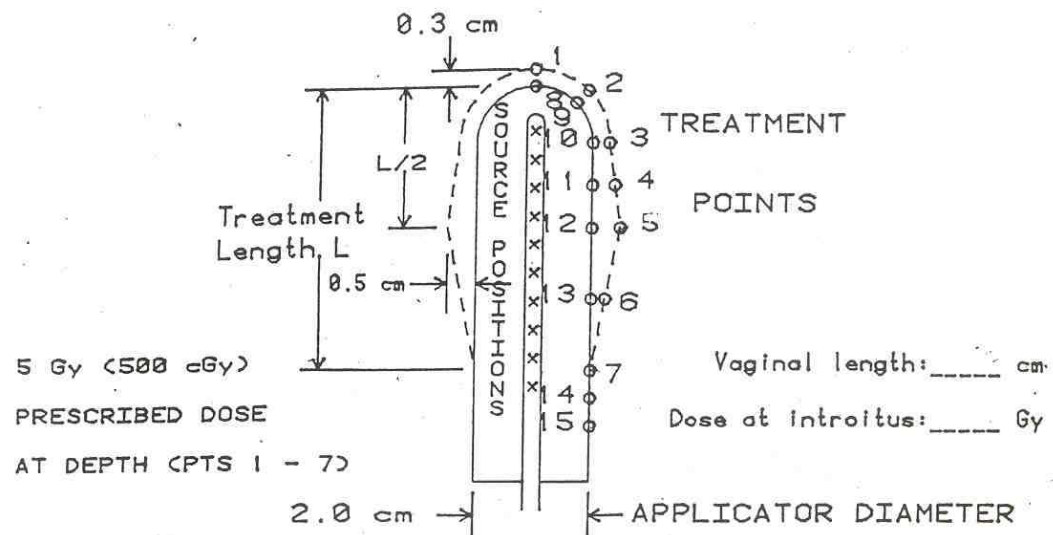
## **The “Classic” MSKCC prescription scheme for Vaginal Cylinder Applications**

- **The dose optimization point configuration on the Memorial System for a “5.0 mm in tissue” prescription is defined at the midpoint of the “Prescription Length”.**
- **The rest of the dose optimization points taper in both directions, such that:**
  - around the hemisphere they lay at 3 mm from the surface of the dome and
  - at the introitus the distance is reduced to zero.
- **The “Prescription Length” is measured from the introitus to the tip of the**



# GAMMA MED II REMOTE AFTERLOADER TECHNIQUE

$^{192}\text{Ir}$  Source of 10 Ci Nominal Activity



Treatment Length(cm) CIRCLE →		Source Dwell Time(sec) for 10 Ci Activity*				Dose (Gy) at Treatment Points			
		4	5	6	7	4	5	6	7
Source	1	32	30	29	29	5.02	4.95	4.90	4.94
	2	16	17	20	22	4.88	4.83	4.80	4.83
Position	3	0	11	0	0	5.26	5.27	5.23	5.22
	4	36	0	16	0	5.02	5.08	5.13	5.16
or	5	11	26	21	40	4.58	4.73	4.74	4.83
	6	0	28	0	0	5.00	5.04	5.04	5.03
Point	7	0	0	31	3	4.94	5.01	5.02	5.05
	8	23	0	0	37	8.59	8.38	8.26	8.32
Number	9		0	0	0	7.89	7.75	7.66	7.71
	10		27	23	0	7.90	7.87	7.78	7.78
	11			0	0	8.17	7.91	7.84	7.72
	12			16	33	8.39	8.24	8.10	7.97
	13				0	6.59	6.57	6.66	6.57
	14				11	3.05	3.27	2.81	2.62
	15	119	131	104	75	1.39	1.48	1.34	1.29

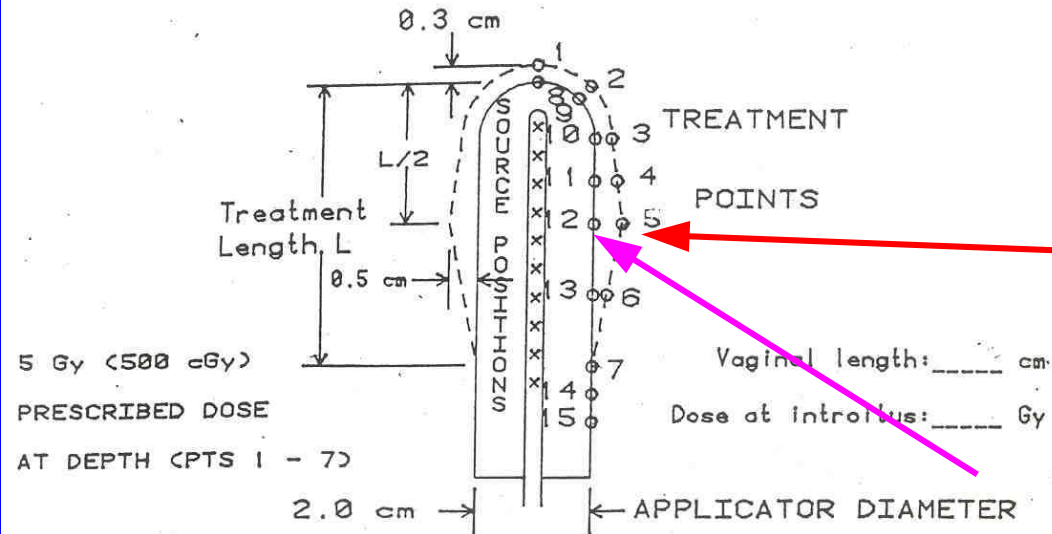
\* Actual times adjusted for source decay

Rev. 6-86



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	7	0	0	31	3	4.94	5.01	5.02	5.05
Number	8	23	0	0	37	8.59	8.38	8.26	8.32
	9		0	0	0	7.89	7.75	7.66	7.71
	10		27	23	0	7.90	7.87	7.78	7.78
	11			0	0	8.17	7.91	7.84	7.72
	12			16	33	8.39	8.24	8.10	7.97
	13			0	0	6.59	6.57	6.56	6.57
	14			11	0	3.05	3.27	2.81	2.62
	15	119	131	104	75	1.39	1.48	1.34	1.29

\* Actual times adjusted for source decay

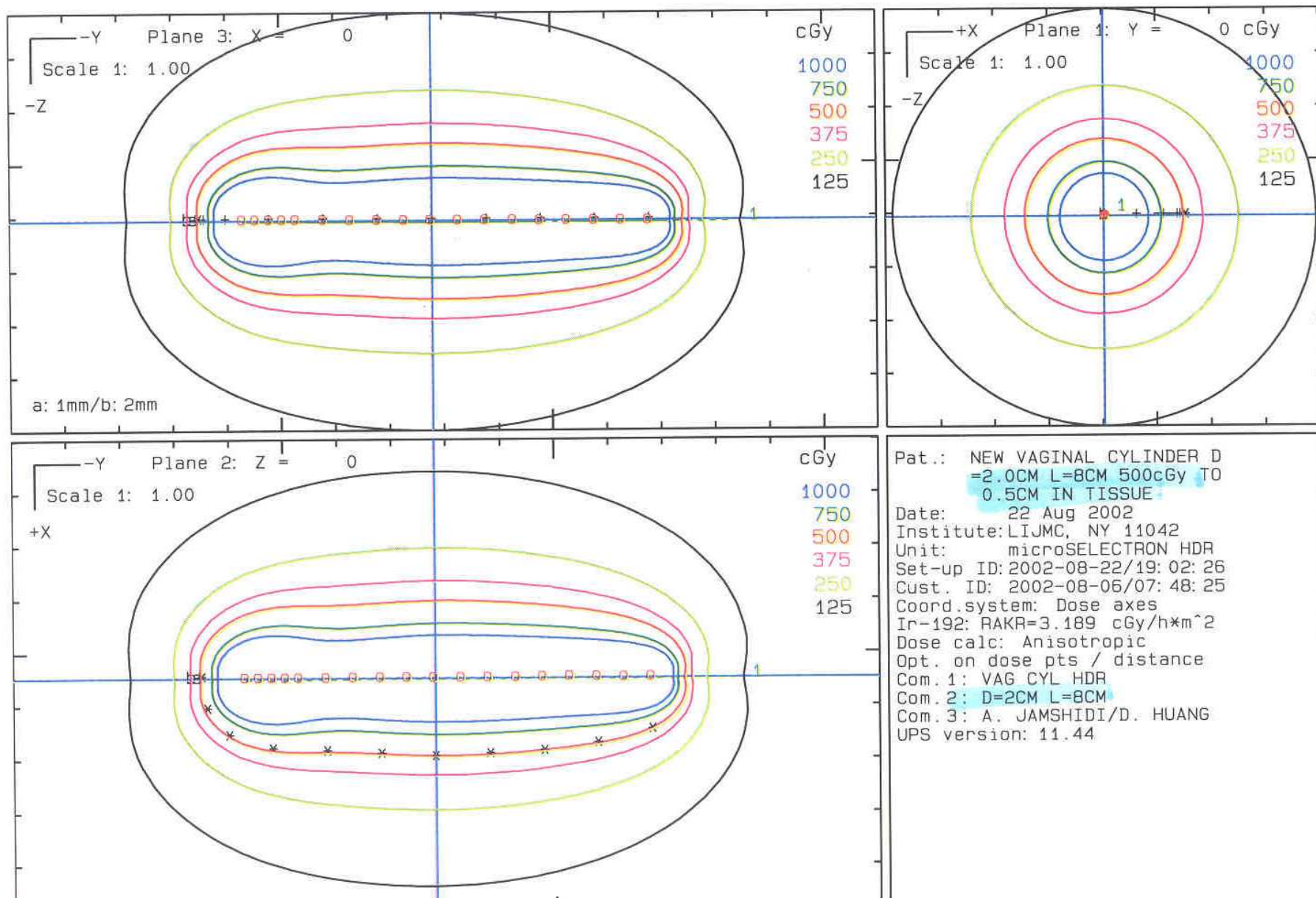
Rev. 6-86

# **Two Factors affect the dose distribution at the tip of the Vaginal Cylinder**

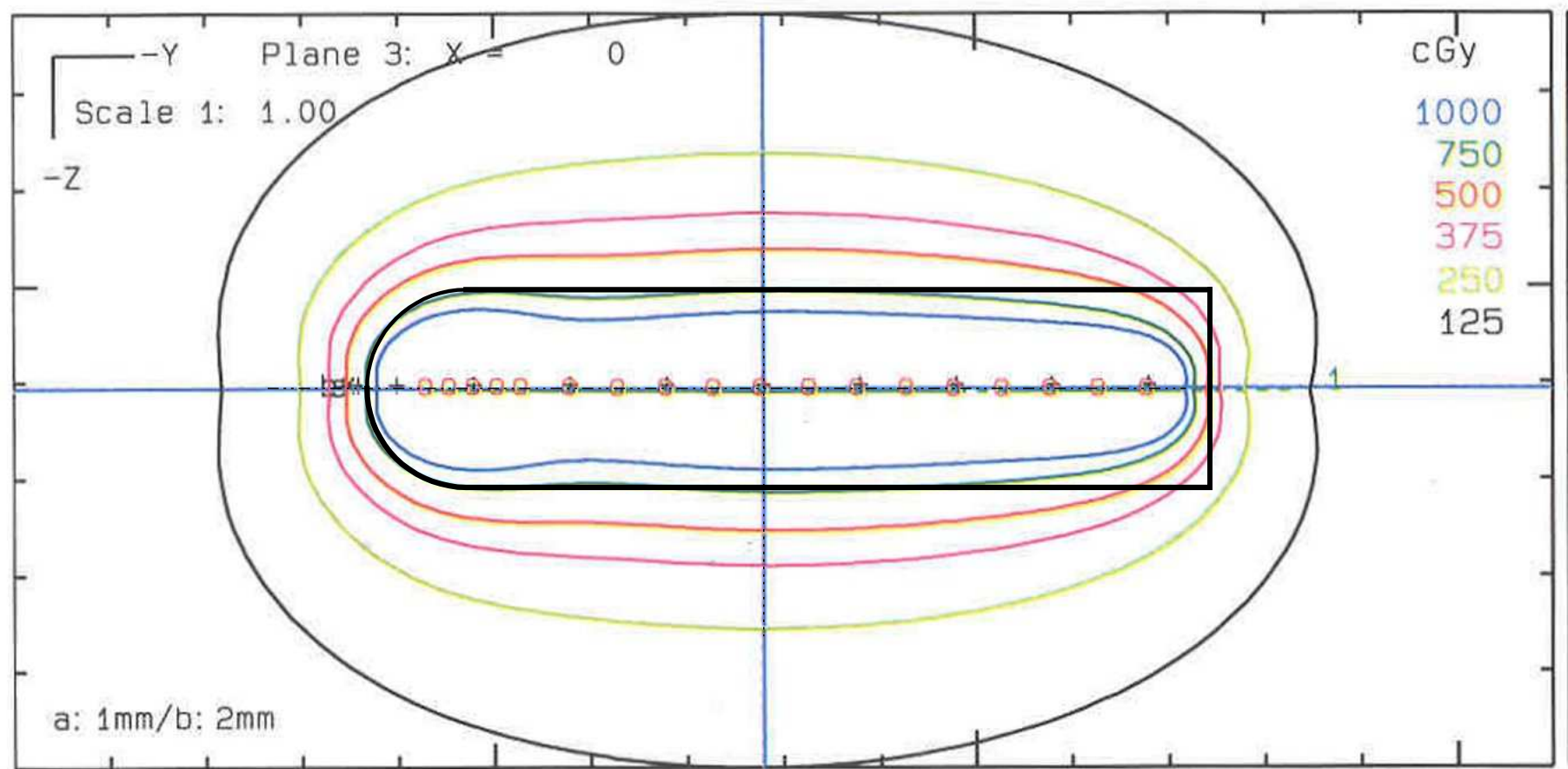
- **The first dwell position**
- **The dose optimization points around the tip of the cylinder**







## Distribution superimposed on the cylinder's geometry



# ***Q: How important is a small source position error in terms of dosimetry?***

- **Typical tolerance in source position is quoted as +/- 1mm.**
- **On a QA test of coincidence between radio-opaque marker and source autoradiograph we detect a discrepancy of program position and marker of 1.5 mm.**
- **Simulation films indicated that the first dwell position is at 6.5 mm (center of source to tip of cylinder), while the dosimetry 'templates' for time calculation based on a MSKCC type of loading assumed the first source position at 5.0 mm from the tip of the cylinder.**

## **The dose variation at points along the cylinder axis, beyond the tip, for a cylinder of 2 cm diameter**

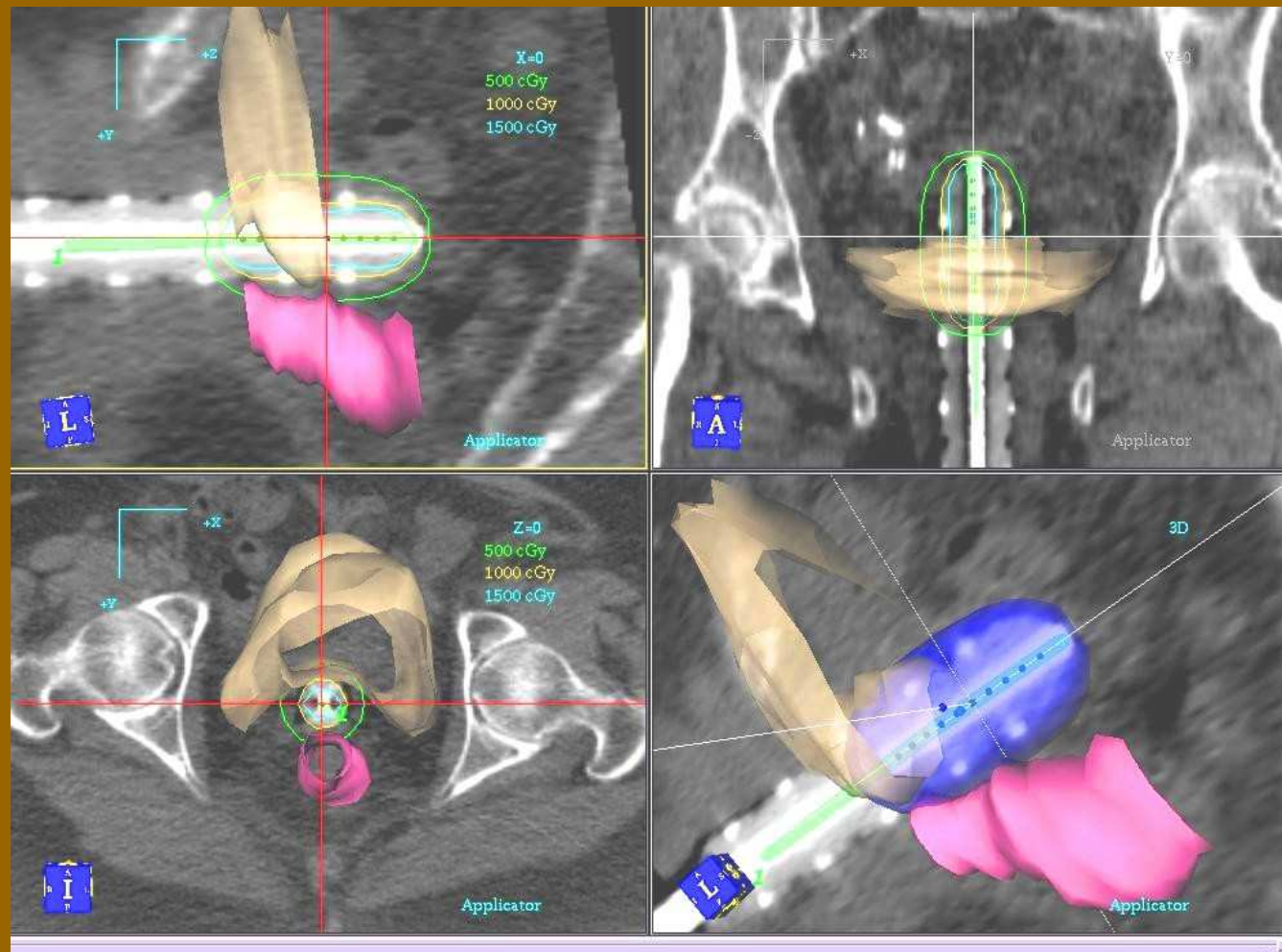
- **At 3.0 mm .....500 cGy**
- **At 4.0 mm .....460 cGy**
- **At 4.5 mm.....435 cGy**
- **At 5.0 mm .....410 cGy**
- **A 1.5 mm displacement in actual source position, corresponds to an underdose at the vaginal apex of 13%. ( $435/500 = 0.87$ )**

**A: In the case of a vaginal Cylinder,  
not so small!**

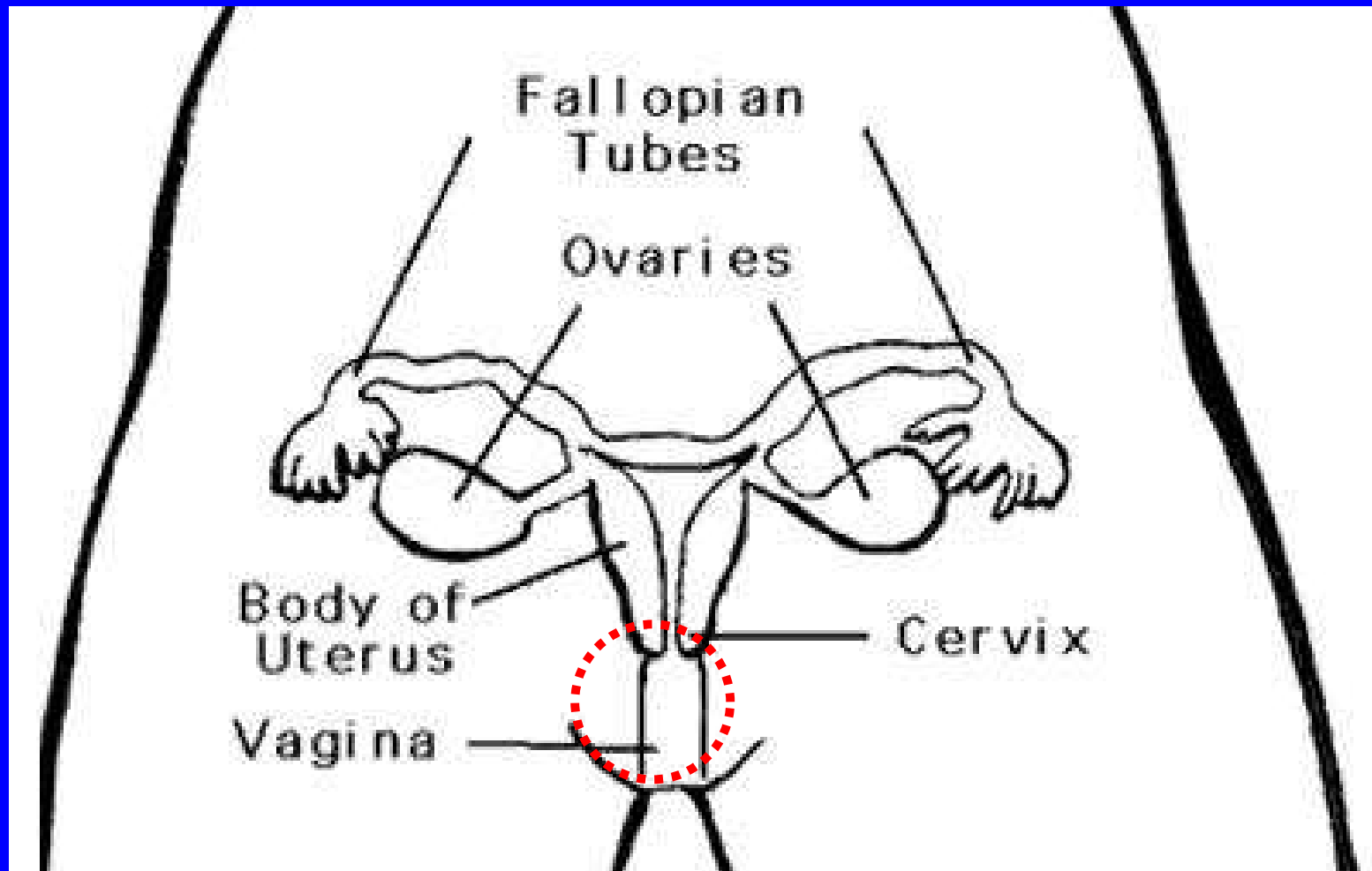


## ***3D distributions for single-channel vaginal cylinder***

***Rectal wall and bladder doses can be determined better.***



# Asymmetric vaginal cuff target



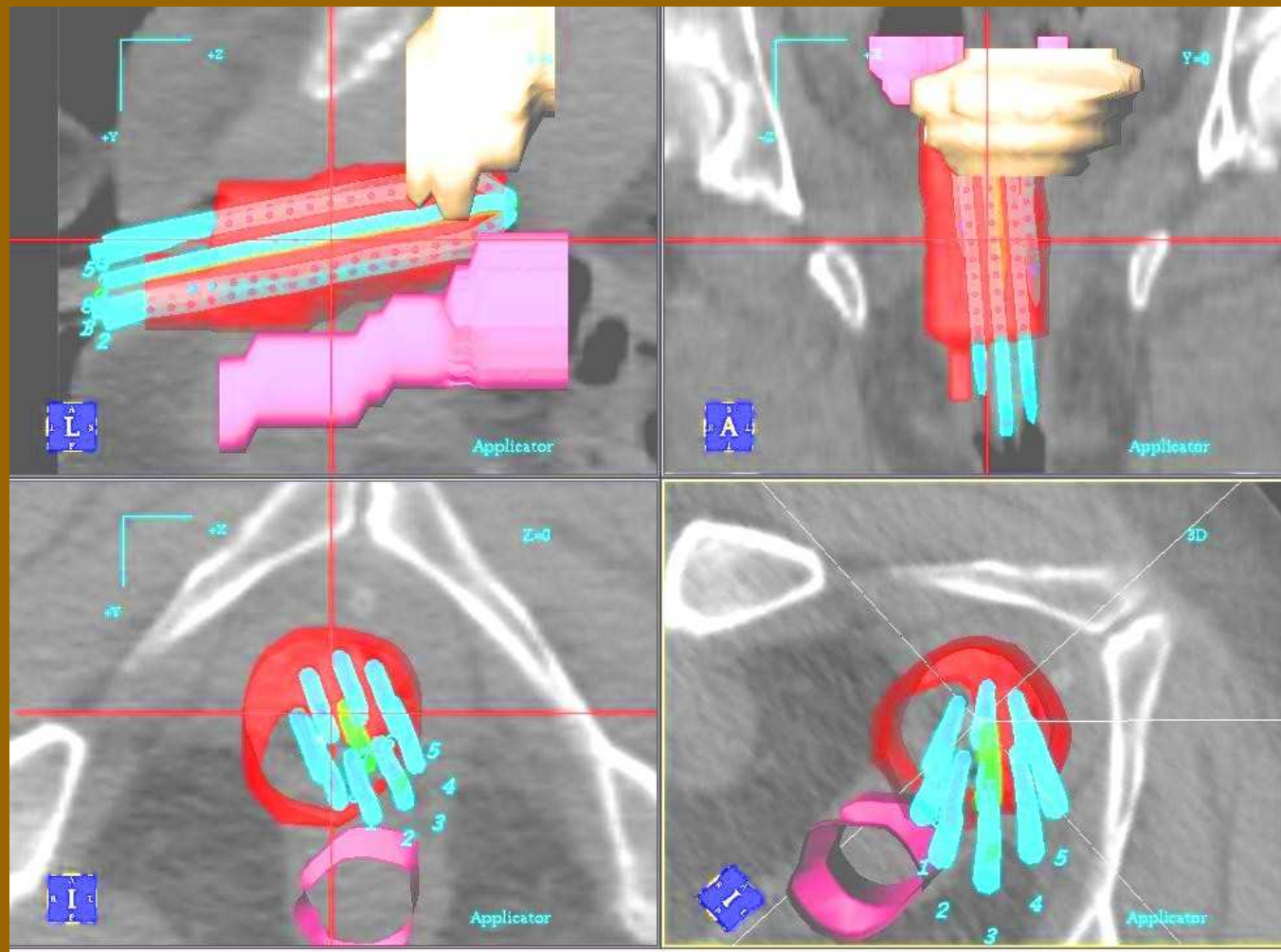
# Modification to vaginal cylinder to treat asymmetric lesions

- **Vaginal cylinder with 9 peripheral channels.**
  - It allows planning a biased and customized dose distribution.



## ***3D views isodoses for 9-channel applicator***

***Stand-off sleeve and differential loading allow better  
targeting of asymmetric target volume***

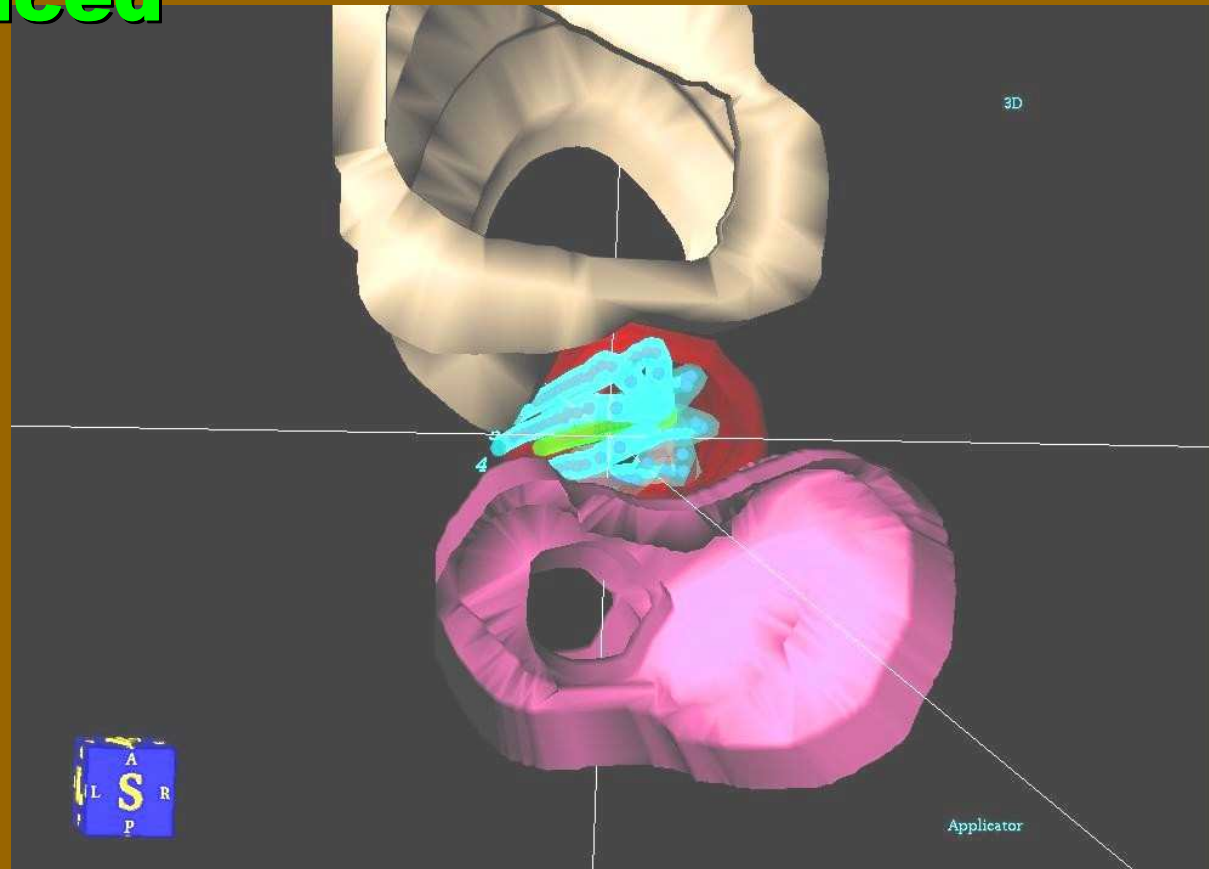




## ***3D view for 9-channel applicator***

***Differential loading allows biasing the distribution***

- **Dose to bladder and rectum can be reduced**



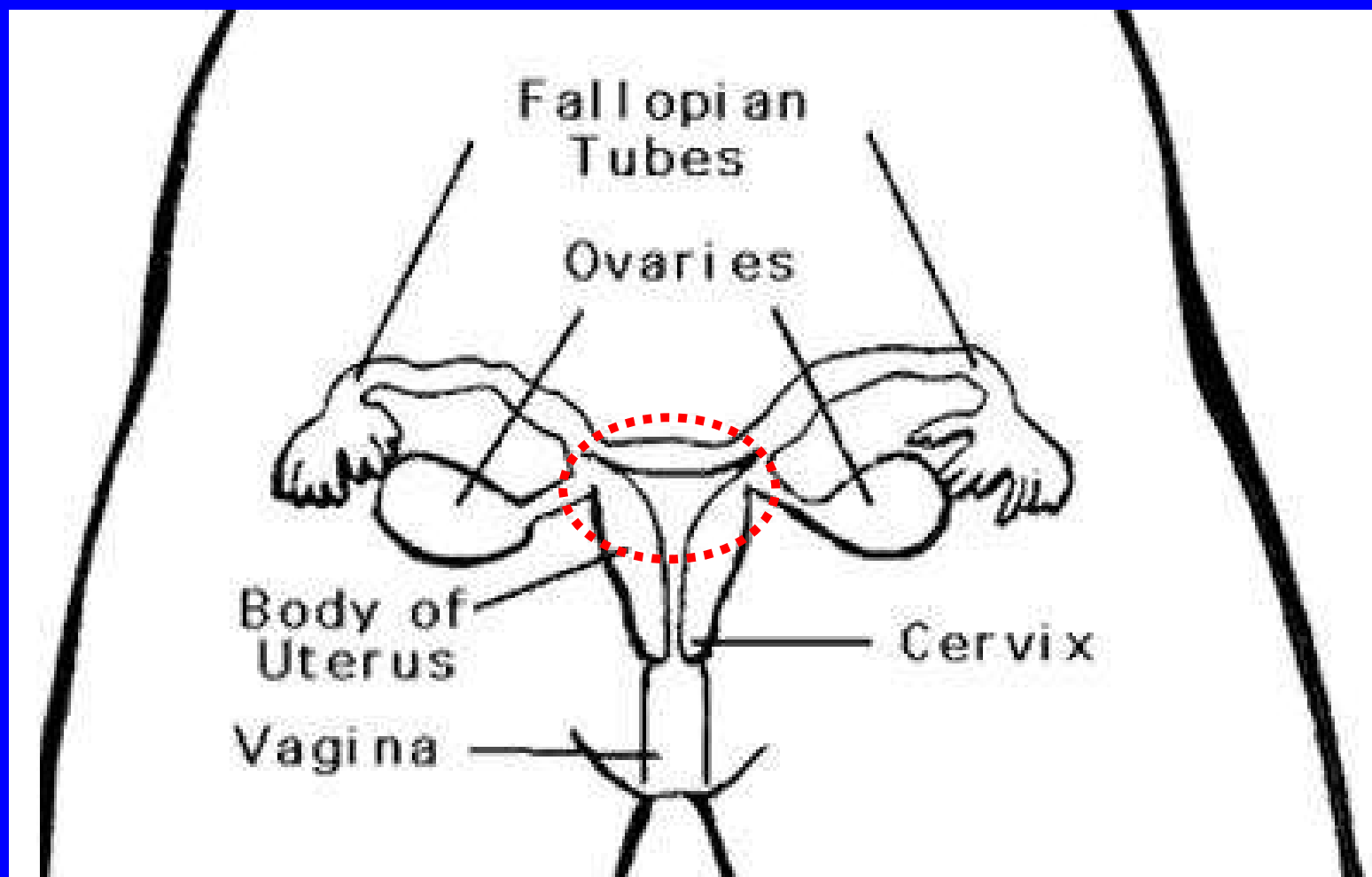
- **Thick red is the target while the thin red is the prescribed isodose line. 150% and 200% lines are inside the cylinder**



Intrauterine brachytherapy  
treatment is also shifting from  
LDR to HDR



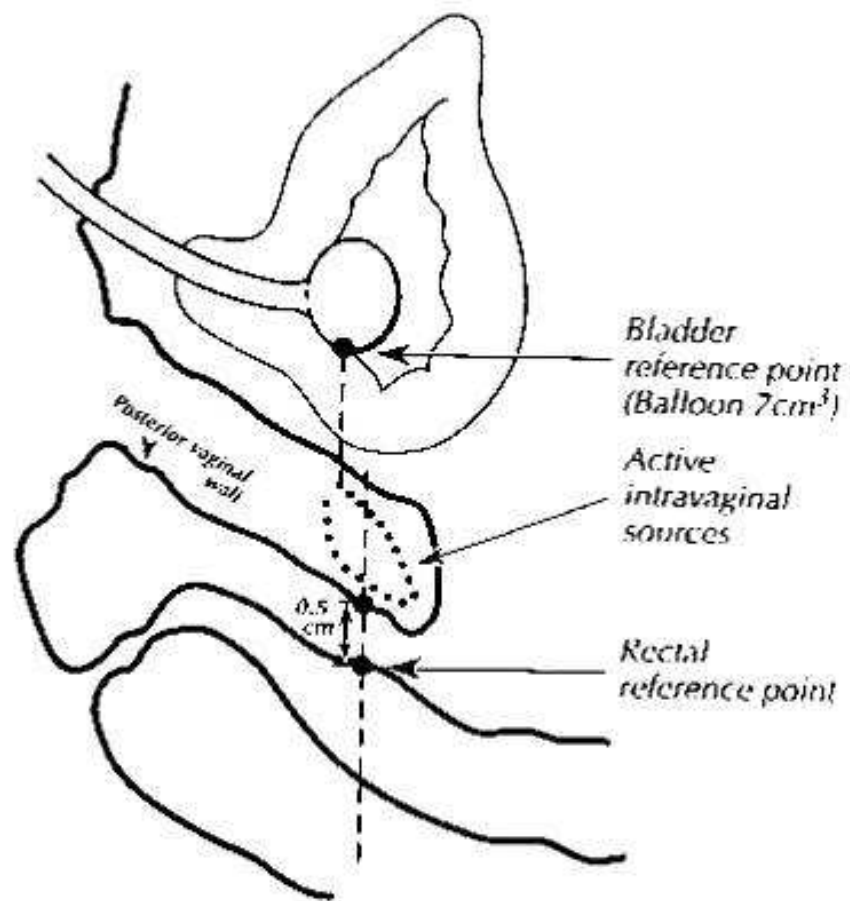
## Intrauterine brachytherapy treatment is also shifting from LDR to HDR



**RTOG 9708-Endometrium  
protocol**  
**APPENDIX VI**

**Definition of Bladder  
and Rectal Points**

Vaginal Colpostats





# Rotte Applicator

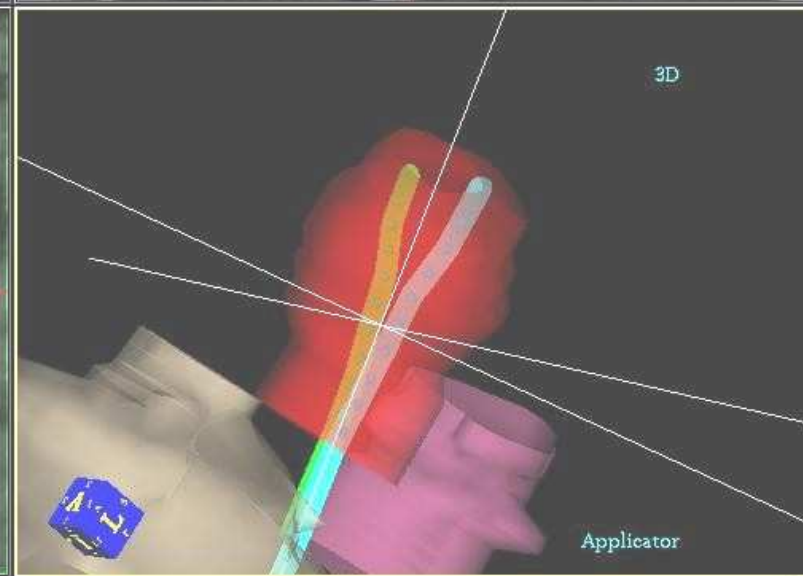
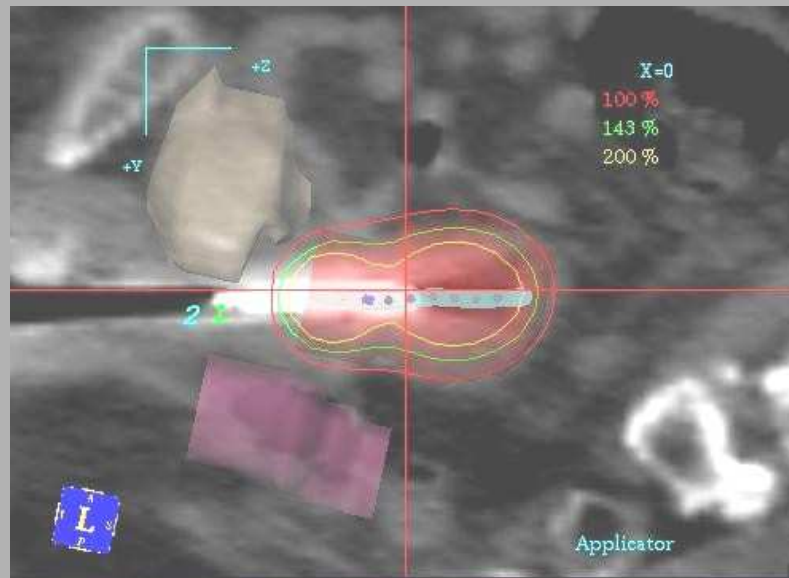
# Sizes

2.0 cm

3.2 cm

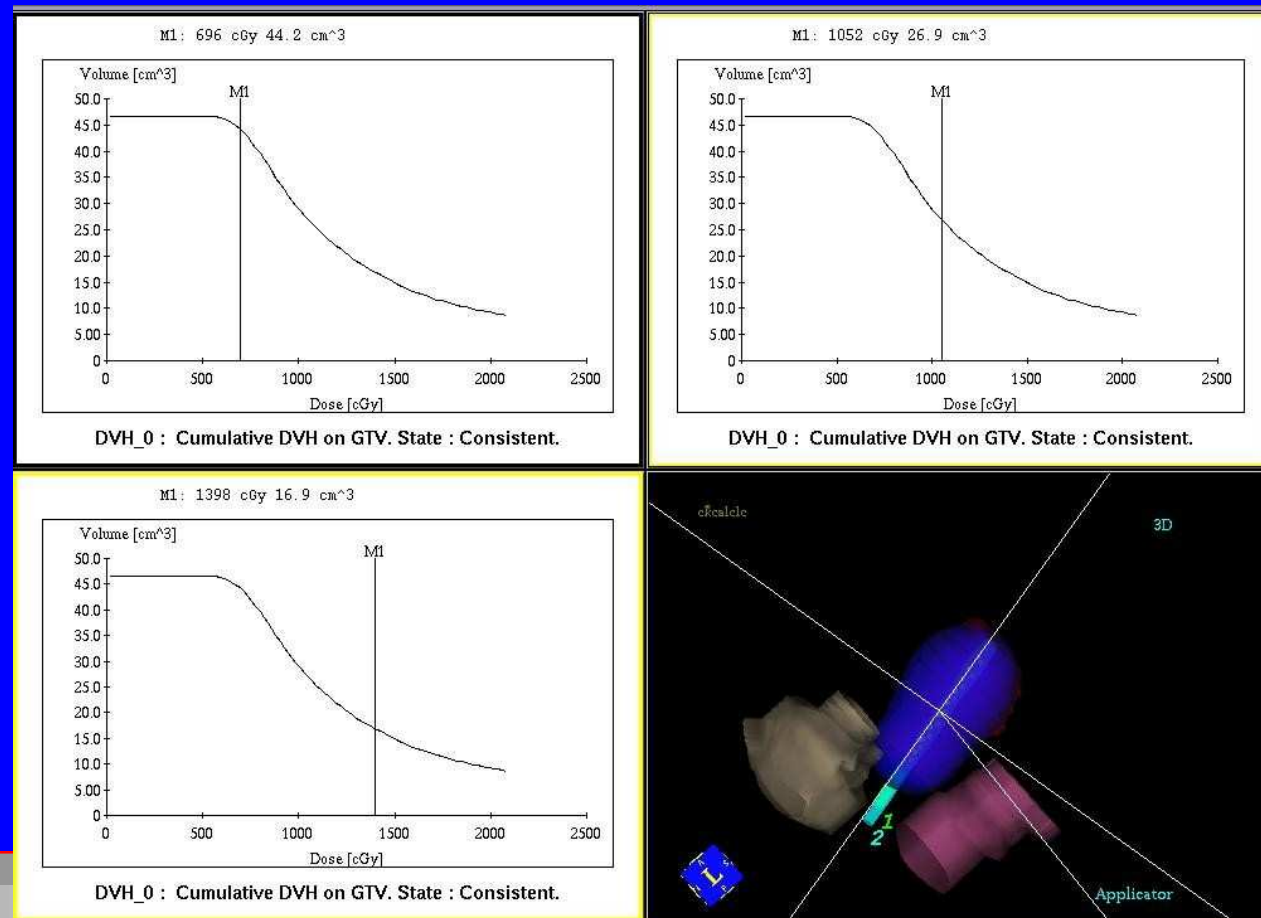
4.0 cm

5.0 cm



# Endometrial Dose coverage

- V100, V150, and V200 are documented.
- Since the applicator is inside the uterus, contouring is used to define the volume for calculating statistics.



## **6.5 Dose to Critical, Sensitive Structures (RTOG 9708)**

- **Maximal doses suggested for the entire radiotherapy regimen**

6.5.1 Small bowel: 55 Gy

6.5.2 Bladder: 70 Gy

6.5.3 Rectum: 65 Gy

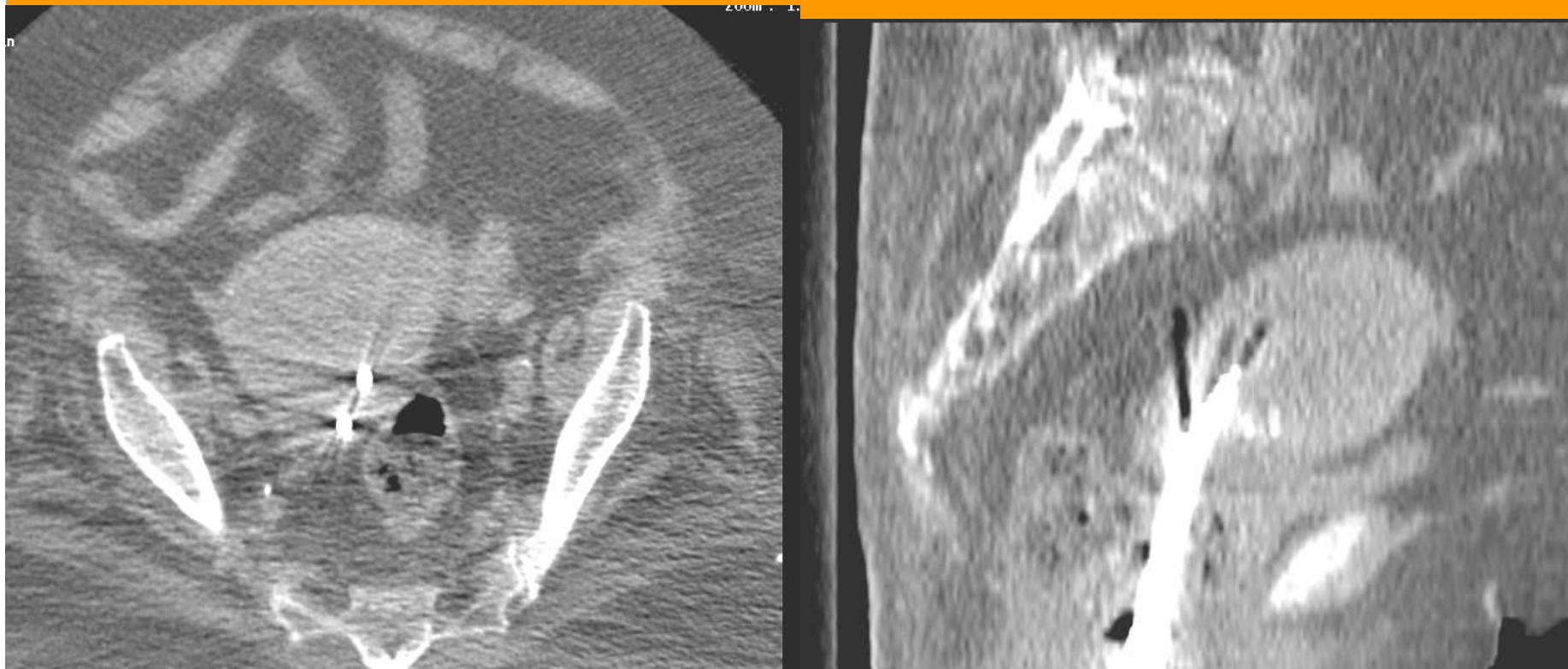
6.5.4 Vaginal surface: 100 Gy

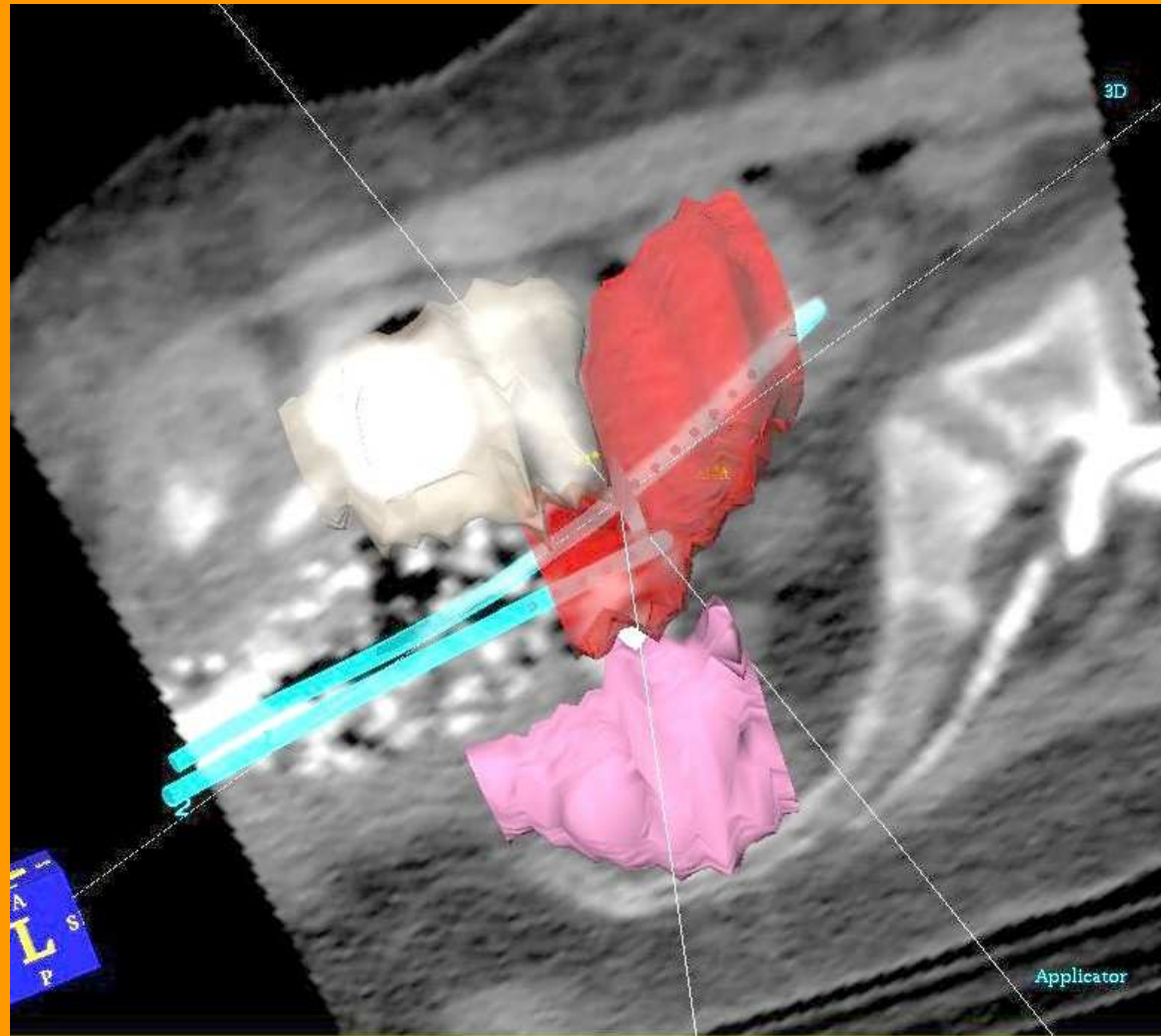


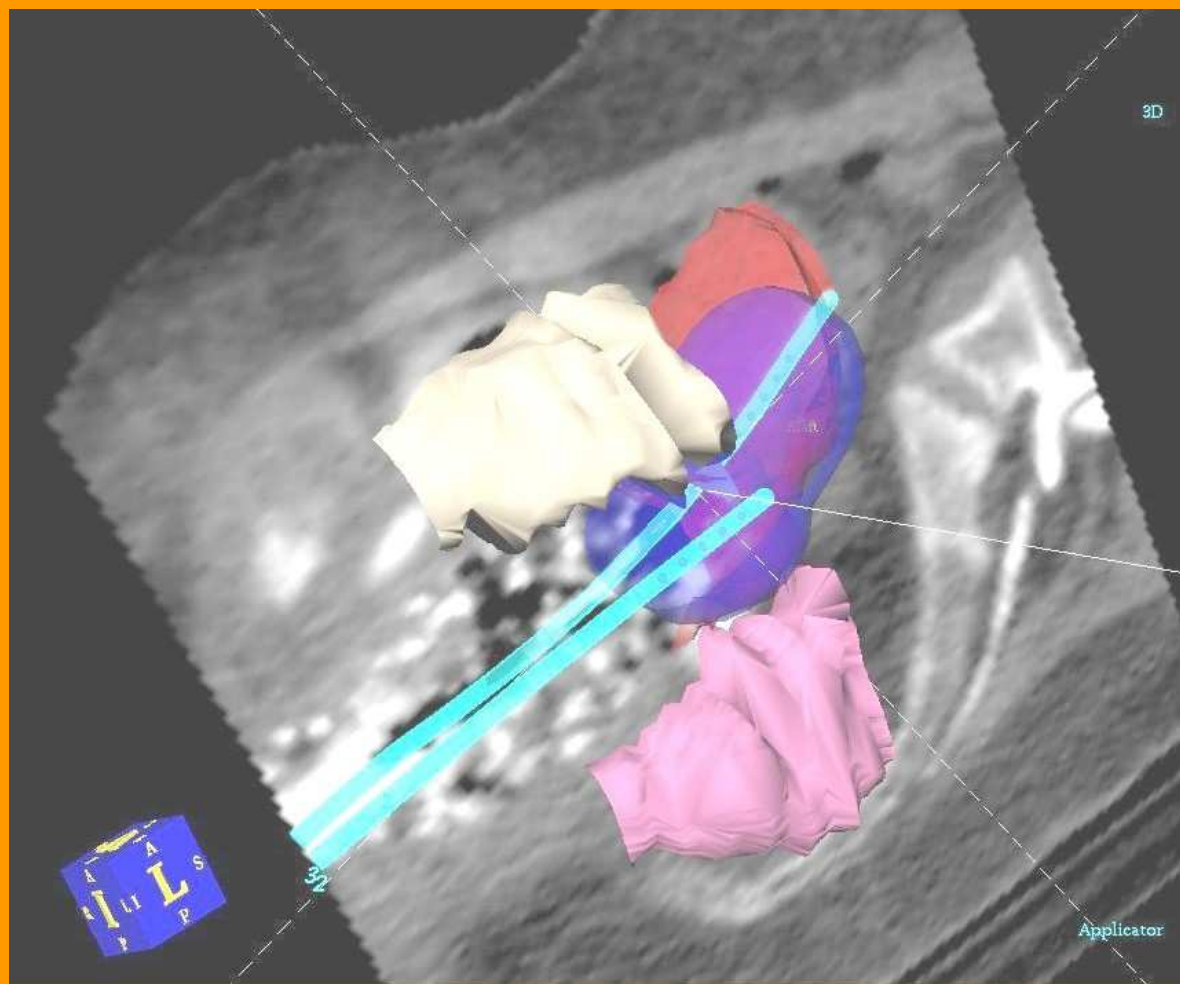


# **Intrauterine double tandem Rotte applicator**

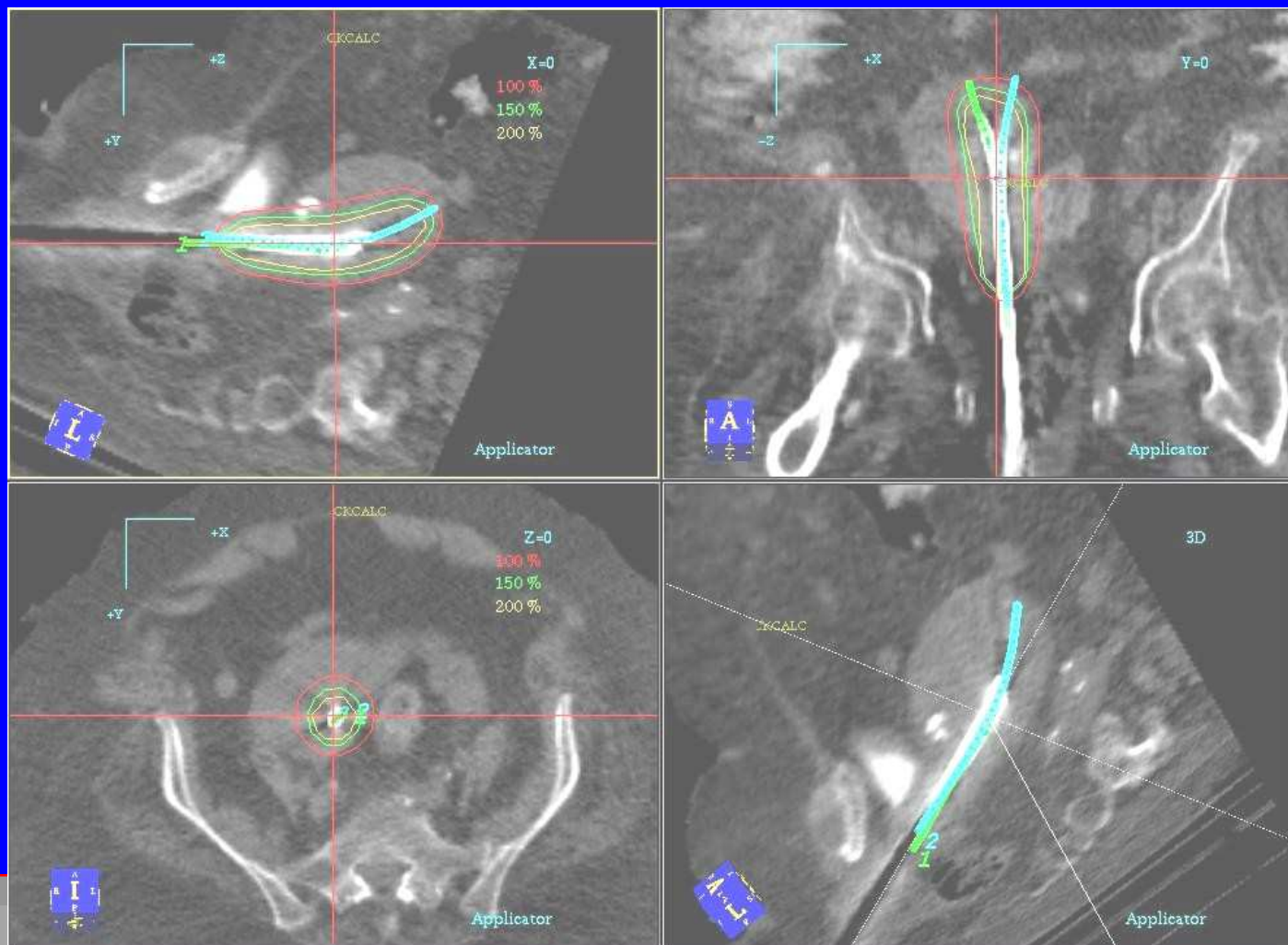
- **Fibroid in the uterus caused a rotation of the applicator. Physician aborted the application.**





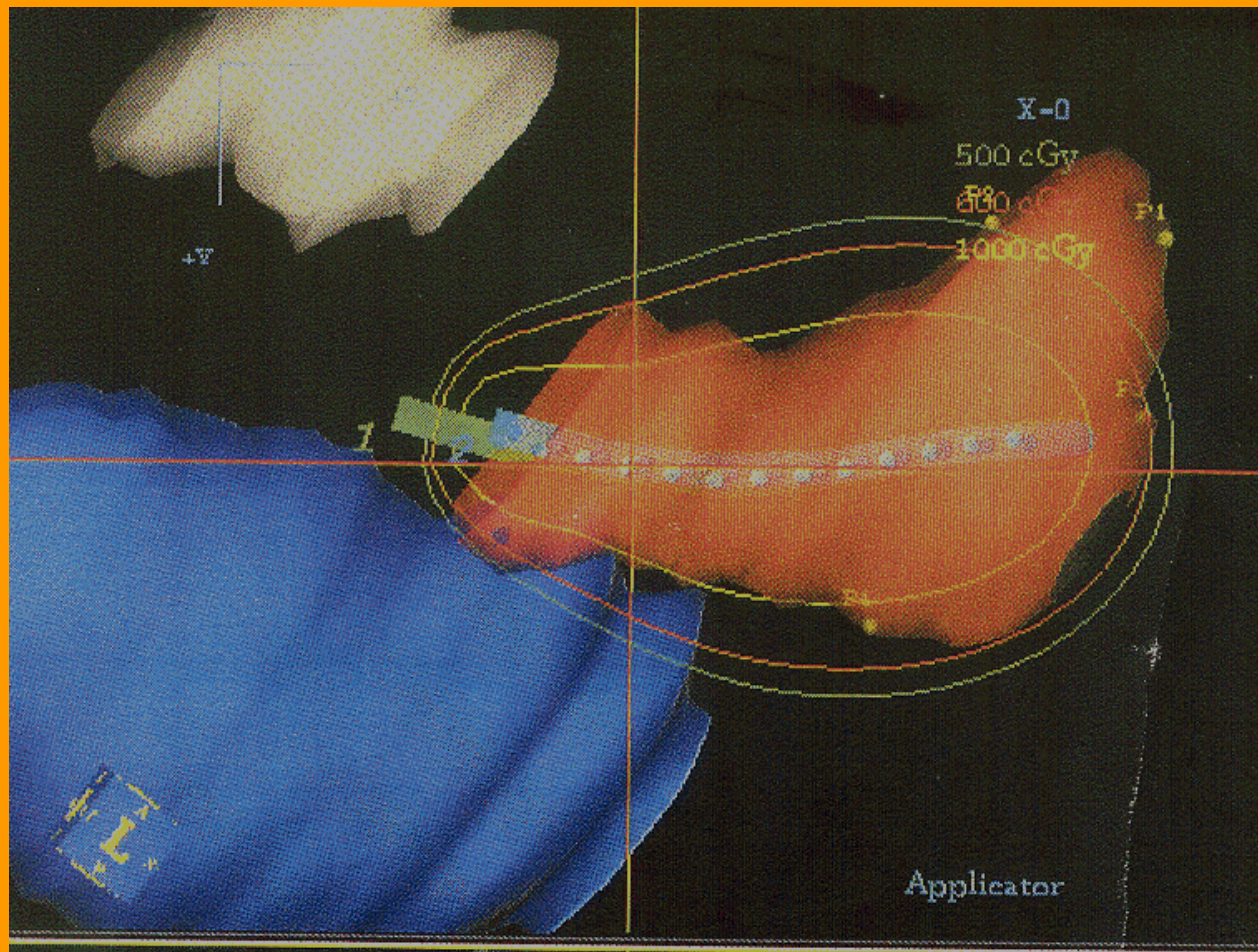


# CT based dosimetry with a Martinez double tandem uterine applicator



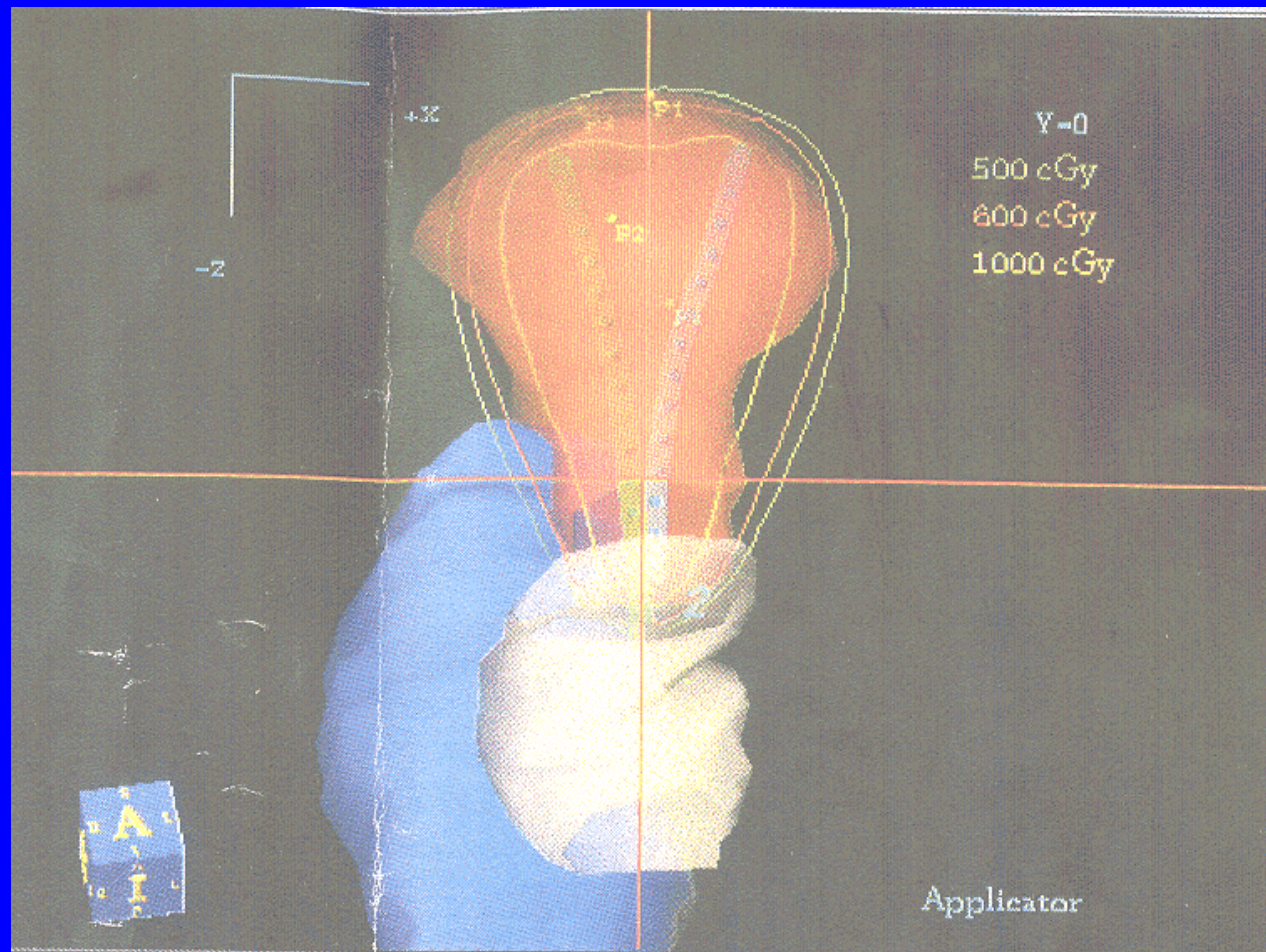


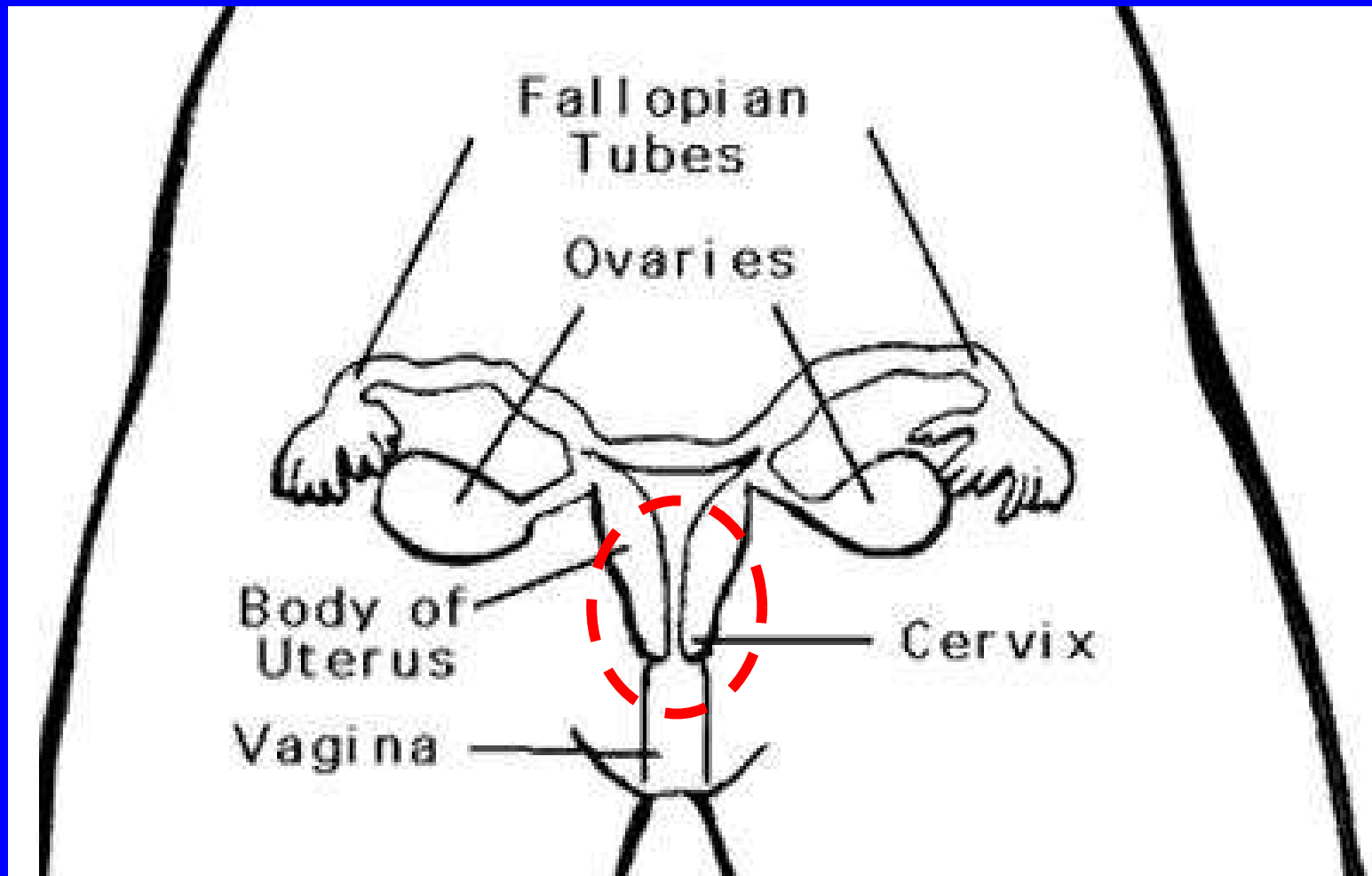
# HDR Martinez Applicator (Lateral 3D view)



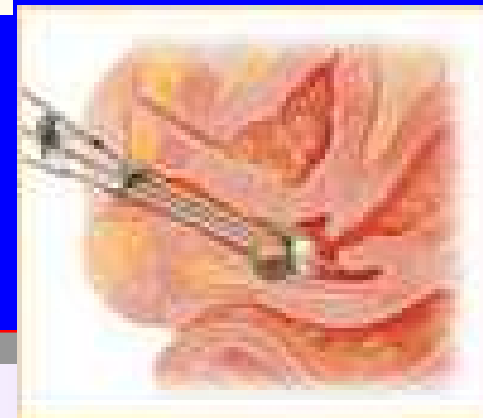
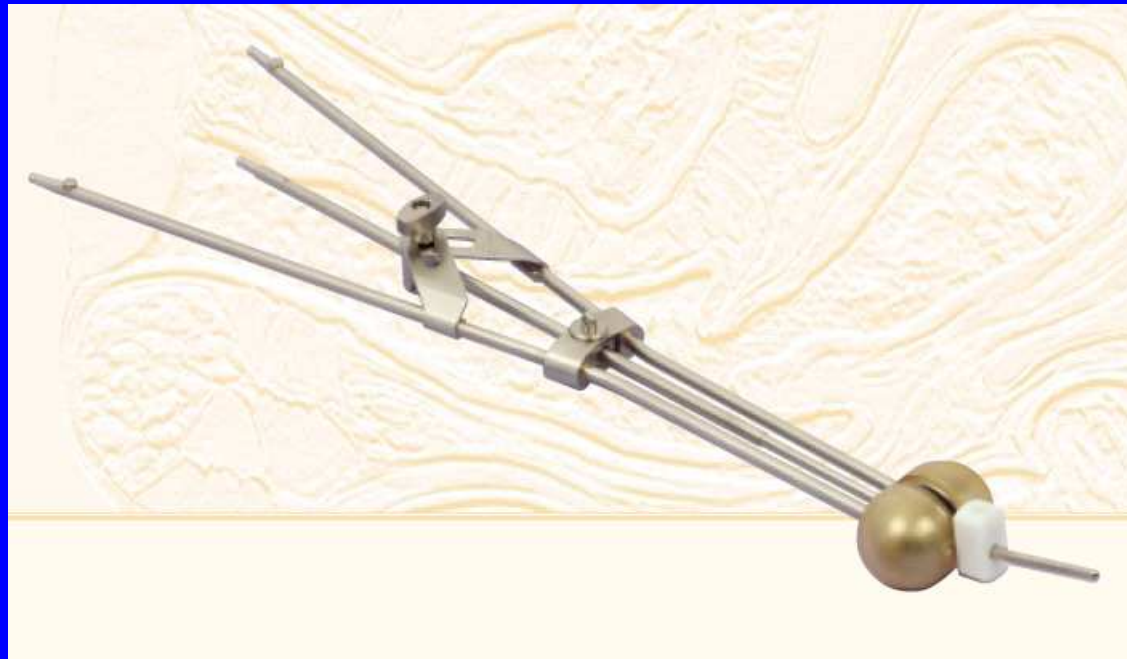


# HDR Martinez Applicator Antero-inferior View



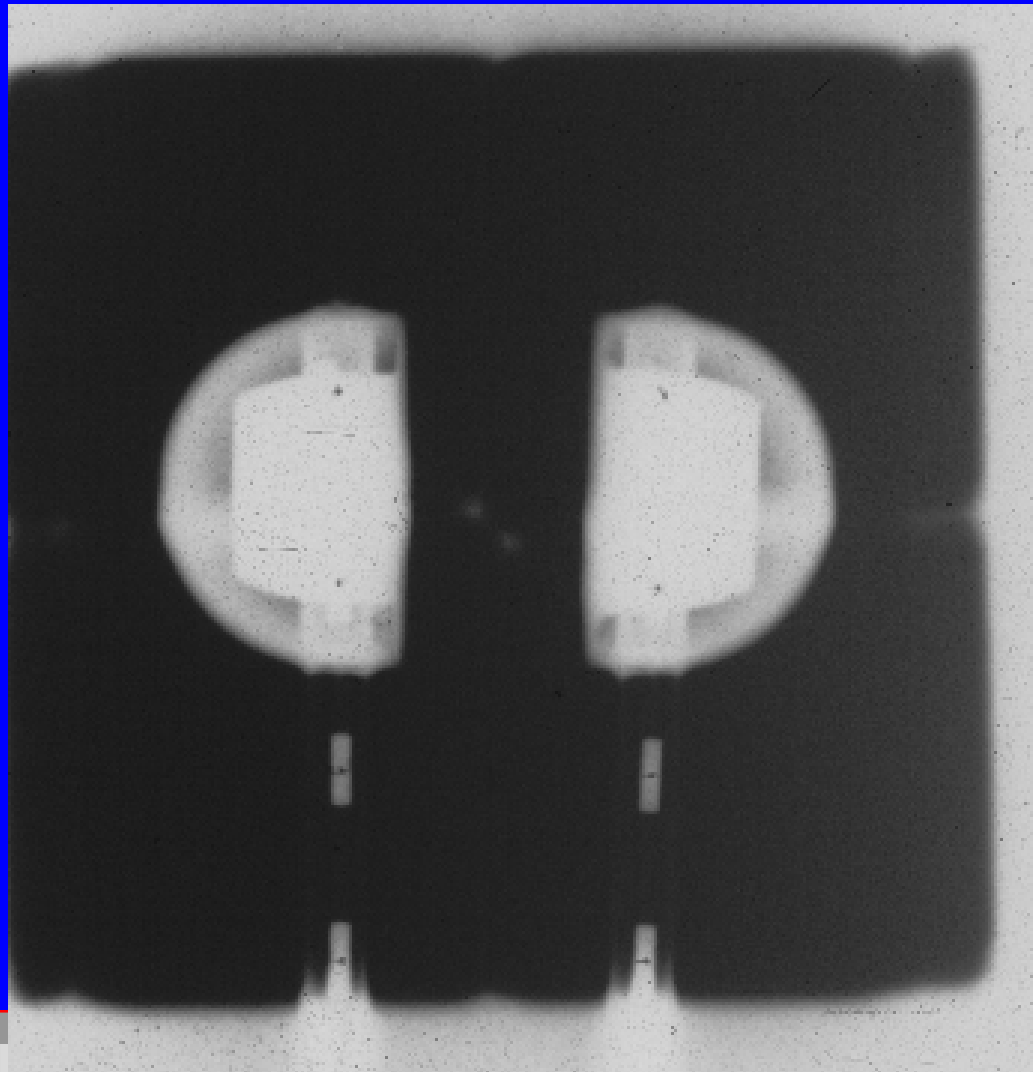


# Henschke HDR Applicator





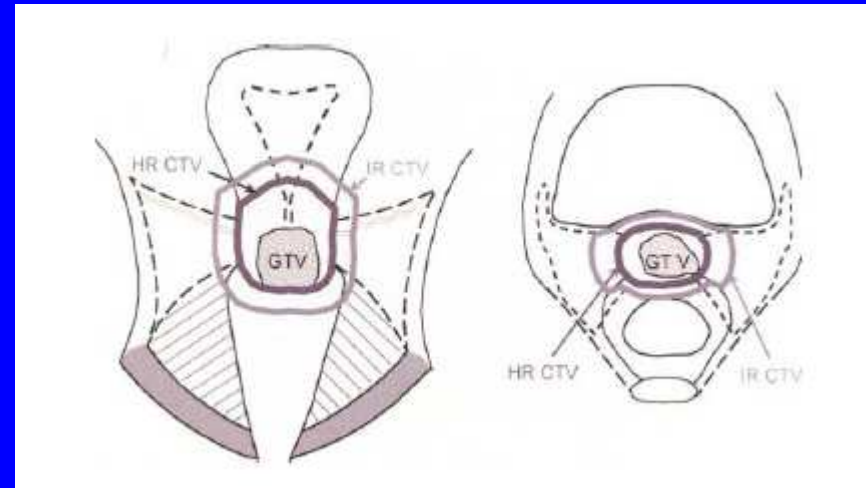
# HDR Shields and source locations



**A PHASE II STUDY OF BEVACIZUMAB IN COMBINATION WITH DEFINITIVE  
RADIOTHERAPY AND CISPLATIN CHEMOTHERAPY IN UNTREATED PATIENTS WITH  
LOCALLY ADVANCED CERVICAL CARCINOMA**

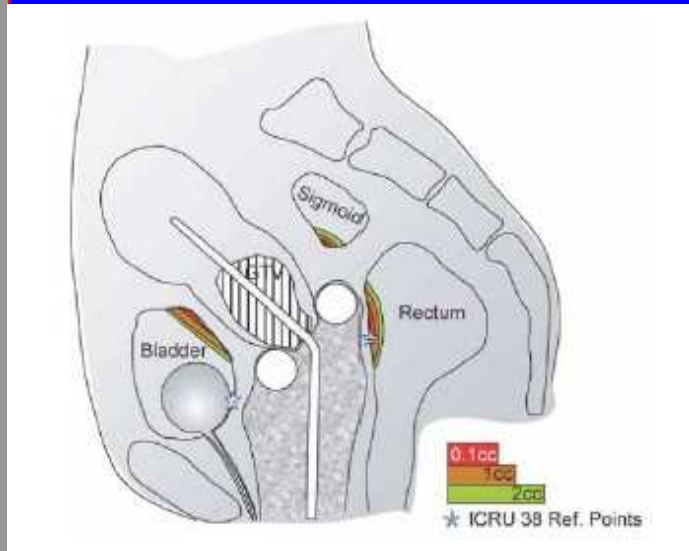
**Recommendations for recording and reporting 3D gynecological brachytherapy**

Fig. 1. Schematic diagram for cervix cancer, limited disease, with GTV, high risk CTV and intermediate risk CTV for definitive treatment: coronal and transversal view (Courtesy of Haie-Meder et al, Radiotherapy and Oncology 74(2005):235-345.)



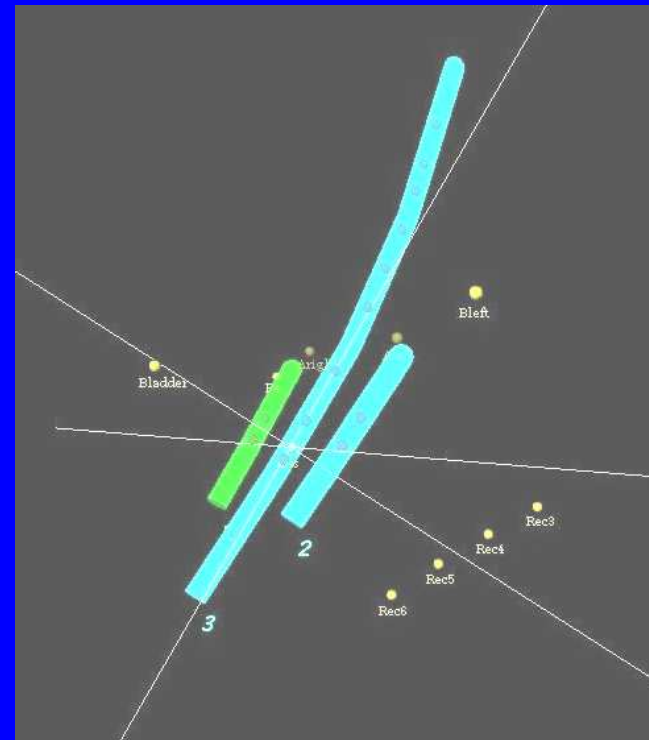
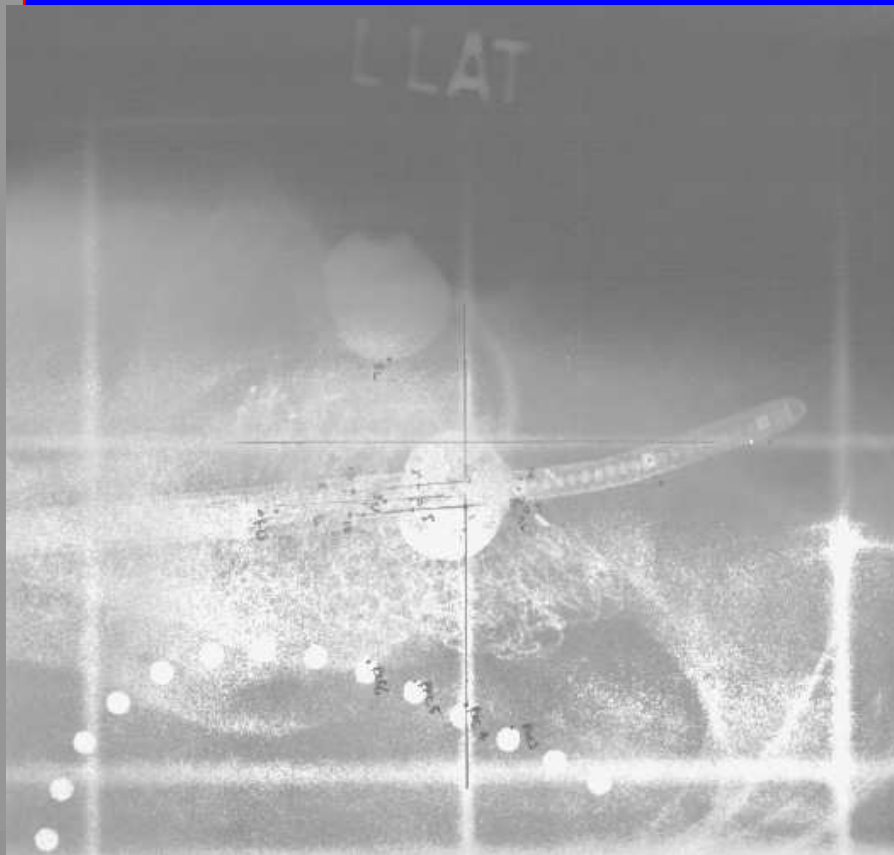
**Fig. 5 Schematic anatomical diagram (sagittal view) indicating the most irradiated tissue volumes adjacent to the applicator for rectum, sigmoid and bladder: 0.1, 1, and 2 cm<sup>3</sup> (identical patient as in Figs. 1 and 2, dose volume parameters for this schematic patient example can be taken from Fig. 5).**

(Courtesy of Potter et al Radiotherapy and Oncology 78 (2006) 67-77)



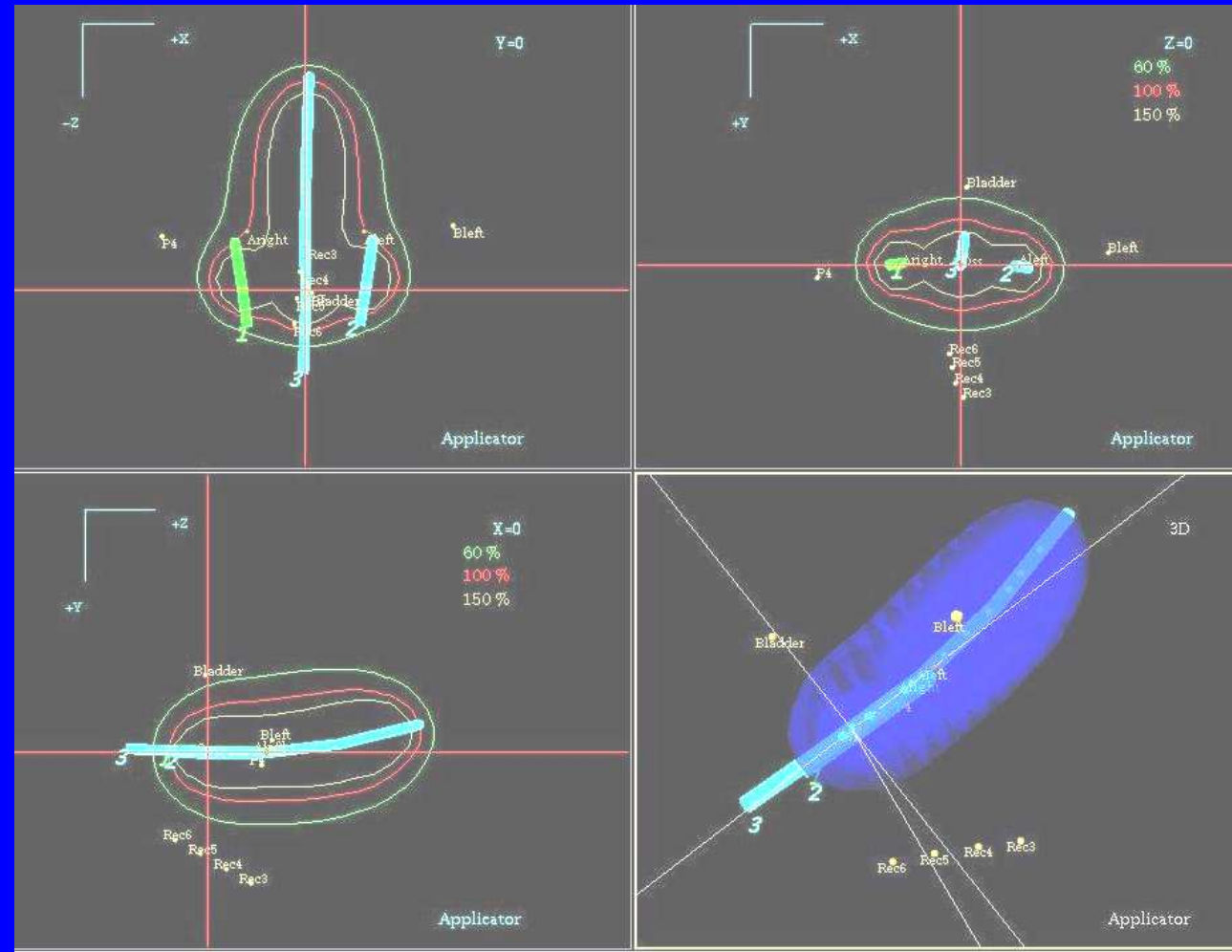
# Cervix and Endometrium - a case study

- **LDR Tandem and Ovoids Placement**
- **Lateral Simulation Film.**
- **LDR planning based on orthogonal films shows normal applicator placement.**



# Cervix and Endometrium - a case study

- **LDR planning based on orthogonal films shows normal applicator placement.**



## **Cervix and Endometrium - a case study**

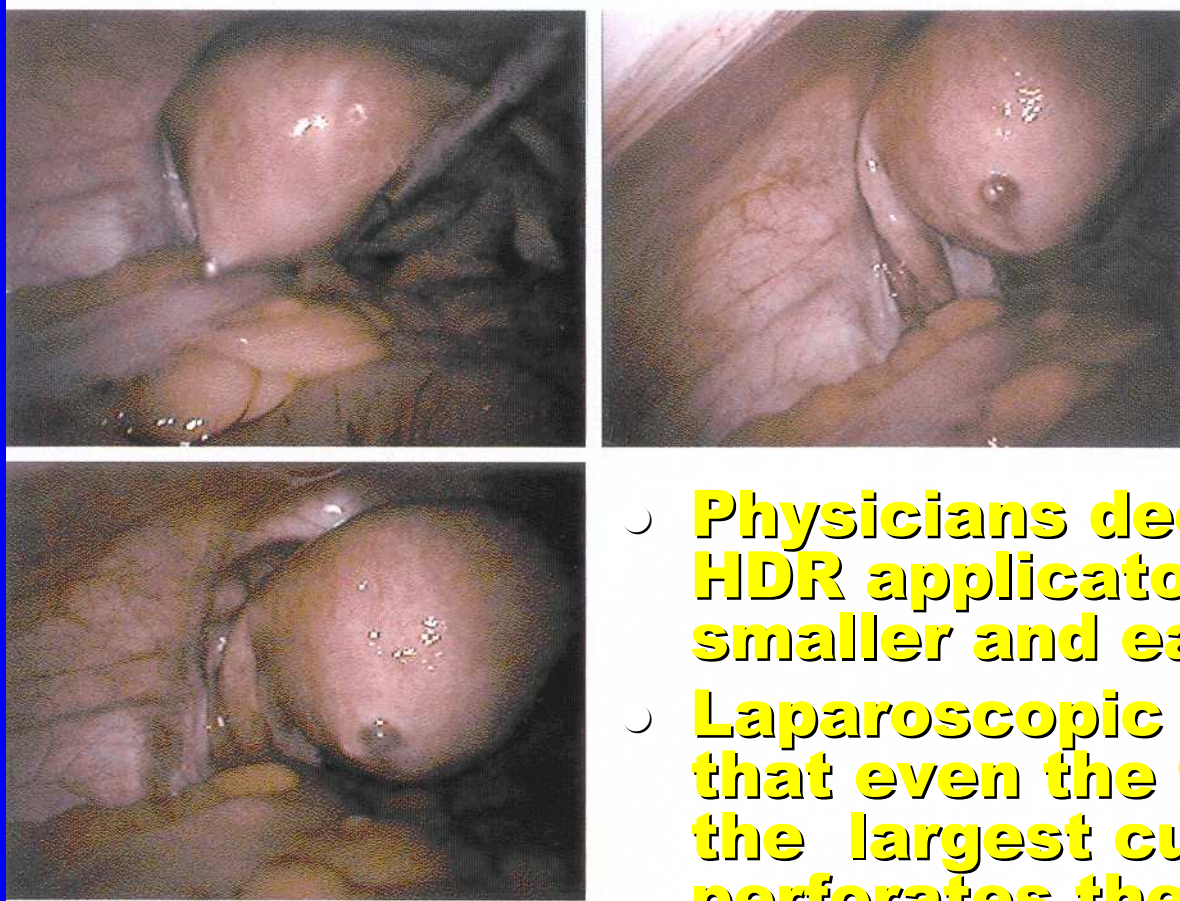
- **Physician had difficulty placing the Tandem applicator and decides to have CT scan.**
- **DRR shows antero-verted uterus and tandem perforation.**







## Second attempt with HDR applicator



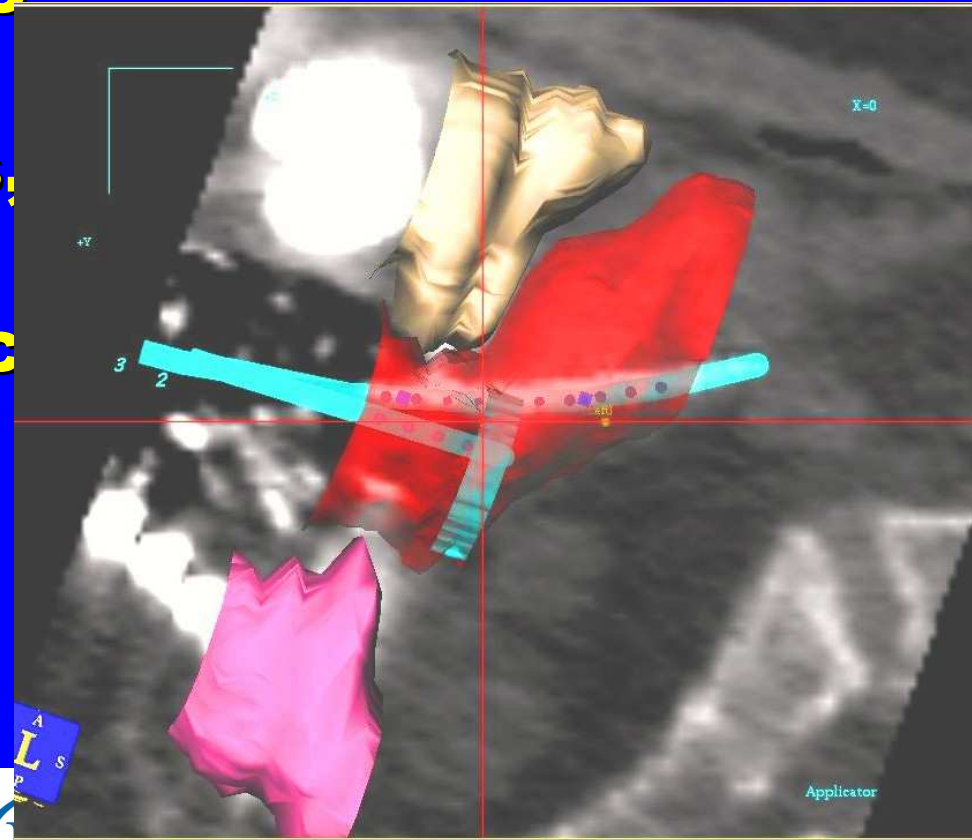
- Physicians decide to use HDR applicator since it is smaller and easier to place.
- Laparoscopic pictures show that even the tandem with the largest curvature still perforates the uterus.
- Procedure is aborted.



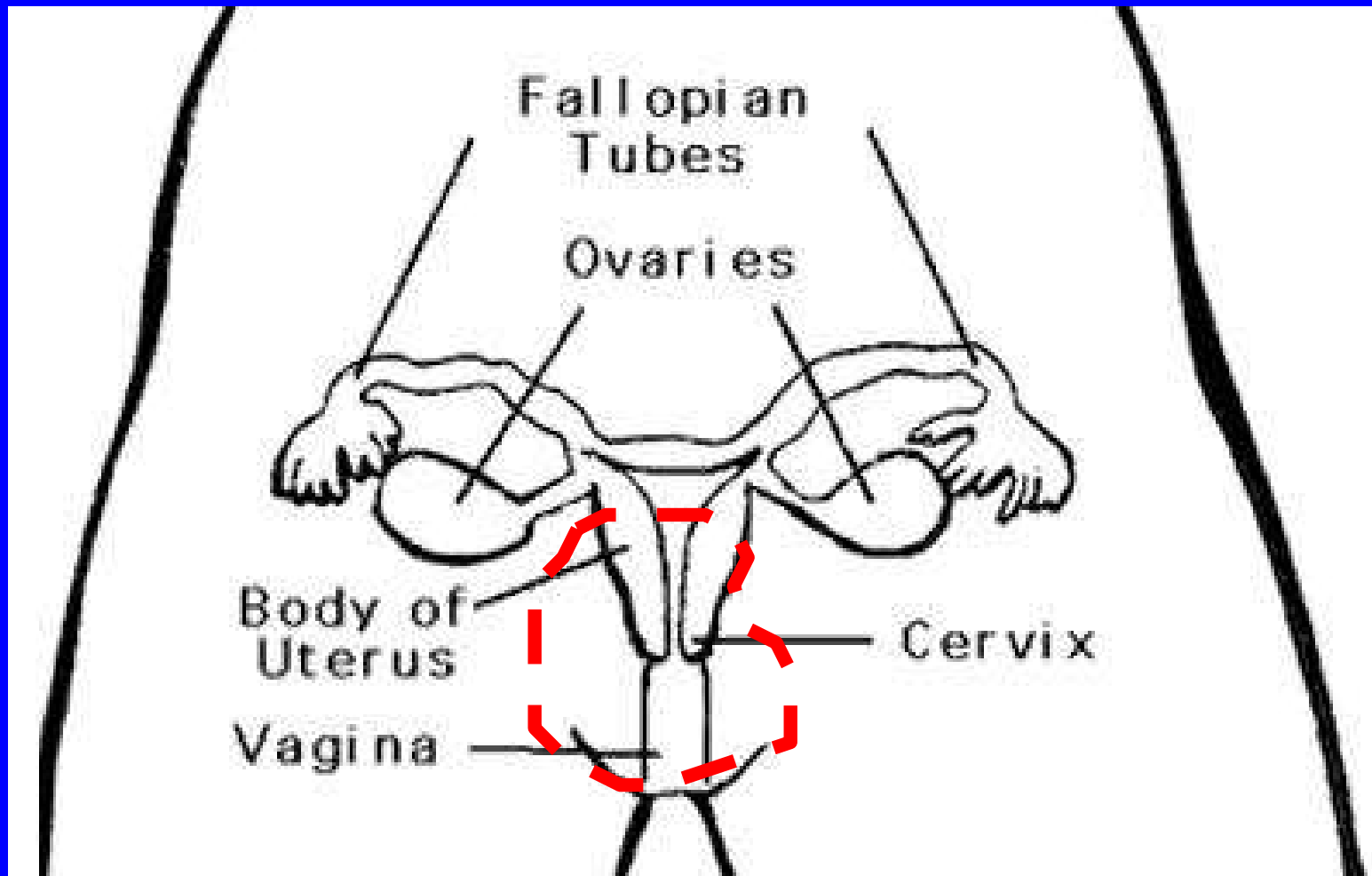


## Third Attempt

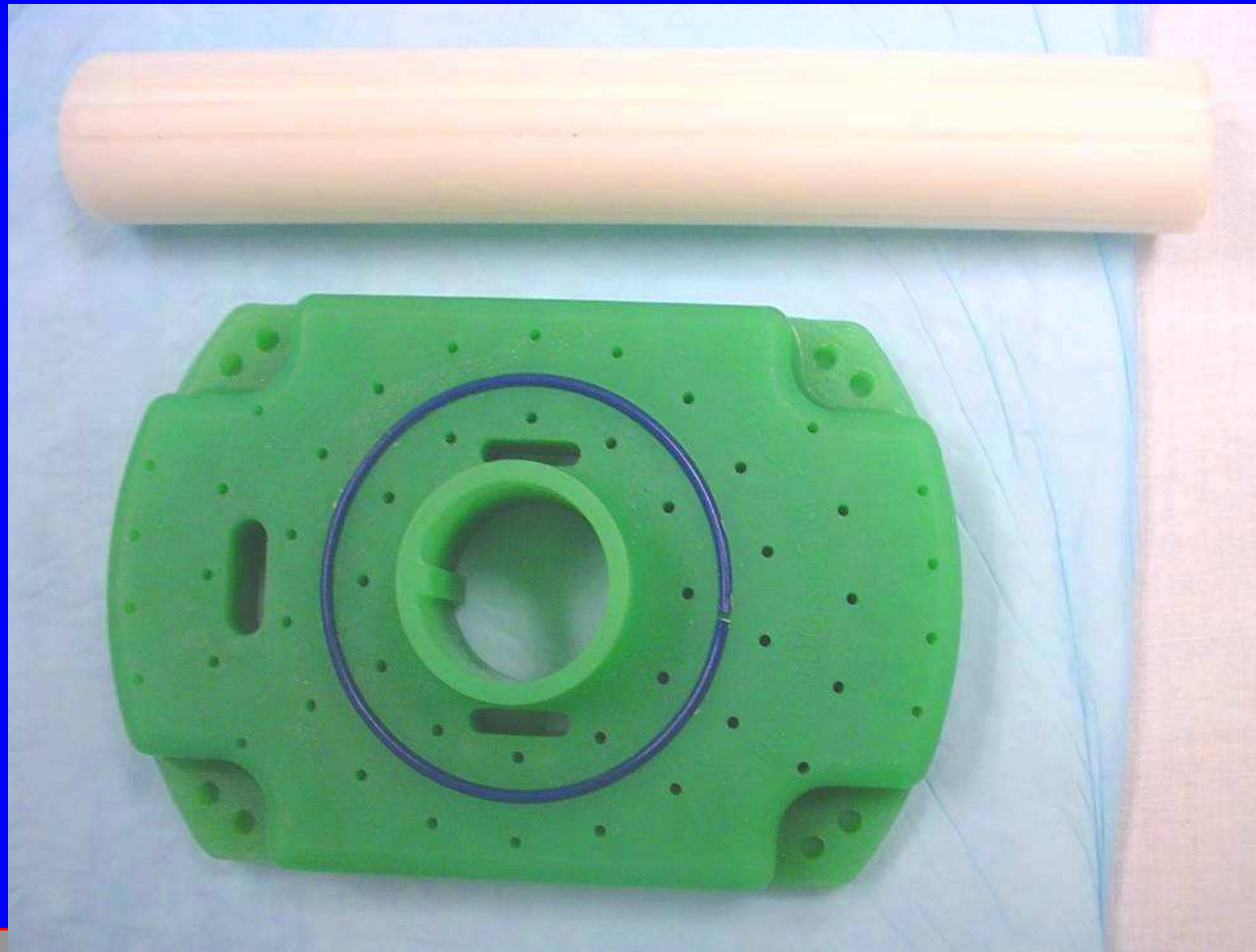
- **A flexible plastic HDR Tandem that can adapt better to the patient's uterus, and Ovoids, are placed again under laparoscopic guidance.**
- **Better placement results in somewhat better dose coverage.**



## Extensive lateral and bulky involvement



# Syed LDR Template (1.5mm diameter steel needles)



# **Why use the Syed-Neblett Technique?**

- **The standard Henschke or Fletcher applicators irradiate a volume that is symmetric around the tandem.**
- **Large and asymmetric target volumes may not be covered without overdosing the normal structures surrounding them.**
- **Interstitial implants using the Syed-Neblett template can be customized to irradiate asymmetric target volumes, typical in advance stage III or IV disease.**
- **Improved local control rates were reported in cases with advanced stage tumors treated with implants using the above technique.**



# Why use the CT based Syed-Neblett Technique?

- **Film based simulation and planning are laborious. (Six hours or more)**
- **CT-based simulation and planning can be done in about 3 hours.**
- **Easier to track individual needles on CT than using radiographs.**
- **Only CT based dosimetry can correlate dose distributions with the target and normal structure volumes, such as rectum and bladder.**
- **For quite some time, Syed template based implantation for GYN were not widely performed, in spite of favorable outcome reports.**



# **Syed Interstitial Brachytherapy Procedure**

- 1. CT Simulation**
- 2. CT/MRI Fusion**
- 3. Physics Planning (Needles positioning and OR Guidelines)**
- 4. Needles Placement**
- 5. Post implant CT Based Simulation**
- 6. Post implant physics treatment planning**
- 7. HDR Treatments**

# **Advantages of Syed LDR GYN Implant**

- **Relatively big clinical experience when compared to HDR**
- **Quite good clinical outcome with large tumors**





## *Why change from LDR to HDR?*

- Better Treatment Planning Optimization**
  - a) Better Dose Coverage**
  - b) Less Dose Inhomogeneity within the Clinical Target Volume, i.e. lesser Hot Spots**
- Better monitoring of needles/implant placement during the course of treatment ( Daily CT scan of Treatment Volume)**
- Usually there is less chance for clinical complications related to stasis in bed, i.e. thrombophlebitis**
- Nursing/medical staff not exposed to radiation**

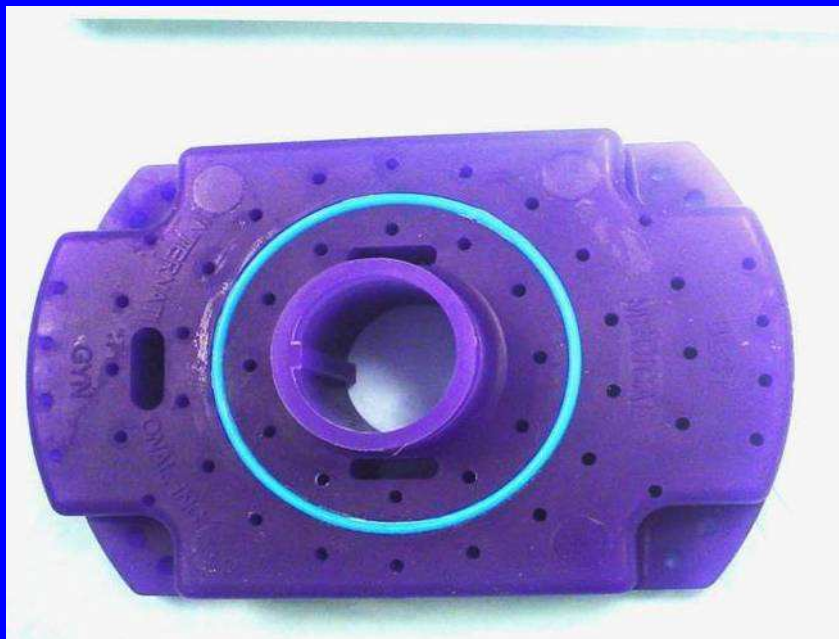
the perception of radiation  
**risk to personnel.**

**This perception can lead to  
very real consequences.**



# Syed HDR Template

## 1.9 mm diameter Plastic Needles



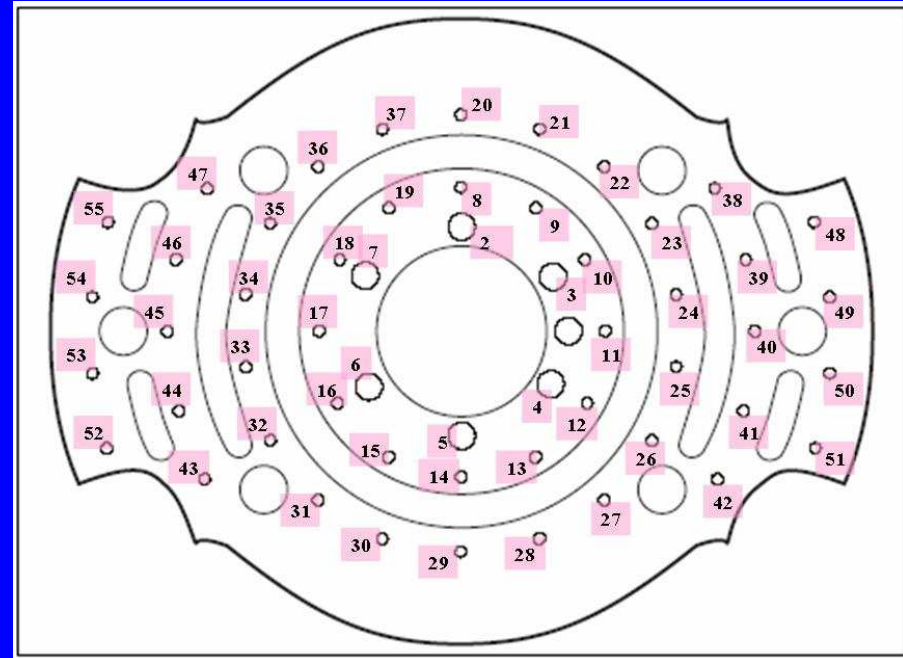
# Pre-OR planning

- **Goal: Determine appropriate number of needles and source distribution pattern for the intended target volume.**
- **Syed template, mounted on a vaginal obturator, is pressed against the perineum and the CT images are acquired with contiguous 5 mm slices.**
- **The vaginal obturator controls the geometry of the vaginal surface and stabilizes the template.**
- **The axial images are transferred to the planning system the target and normal structures are outlined by the physician.**
- **The intended needle-entry points and needle depths are estimated based on the location of the tumor volume relative to the template and the obturator.**



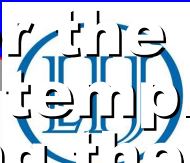
# Instructions for the OR

- **Each catheter location at the template plane is a needle entry-point and marked on the template diagram.**
- **The depth of a particular needle is calculated from the distance of the catheter tip from the most caudal surface of the template.**
- **Since the needle length is known (20 cm), the length of the protruding portion out of the template is recorded for the OR.**



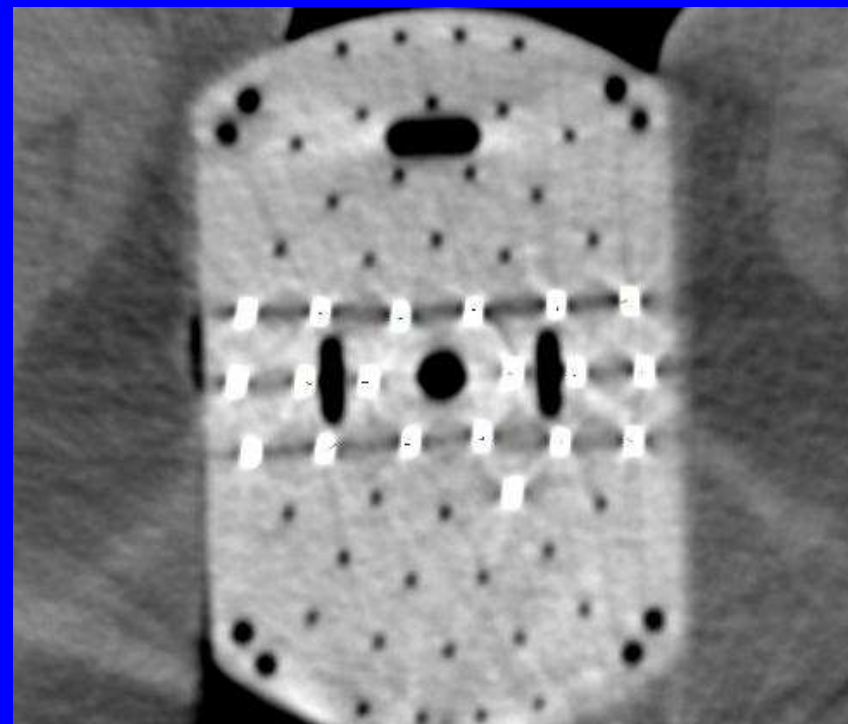
# OR procedure

- **The patient is on the OR table in the lithotomy position.**
- **A Foley catheter may be inserted in the urethra for visualizing it in the post-OR CT-images.**
- **The Syed-Neblett template is mounted on the vaginal obturator and the template is pushed against the perineum and sutured in place.**
- **Special flexible catheters are inserted with a metal obturator to the planned depth.**
- **Additional needles may be inserted at this time for potential use if needed.**
- **All needles are filled-in with a removable solid plastic thread to prevent them from kinking or collapsing. Fillers are used at all times when the patient is not treated.**
- **The entry-points for the additional needles are marked on the template diagram for identification during the post-OR**



# Post-OR CT-data acquisition

- The scanning region extends from the caudal surface of the template up to the abdomen region encompassing the bladder volume.
- Only dilute contrast for the bladder and the urethra should be used to reduce artifacts.
- The axial images are transferred into the planning system and the physician once again outlines the target and the normal structures.
- Catheter identification starts from the image at the template level, where entry-points are easily identified.
- Each catheter track is followed scan-by-scan up to its tip.
- In the planning system, the pre-planned source configuration can be modified as necessary.
- A final plan can be obtained in about 2 hours.





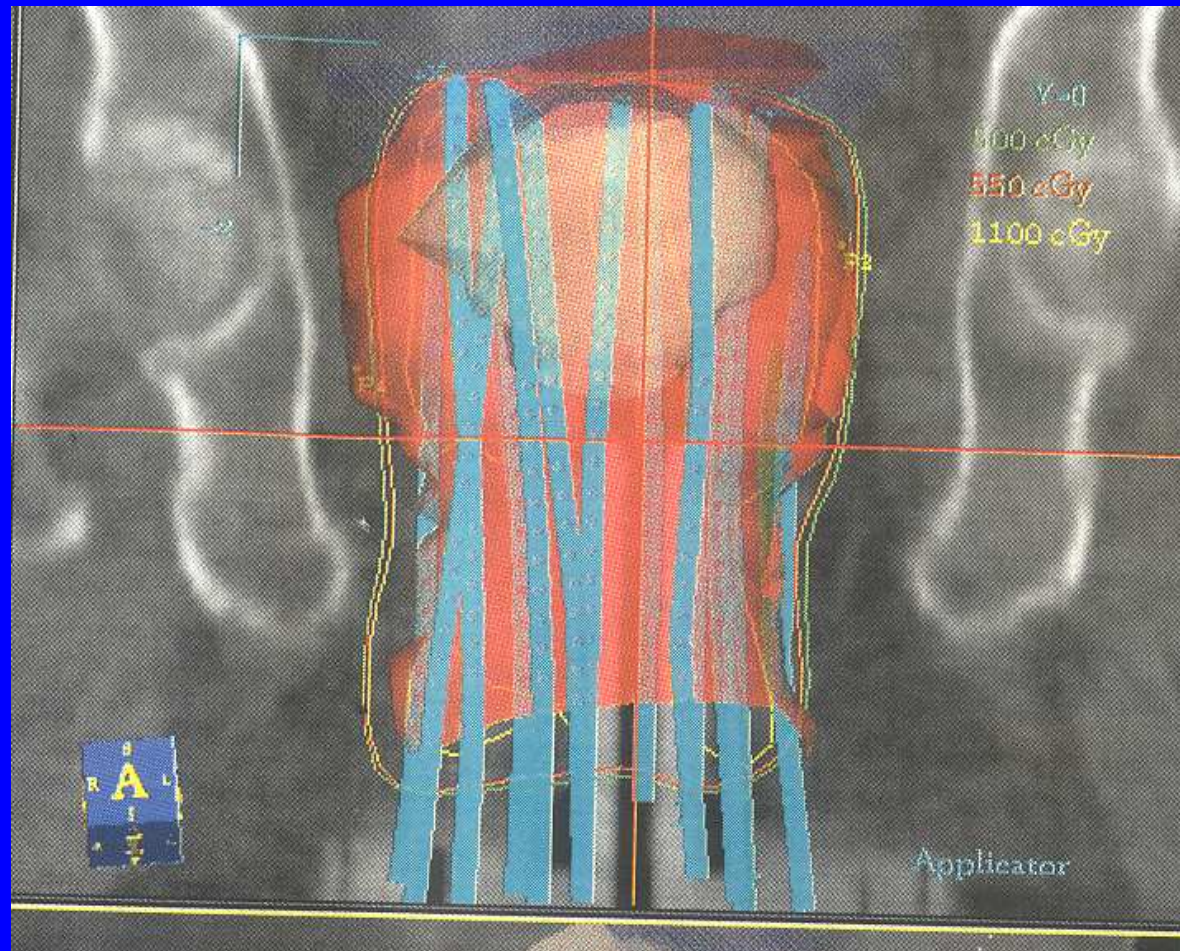
**Proper identification of the channel  
tube that connects to each needle  
is critical!**

**Few things are worse than a great  
plan – when it is executed wrong!**



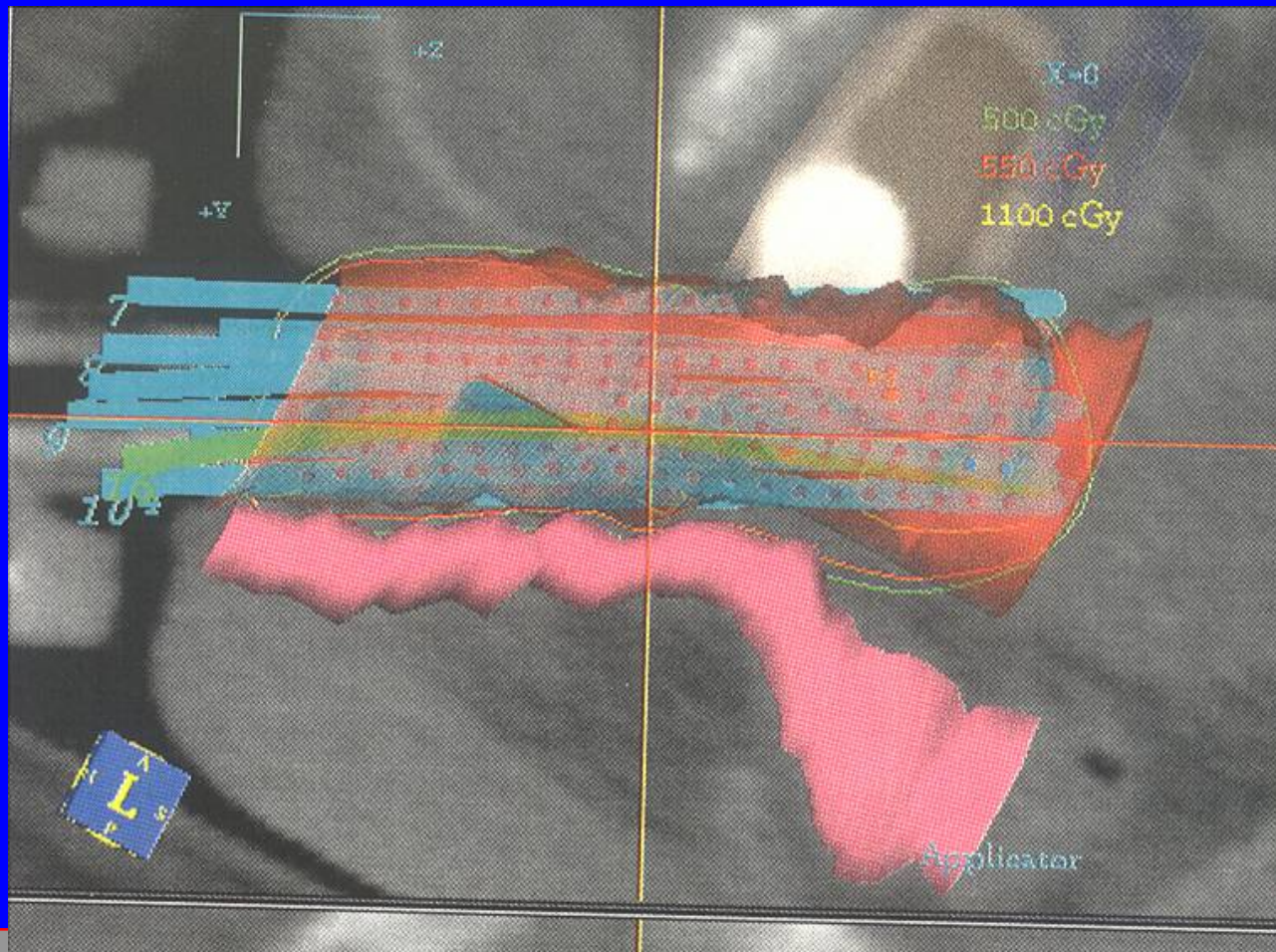
# HDR Dose Conformity

## Coronal View

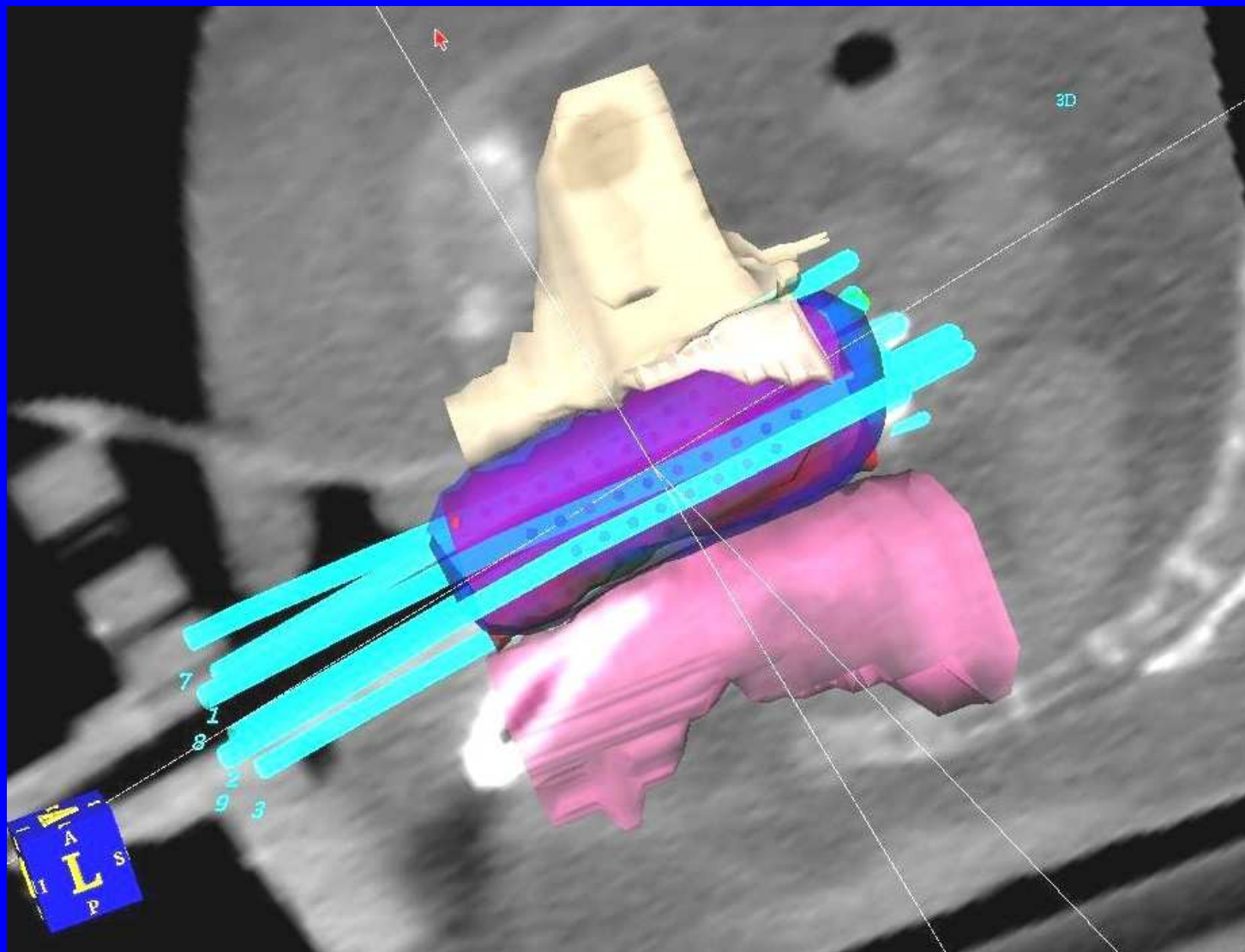




# HDR Dose Conformity- Sagittal View

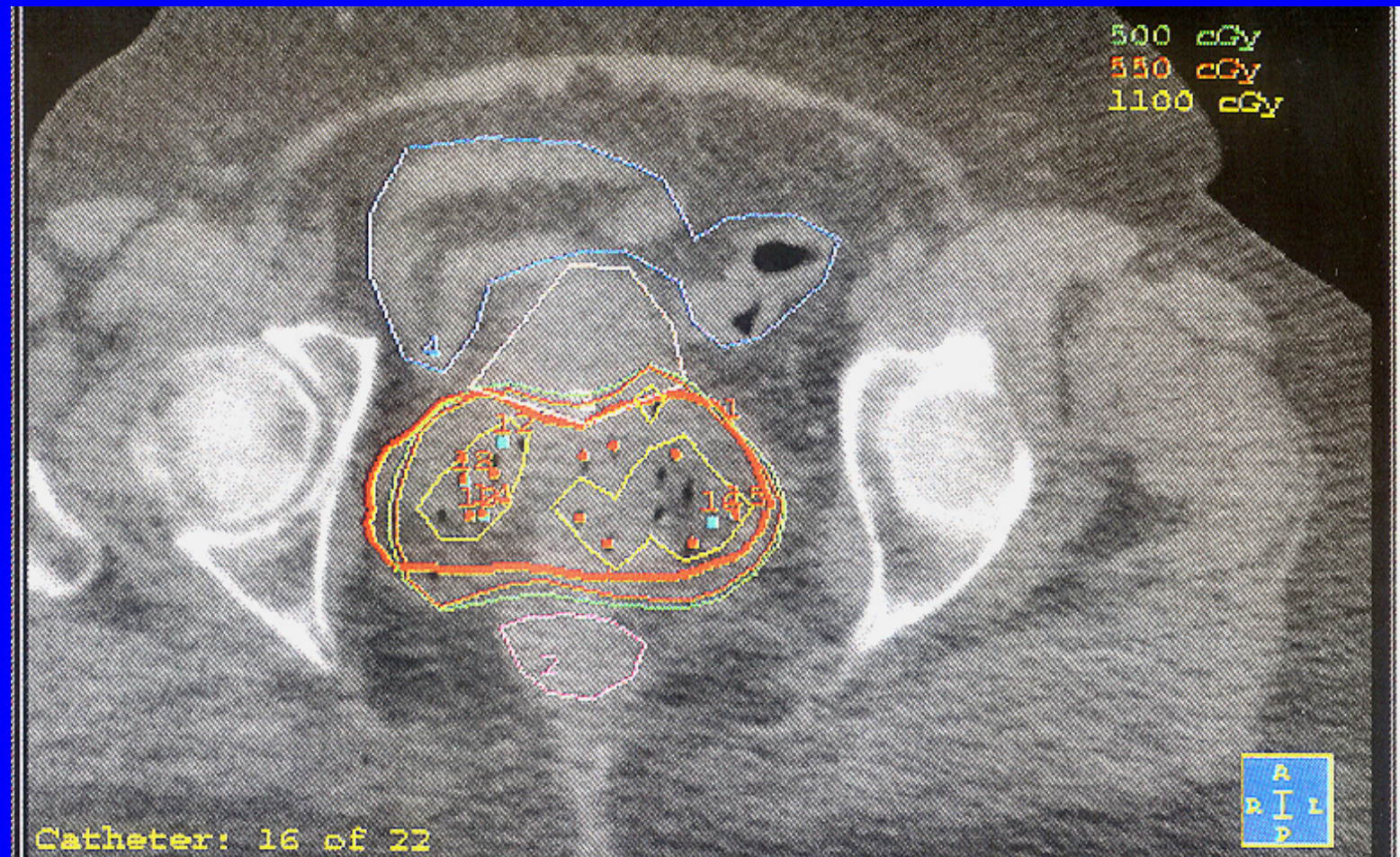


## 3D view



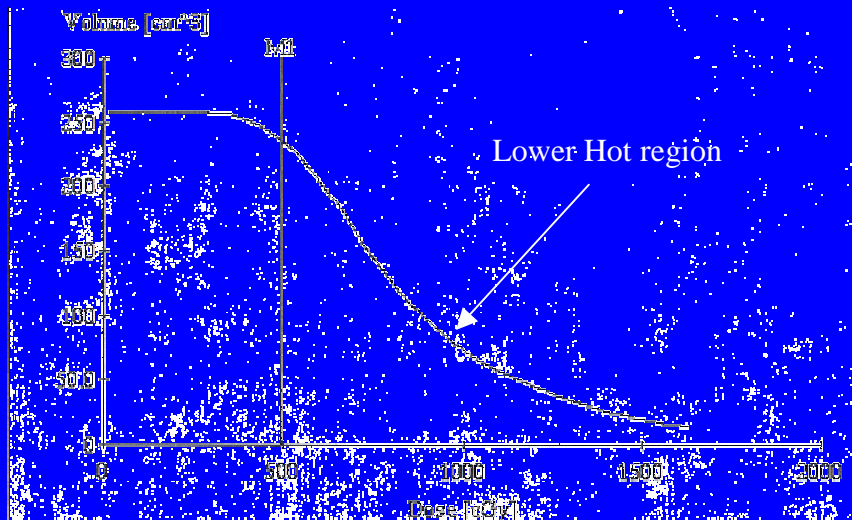


# HDR Dose Distribution (High Conformity)

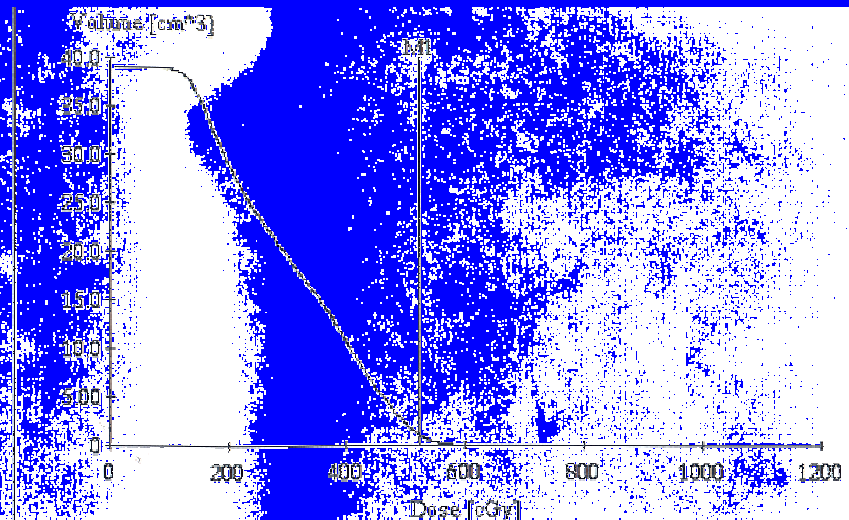




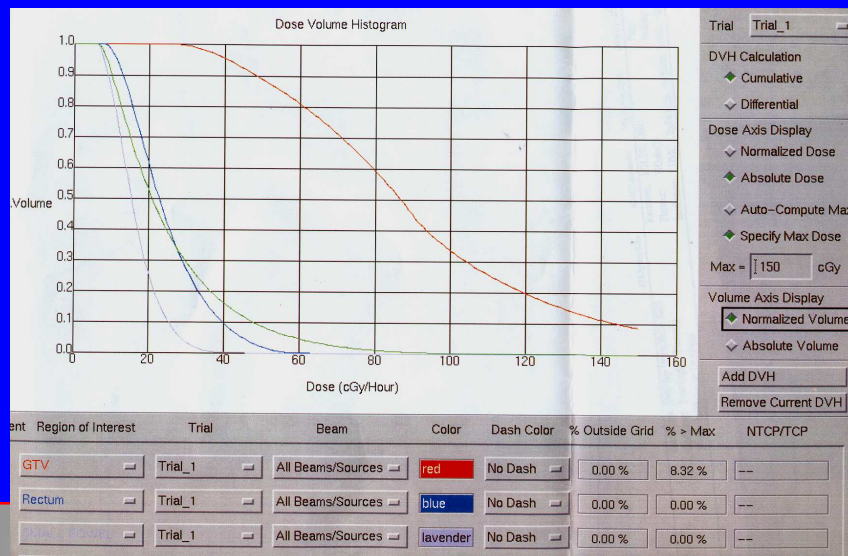
# HDR: CTV dose inhomogeneity and Max. Dose to the rectum are minimized



DVH\_0 : Cumulative DVH on CTV. State : Consistent.



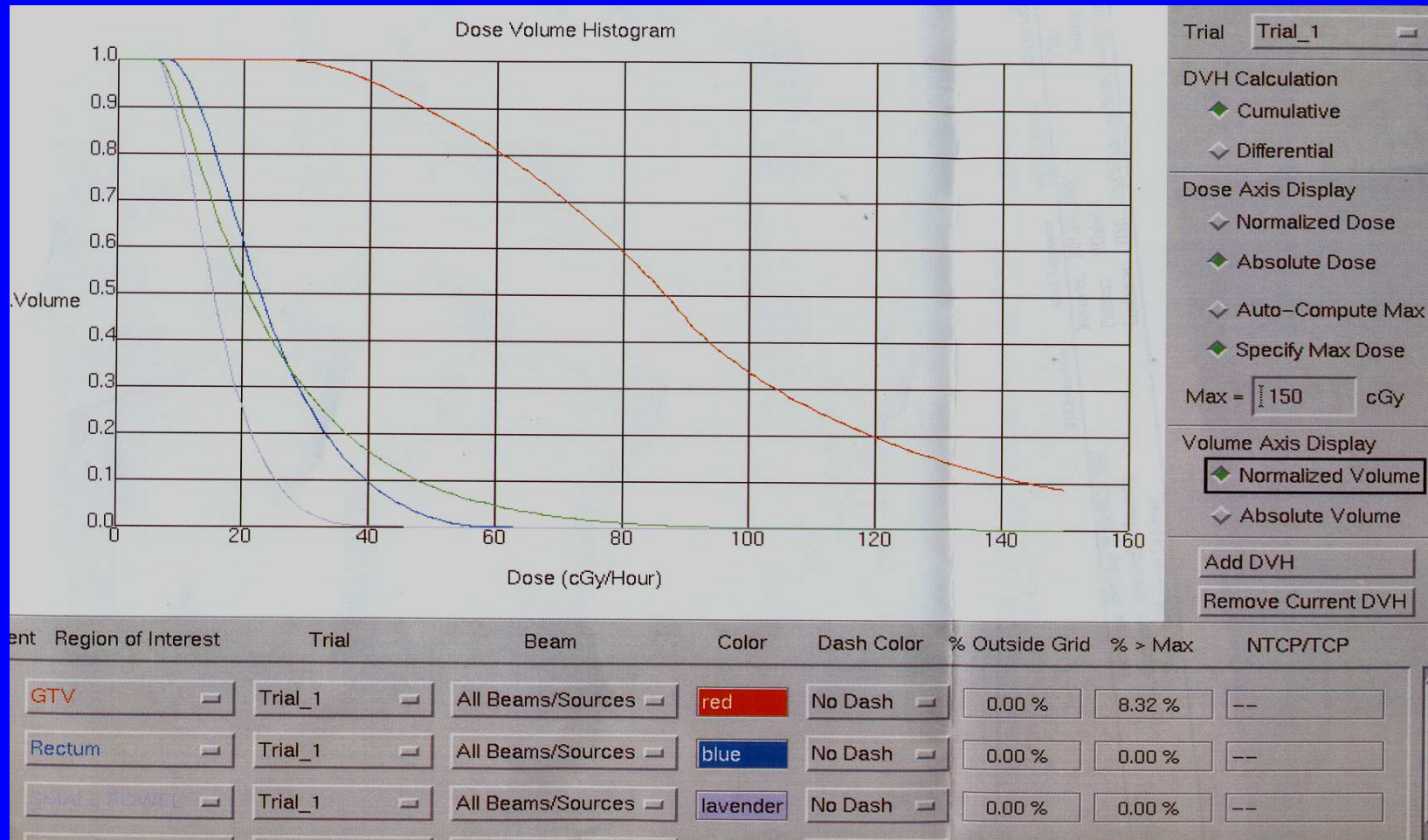
DVH\_1 : Cumulative DVH on Rectum. State : Consistent.



## LDR DVH



# LDR Dose Vol. Histogram



# Conclusion

- ❑ **When compared to LDR, Brachytherapy HDR Brachytherapy offers more flexibility in terms of optimizing Treatment Plans**
- ❑ **At LIJ 2004 and 2005 Statistics indicate that Fractionated HDR Treatment Schemes led to a gradual increase in the number of outpatient gynecologic brachytherapy treatments**

# **Summary of CT based HDR brachytherapy**

- **Volumetric imaging, such as CT datasets, allows for target and organ delineation in 3D but it requires training in CT anatomy.**
- **Higher demands on soft tissue contrast.**
- **Enhanced knowledge of the target to be treated is required.**
- **Source/applicator position may be corrected. They require repeat CT acquisitions.**
- **Margins to the target volume, to account for uncertainties in localization, for patient repositioning and immobilization and for organ motion, typical of EBRT, are not necessary as the sources are placed directly into the tissue.**
- **Highly conformal dose distributions are similar to those achieved with IMRT, provided that the applicators or catheters are carefully placed.**
- **While inhomogeneities are higher than in EBRT, they can be kept within the target and at a clinically safe level.**

