Brachytherapy for the Treatment of Prostate Cancer

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Clinical Considerations

- Prostate Cancer grows slowly
- Early detection is more common
- Larger Doses are required to control Prostate tumors
- Life expectancy is longer
- Quality of life is affected by side effects and complications

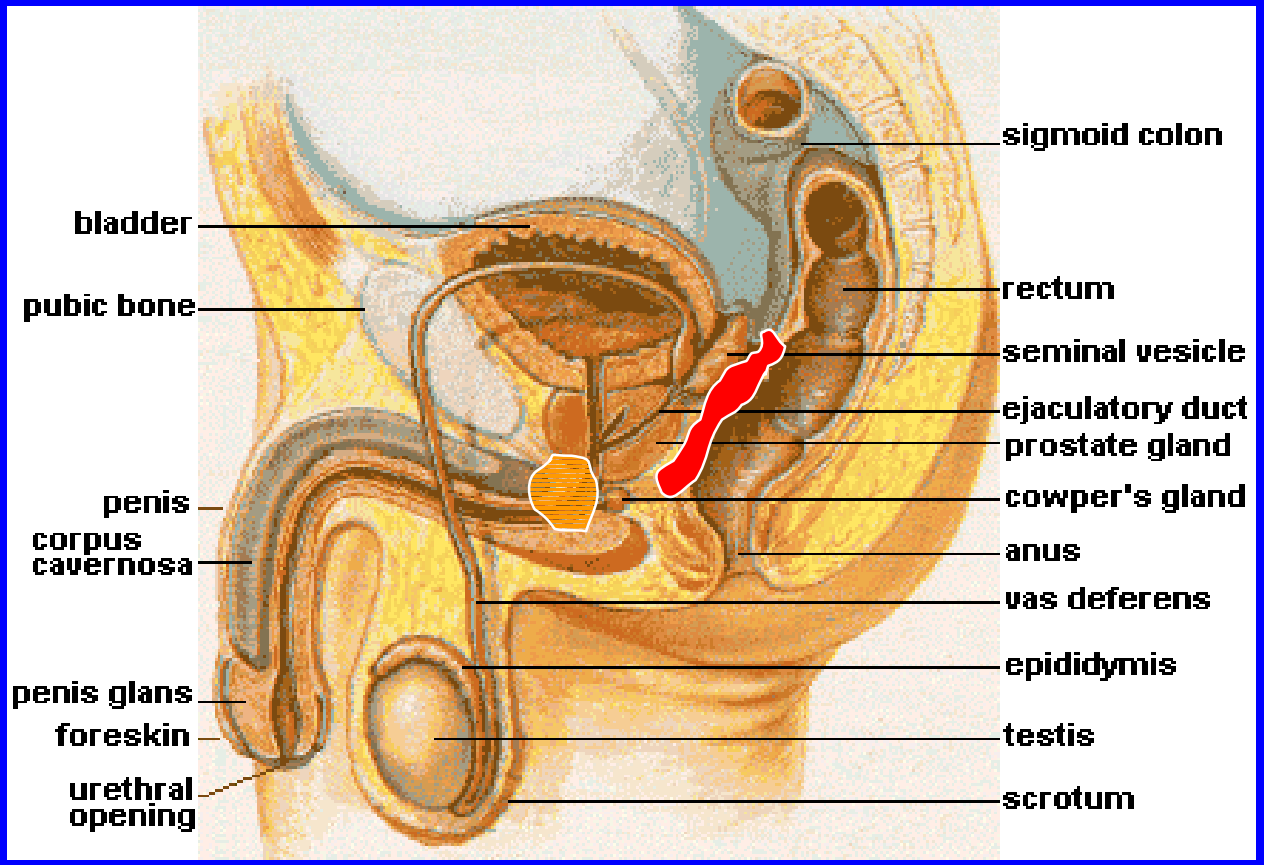
The most common treatments for prostate cancer include:

- surgery
- external beam radiotherapy (EBRT)
- hormone therapy
- radioactive seed implants (TPPI)
- watchful waiting.

Main Modalities for Prostate RT

- **External Beam Radiation Therapy**
  - Classical 2-D planning
  - 3D-Conformal RT (3D-CRT)
  - IMRT
- **Permanent Implants**
  - Nomogram and rule based
  - Preplanned and preloaded
  - Intraoperative Interactive dose planned
- **HDR Brachytherapy**

It is what lays around the prostate that affects the limits of RT



Dose Response in Prostate Ca

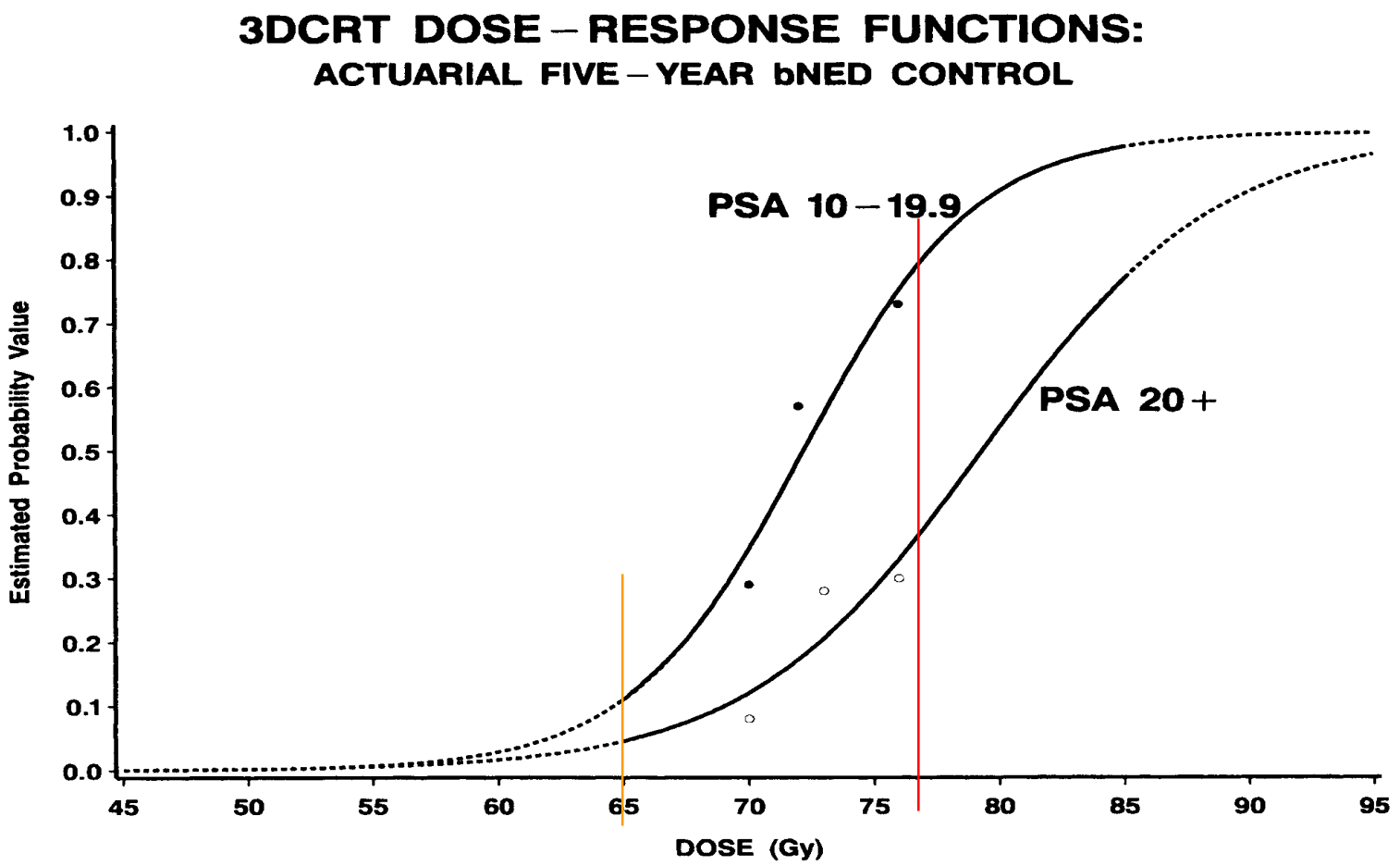


Fig. 2. Logistic response models for bNED for two pretreatment PSA groups.

- From: G.E.Hanks et. al., IJROBP, June 1998

Morbidity Vs. Dose

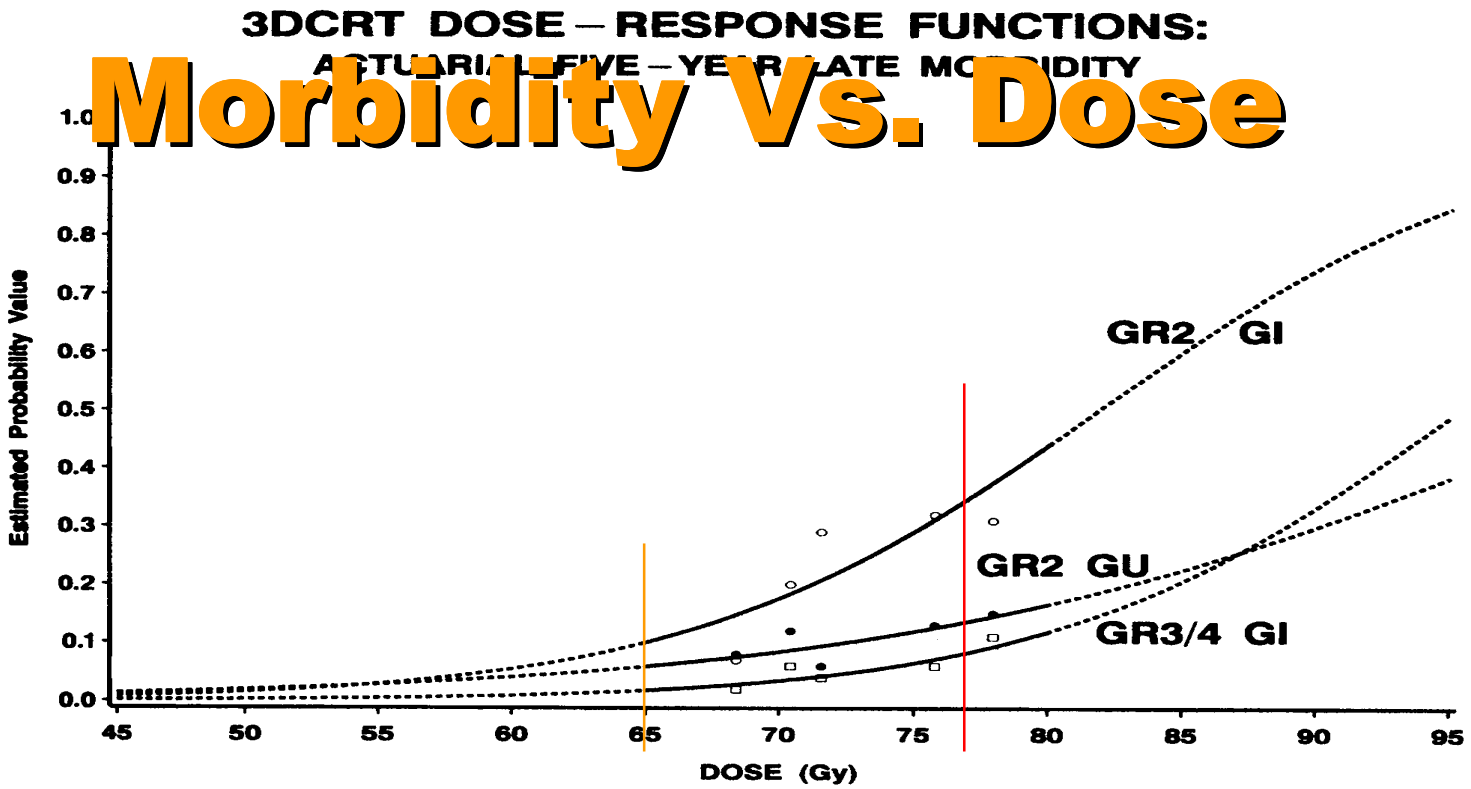
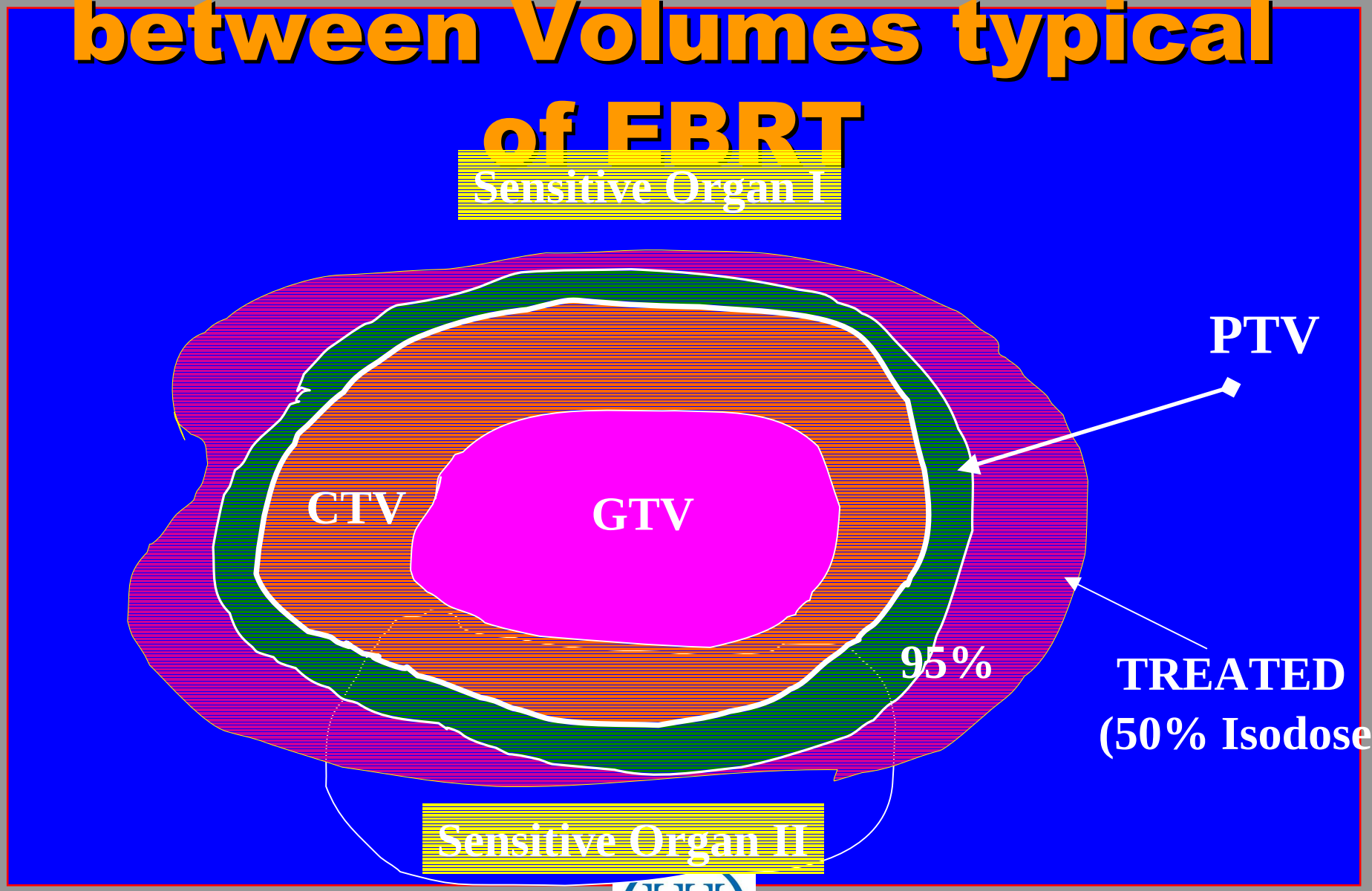


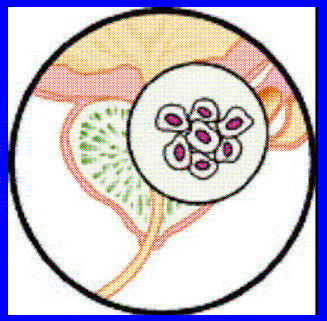
Fig. 5. Logistic response models for gastrointestinal and genitourinary radiation sequelae.

From:G.E.Hanks et. al., IJROBP, June 1998

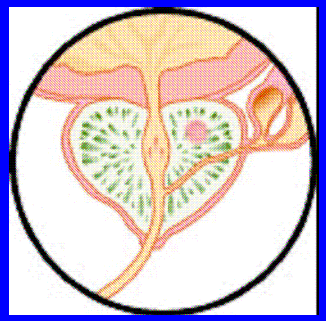
Spatial Relations between Volumes typical of EBRT



Stages amenable to Brachytherapy



- **T1 - The tumor is located within the prostate gland and is too small to be detected by DRE. It may be discovered through other diagnostic procedures (PSA test, biopsy) Generally produces no Physical symptoms.**



- **T2 Stage - The tumor is still located within the prostate gland but it can be felt during a DRE exam or**

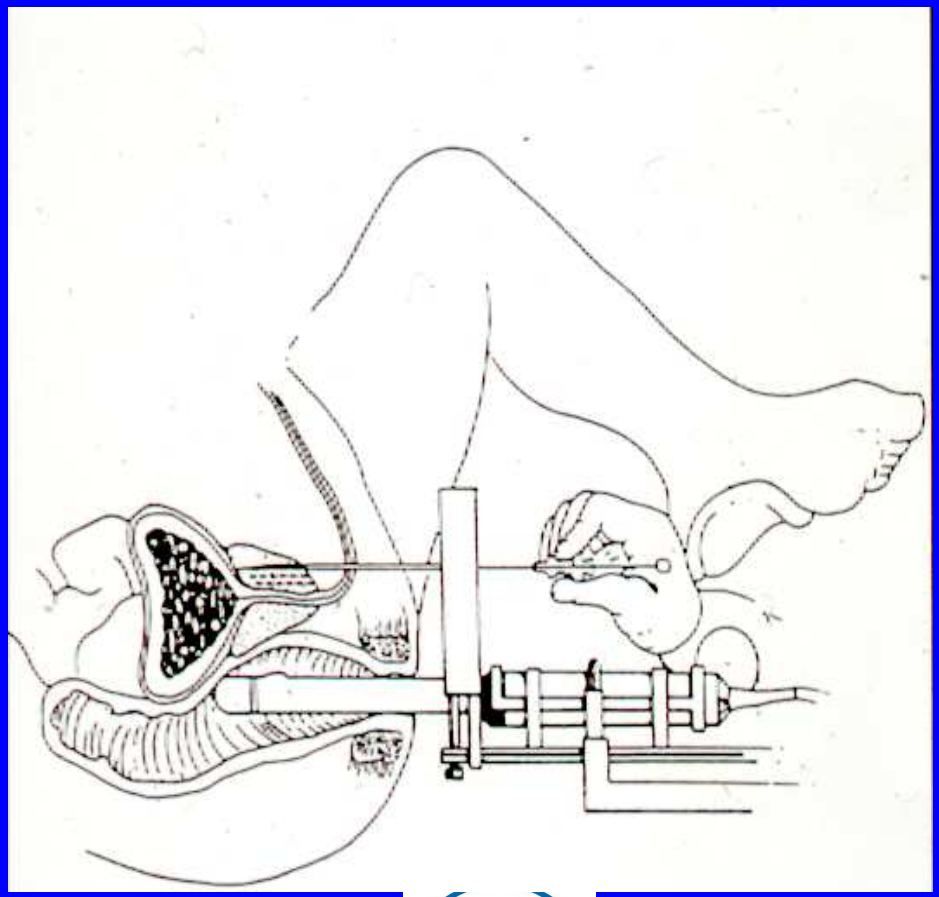
Sources of uncertainty in EBRT that can be avoided in Brachytherapy

- **Physiological movements and variations in size, shape and position of the Prostate gland in relation to anatomic landmarks or an internal reference point. The CTV is expanded by the Internal Margins (IM) to create the Internal Target Volume (ITV).**
- **Typically Internal Margins are:**
  - **A: 5 mm posterior**
  - **B: 10 mm anterior and lateral, and**
  - **C: Two slices each, superior and inferior, "copied" from the last delineated contour. Slices are 3 mm apart so the IM=6 mm.**

Prostate seed implants

- **Prostate implants were developed in the 1960's at Memorial Sloan Kettering Cancer Center and on the West coast. The initial technique involved open access to the prostate.**
- **On the last fifteen years, Transperineal prostate implants became predominant in the USA, pioneered by SPI - Washington State, Mt Sinai and MSKCC in NY.**
- **More than 800 papers published on this subject since 1990.**

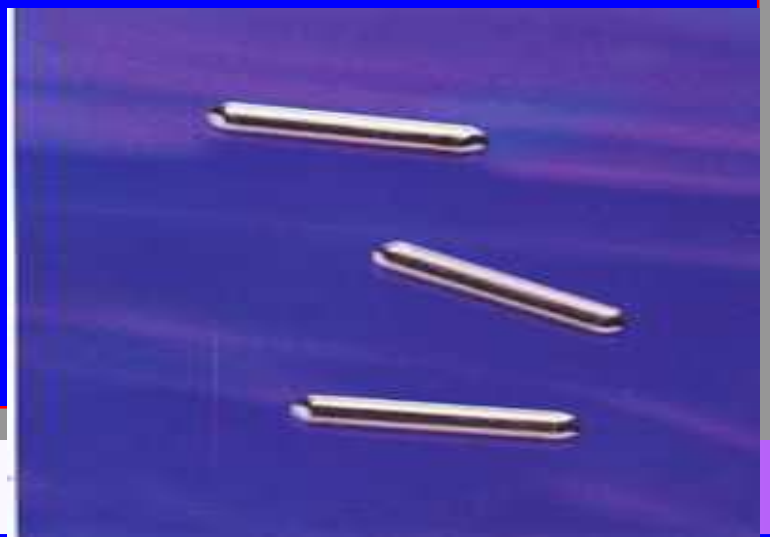
Transrectal Ultrasound Guided Brachytherapy



tioning

- High Lithotomy
- Patient to edge of table
- Symmetry of legs
- Tilt US forward to remove air from the

Different Implant techniques



Prescription Dose

- The American Brachytherapy Society (ABS) recommends an RX of 145 Gy and 125 Gy for ^{125}I and ^{103}Pd, in monotherapy brachytherapy, and 110 Gy of ^{125}I and 100 Gy ^{103}Pd if used as a boost following pelvic EBRT of 40 to 50 Gy.
- Typically the doses are prescribed to the minimum peripheral dose (MPD) which is the maximum dose that cover 100% of the target volume. Usu. 90% of the target volume will receive the prescription dose.

- The Mean Peripheral dose is the average of the dose at the surface of the target volume, and varies less than the MPD with seed position.

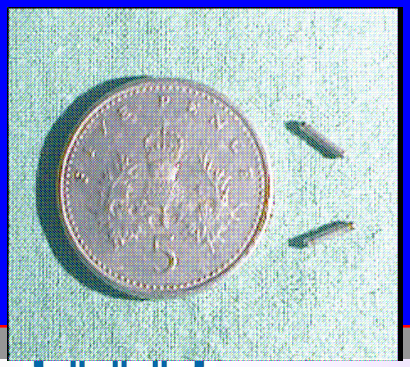
Prescription Dose

LDR Seed selection

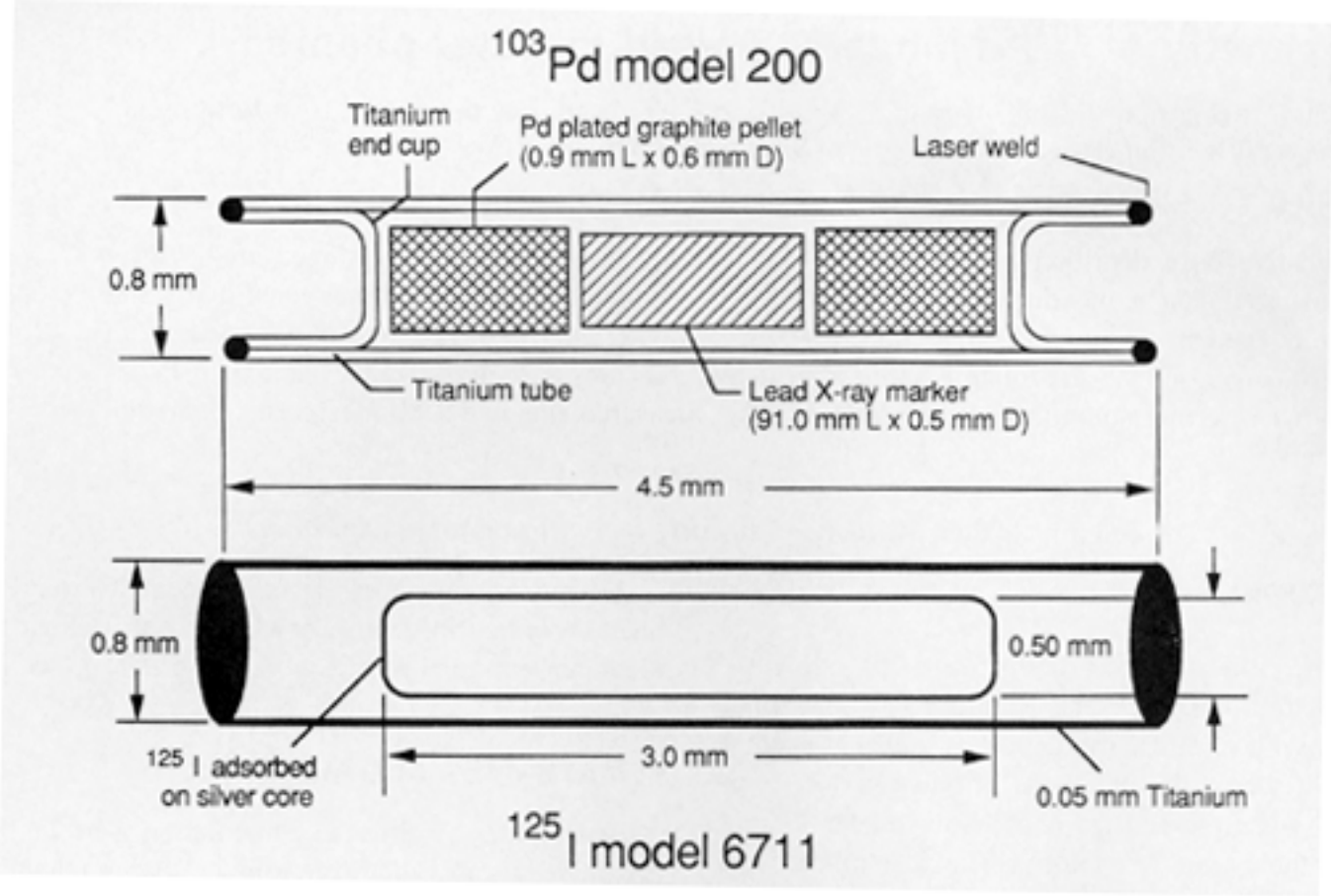
- Iodine 125 (^{125}I) and Palladium103 (^{103}Pd) are the most commonly used isotopes.

Properties:

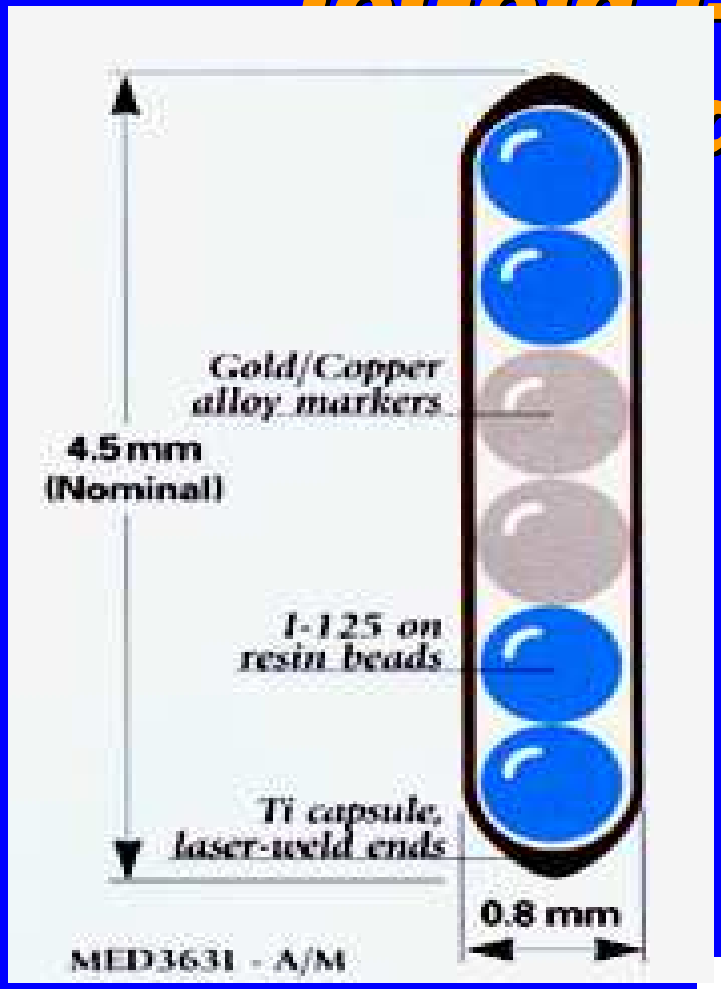
	^{125}I	^{103}Pd
• Half life (d)	59.4	17
• Energy (kV)	28	21
• Radiobiologic Equiv.	1.4	1.9

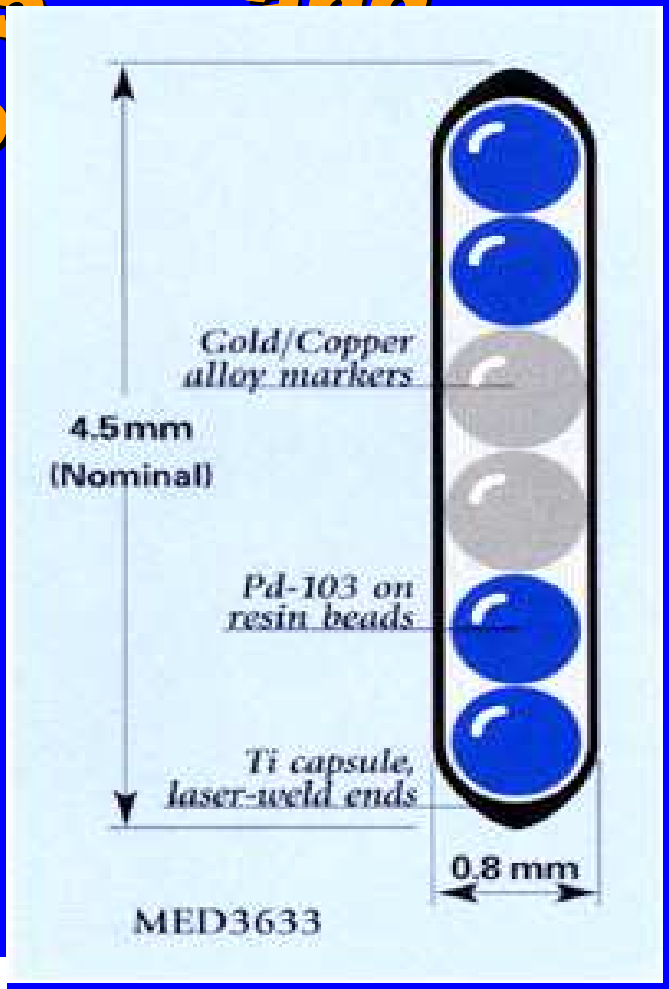


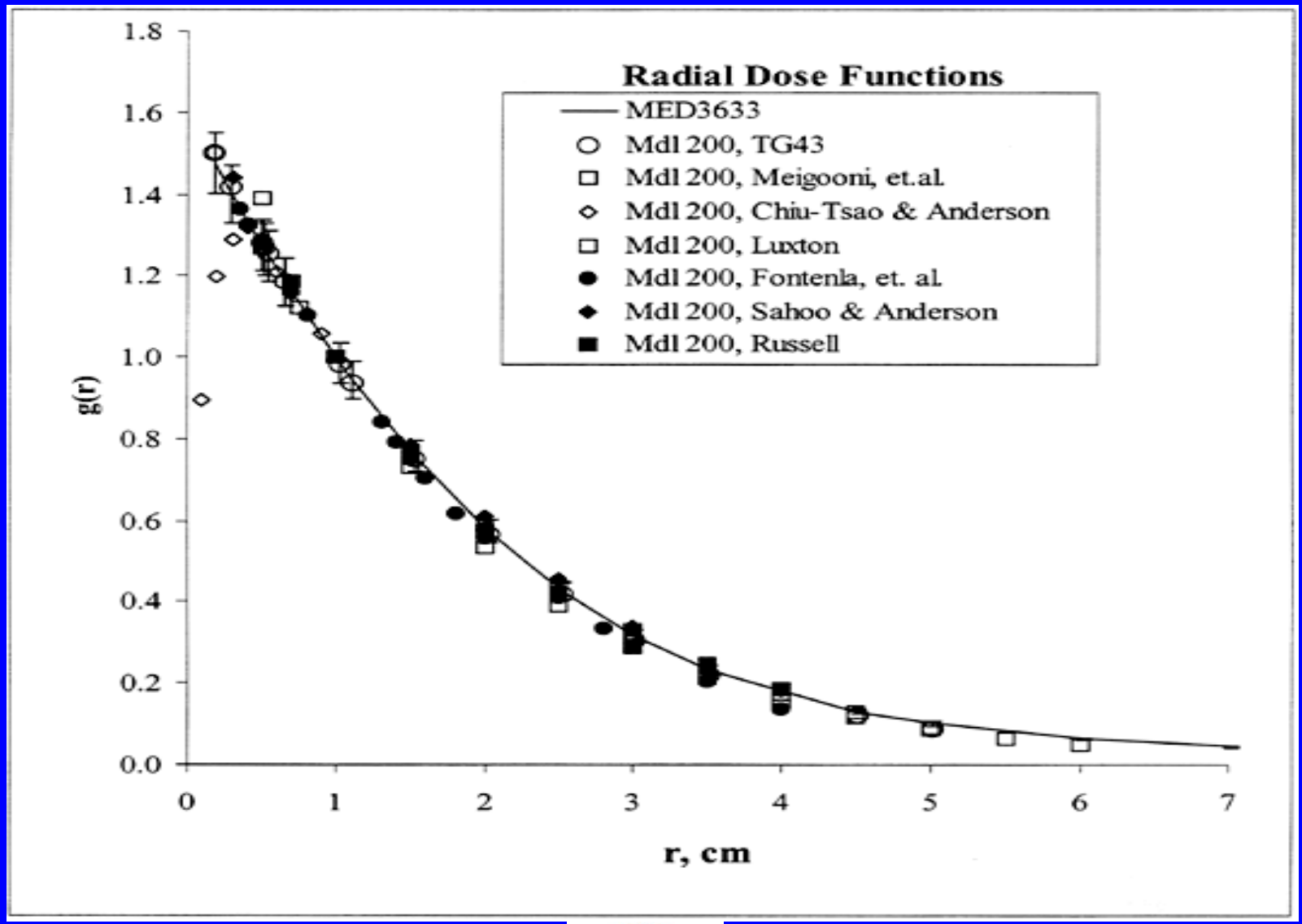
I-12 0


103Pd model 200
Titanium end cup
Pd plated graphite pellet (0.9 mm L x 0.6 mm D)
Laser weld
0.8 mm
Titanium tube
Lead X-ray marker (91.0 mm L x 0.5 mm D)
4.5 mm
0.8 mm
0.50 mm
125 I adsorbed on silver core
3.0 mm
0.05 mm Titanium
125I model 6711

JoGold I-125 and dGo






Radial Dose Functions
MED3633
Mdl 200, TG43
Mdl 200, Meigooni, et.al.
Mdl 200, Chiu-Tsao & Anderson
Mdl 200, Luxton
Mdl 200, Fontenla, et. al.
Mdl 200, Sahoo & Anderson
Mdl 200, Russell
g(r)
r, cm
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7

Advantages of seed implants:

- **Recent clinical data shows a high percentage of implant patients remaining disease free than with either radical prostatectomy or external beam therapy.**

- **Seed implantation normally takes about one or two hours. The patient usually leaves the hospital the same day. Many patients resume normal activities within a few days.**

- **Seeds can deliver two to three times more dose than EBRT.**

- **Incontinence occurs in less than 5% of patients under the age of 60. More often for patients over the age of 60.**

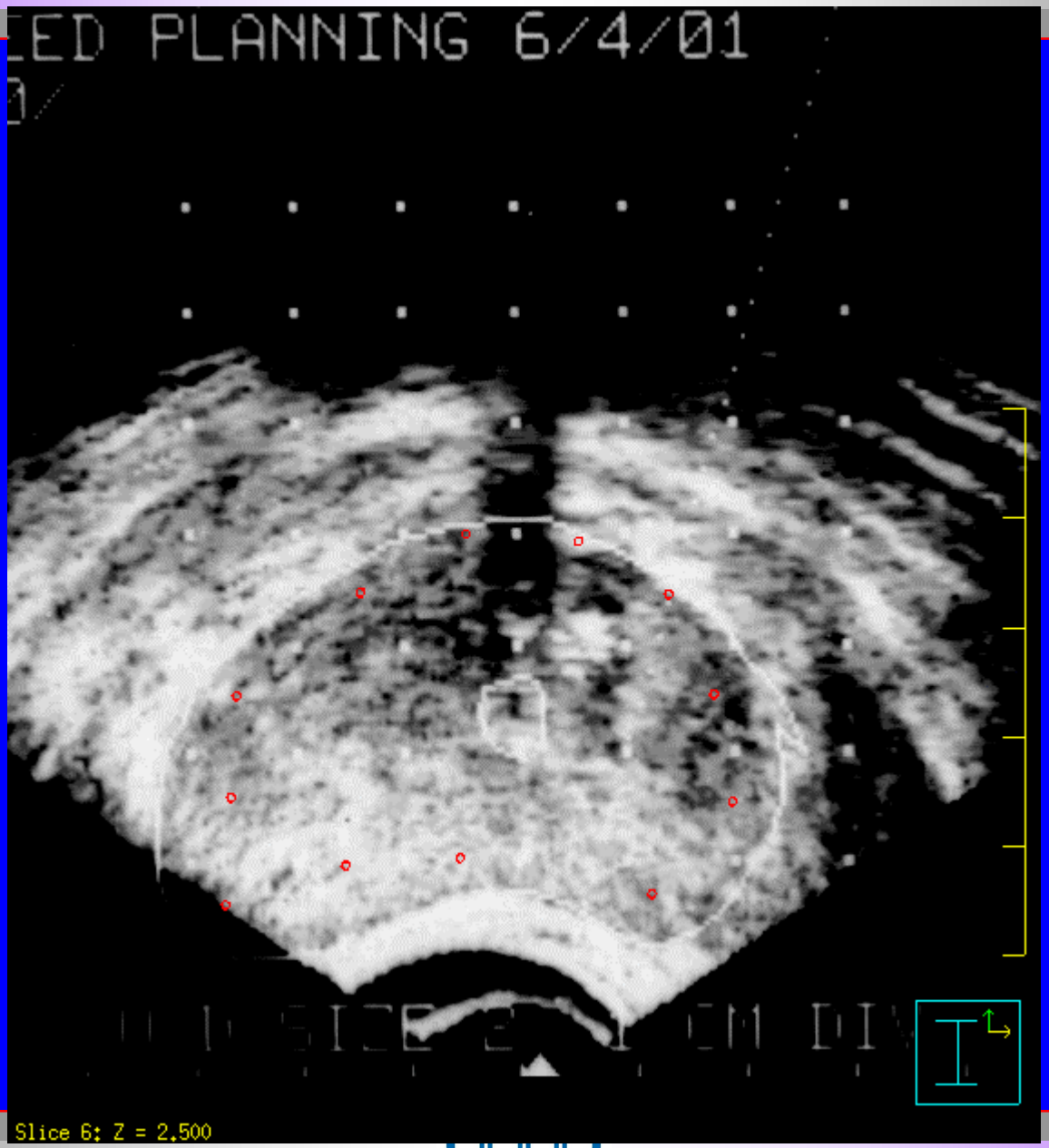
- **This procedure is better tolerated than surgery or external radiation.**

Disadvantages of seed implants:

- The long term results are fully established yet. The current clinical data show good results up to seven years.

- It is common to experience problems with urination for several months after seed implantation. These symptoms will, however, gradually ease and eventually disappear.

- Although the seeds remain radioactive for several months, the energy and activity of the seeds is so low that there is negligible risk of exposure to others and only simple precautions are necessary for the first 2-3 months.


ED PLANNING 6/4/01
Slice 6: Z = 2.500

1. **RTOG 98-05:**

"Phase II Trial of TRUS Permanent Radioactive Implantation of the Prostate for the Definitive Management of Localized Adenocarcinoma of the Prostate."

2. **American Brachytherapy Society: "*The ABS Recommendations for Permanent Prostate Brachytherapy Post implant Dosimetric Analysis" Int.J.Radiat Oncol Biol Phys, 2000;46,N 1:221-230"***

RTOG Objectives

- **Evaluate effectiveness of TRUS permanent implantation of the prostate for organ confined adenocarcinoma as compared with historical data of prostatectomy or external beam.**
- **Establish & Test QA standards for future protocols.**
- **Test dosimetric evaluation of implants.**

RTOG Parameters:

- Criteria for Patient Selection.
- Definition of Planning Target Volume:
  (PTV = Pre-implant TRUS+margins)
- Evaluation Target Volume
  (ETV = Post-Op CT).
- Seed Calibration and Handling.
- Post-Op evaluation.
- Dose Volume Histogram.

Evaluation criteria

- **Per Protocol : ≥ 80% of ETV receives at least 90% of PD.**
- **Variation, Acceptable: ≥50% of the ETV receives at least 90% of PD**
- **Deviation, Unacceptable: ≥ 50% of the ETV receives <90% of PD.**

GENERAL LISTING OF I-125 SEED IMPLANT INFORMATION

Iodine-125 Properties

I-125 sealed in metal *seed*

Average energy = 28 keV,

***Patient Dose*:**

(Assuming 145 Gy isodose at the surface of the prostate of diameter = 5cm)

Average Dose Rate=7cGy/hour =168 cGy/day

(Similar to external beam therapy).

Total dose (calculated for Half Life x 1.44)

Total Dose = 7*cGy* x 24*hour* x 60*days* x 1.44

hour day

=14,500 cGy = 145 Gy

Shielding

Half Value Layer = 0.025 mm lead = 20 mm tissue. So, 10 cm of tissue attenuates 97% of x-rays.

External Exposure

Pelvic surface = 2 - 20 mrem/hour

Three foot distance = 0.1 -> 1 mrem/hour

Background = 2 mrem/week

- ***Pre-planning (PP)*: Creation of a plan a few days or weeks before implant procedure.**
- ***Intra-operative Planning (IOP)*: Tx Planning in the OR: Pt and TRUS probe are not moved between the volume study and the seed insertion.**
- ***Interactive Planning (IP)*: Stepwise refinement of the Tx plan using computerized dose calculations derived from image-base needle position feedback.**
- ***Dynamic Dose Calculation (DDC)*: Constant updating of dose distribution calculations using continuous**

From: Report of Abs.: IJROBP 51(5): 1422-1430, Dec 2001

General 1-D formalism

- Used for most RTPS.
- It eliminates the need to determine the orientation of the source longitudinal axis from imaging studies.

1-D isotropic point source calculation

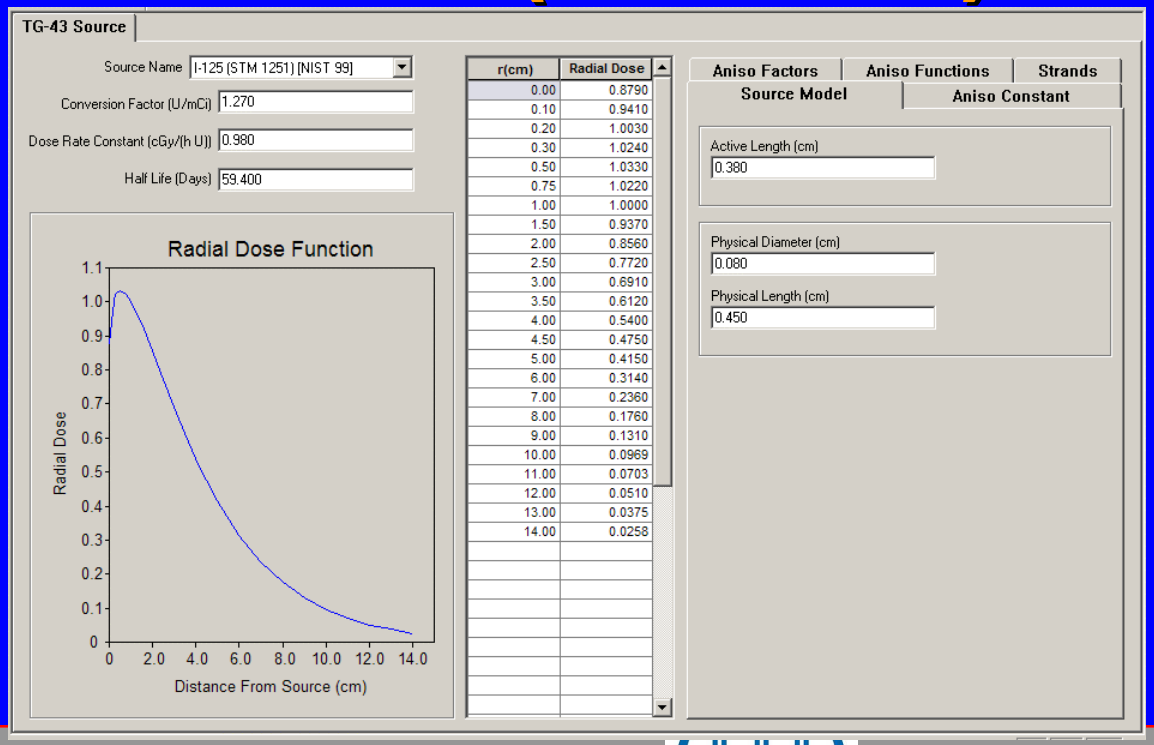
$$\dot{D}(r) = S_K \cdot \Lambda \cdot \frac{G_X(r,\theta_0)}{G_X(r_0,\theta_0)} \cdot g_X(r) \cdot \phi_{an}(r)$$

1D anisotropy function

$$\phi_{an}(r) = \frac{\int_0^{\pi} \dot{D}(r,\theta)\sin(\theta)\,d\theta}{2\,\dot{D}(r,\theta_0)}$$

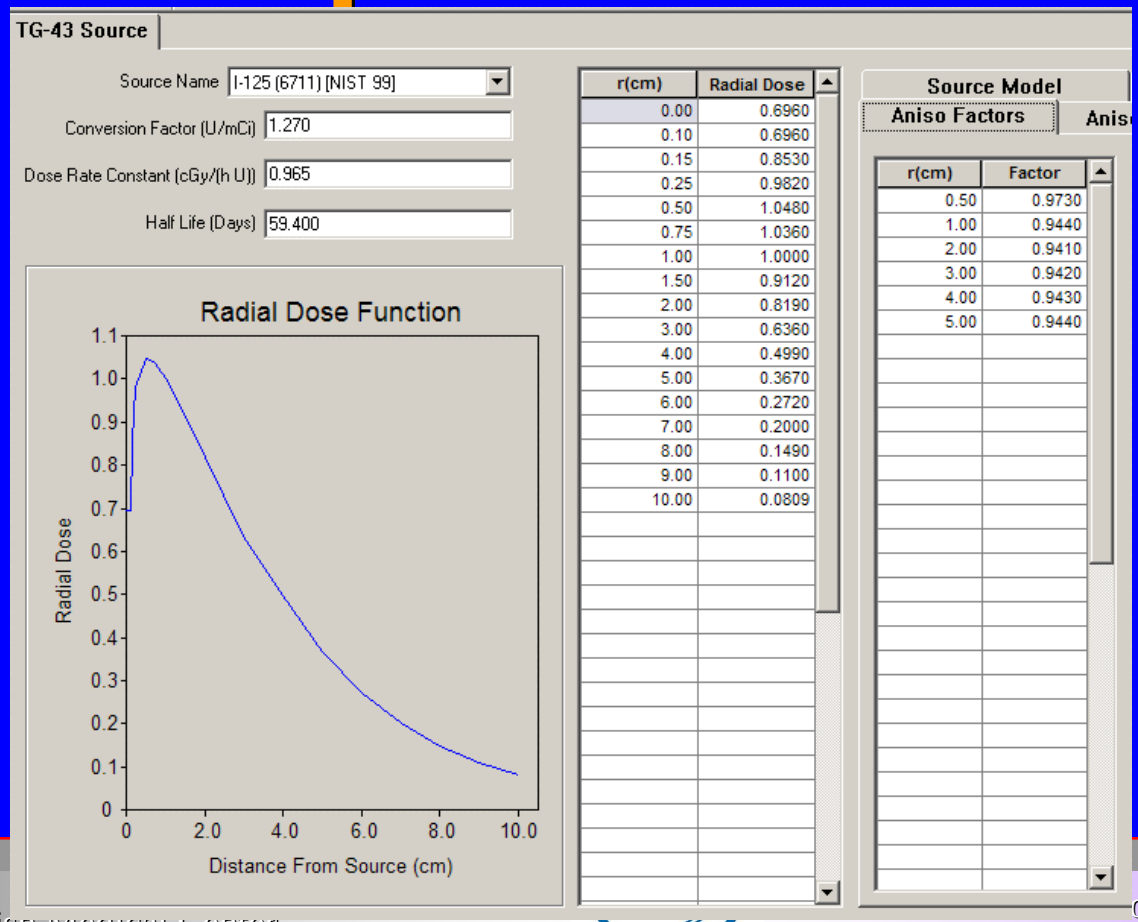
- Source ^{125}I [STM 1251] [NIST 99]
- Radial Dose Function, source description and anisotropy factor

How is implemented in the RTPS (Variseed)



- Source ^{125}I [6711] [NIST 99]
- Radial Dose Function and anisotropy factor?

How is implemented in the RTPS?



Source Calib

- "Each institution planning to provide brachytherapy should have the ability to independently verify the source strength provided b the manufacturer". (TG-40).
- The Medical Physicist (MP) should independently measure 10% of the sources to be implanted in the patient (TG-56).
- The MP is responsible for the dose given to the patient.

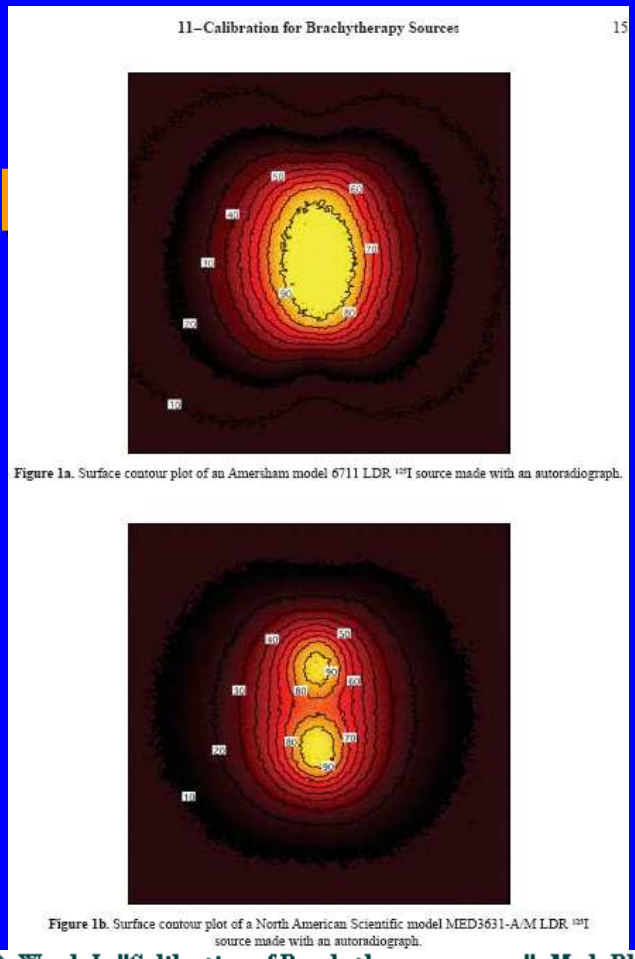
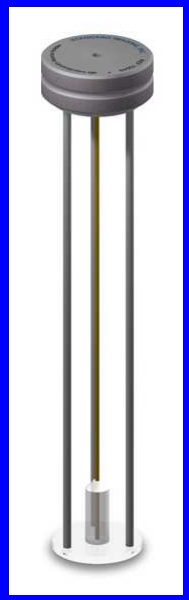

11–Calibration for Brachytherapy Sources 15

Figure 1a. Surface contour plot of an Amersham model 6711 LDR ^{125}I source made with an autoradiograph.

Figure 1b. Surface contour plot of a North American Scientific model MED3631-A/M LDR ^{125}I source made with an autoradiograph.

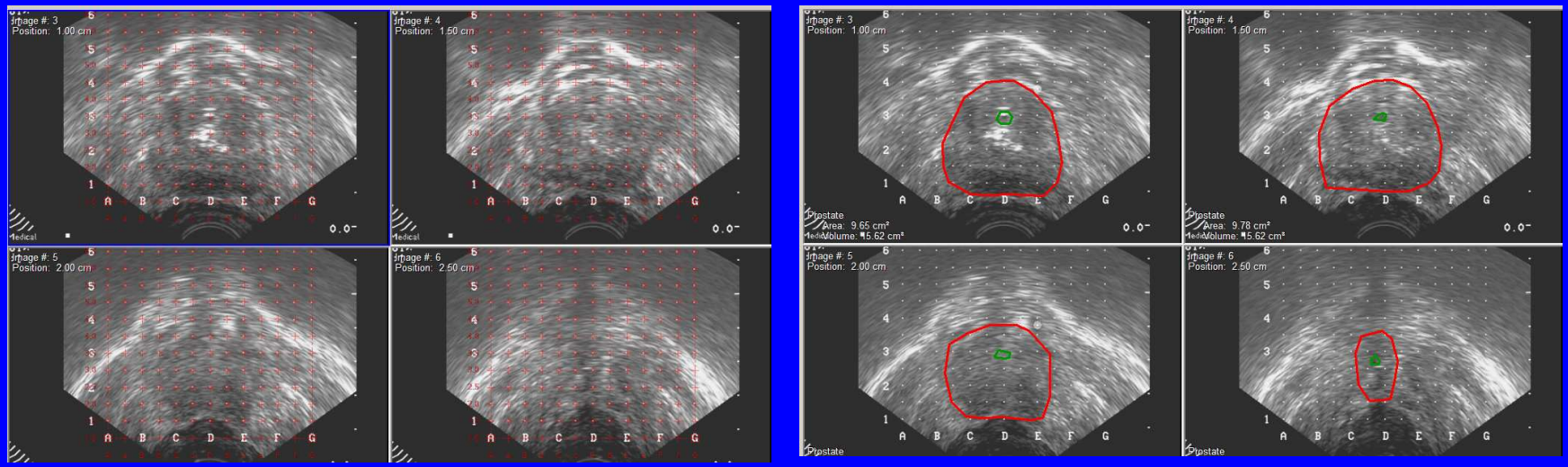
From: DeWerd, L."Calibration of Brachytherapy sources", Med. Phys. Monograph 31:153-171.

Ionization Chamber and inserts for single seed and cartridge



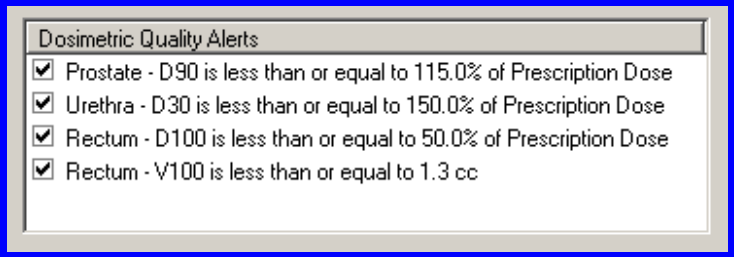
- **Acquisition and contouring of US images**

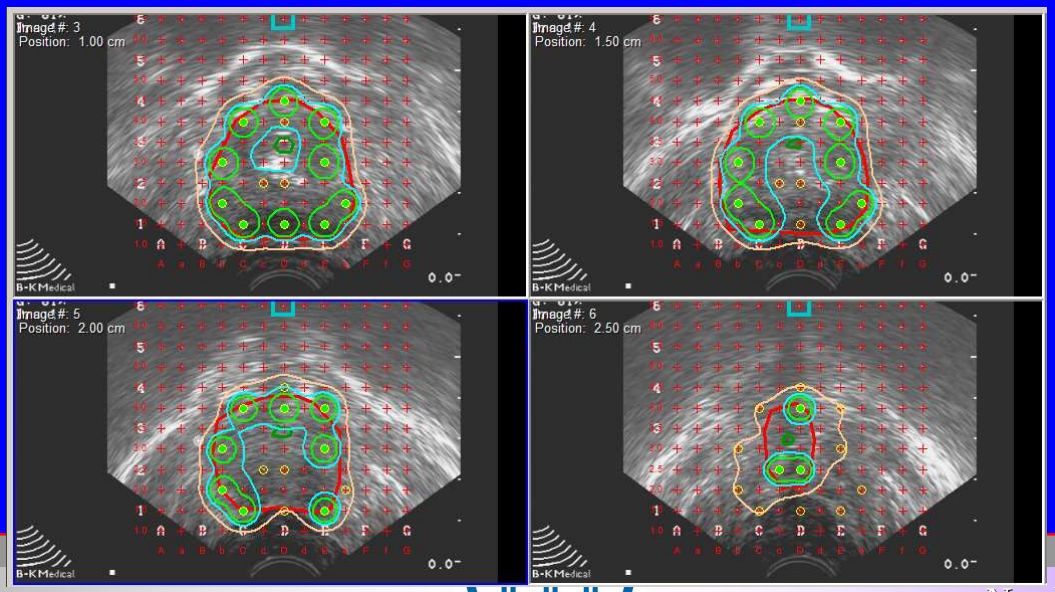
In OR Planning

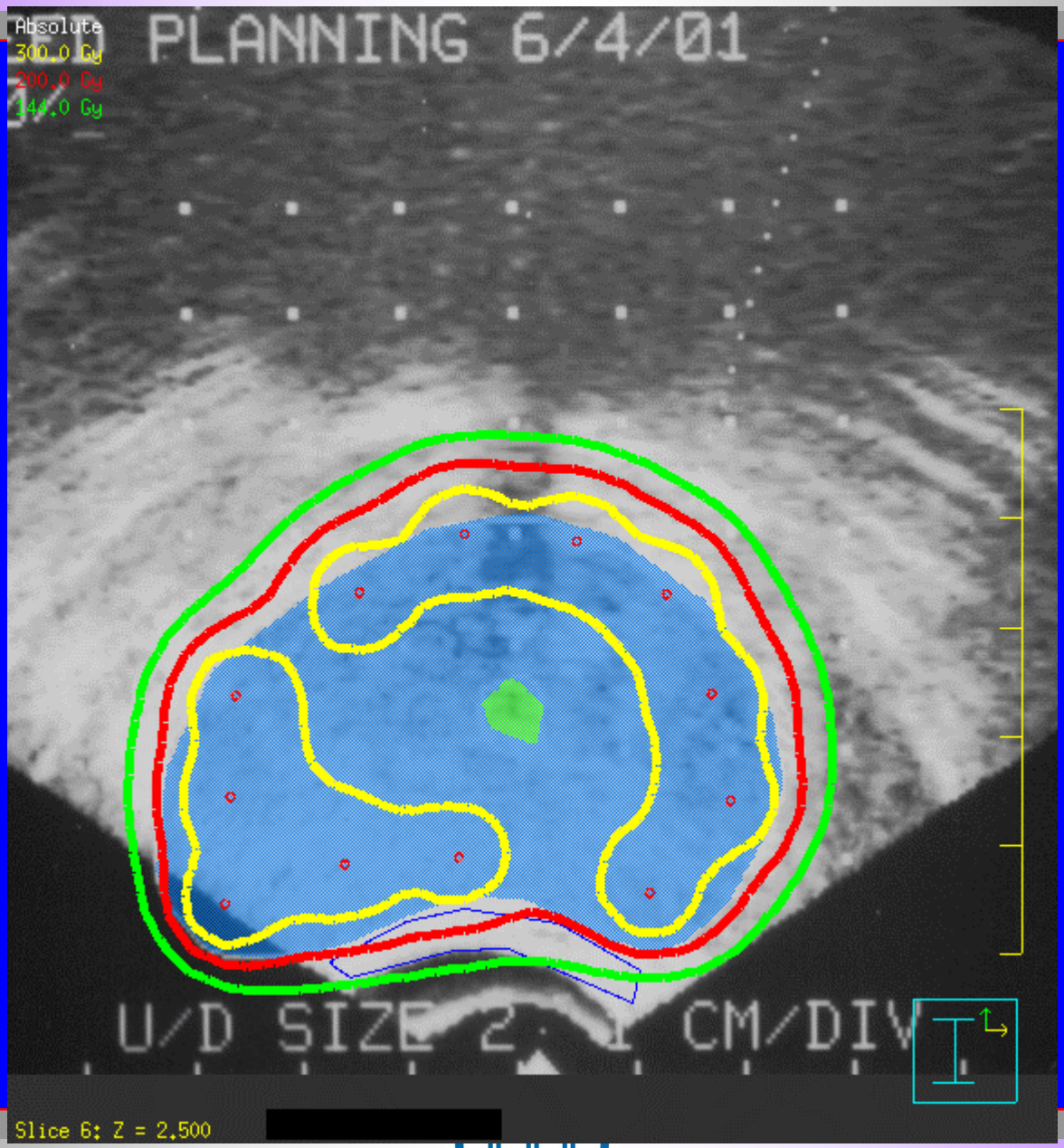


..In OR Planning

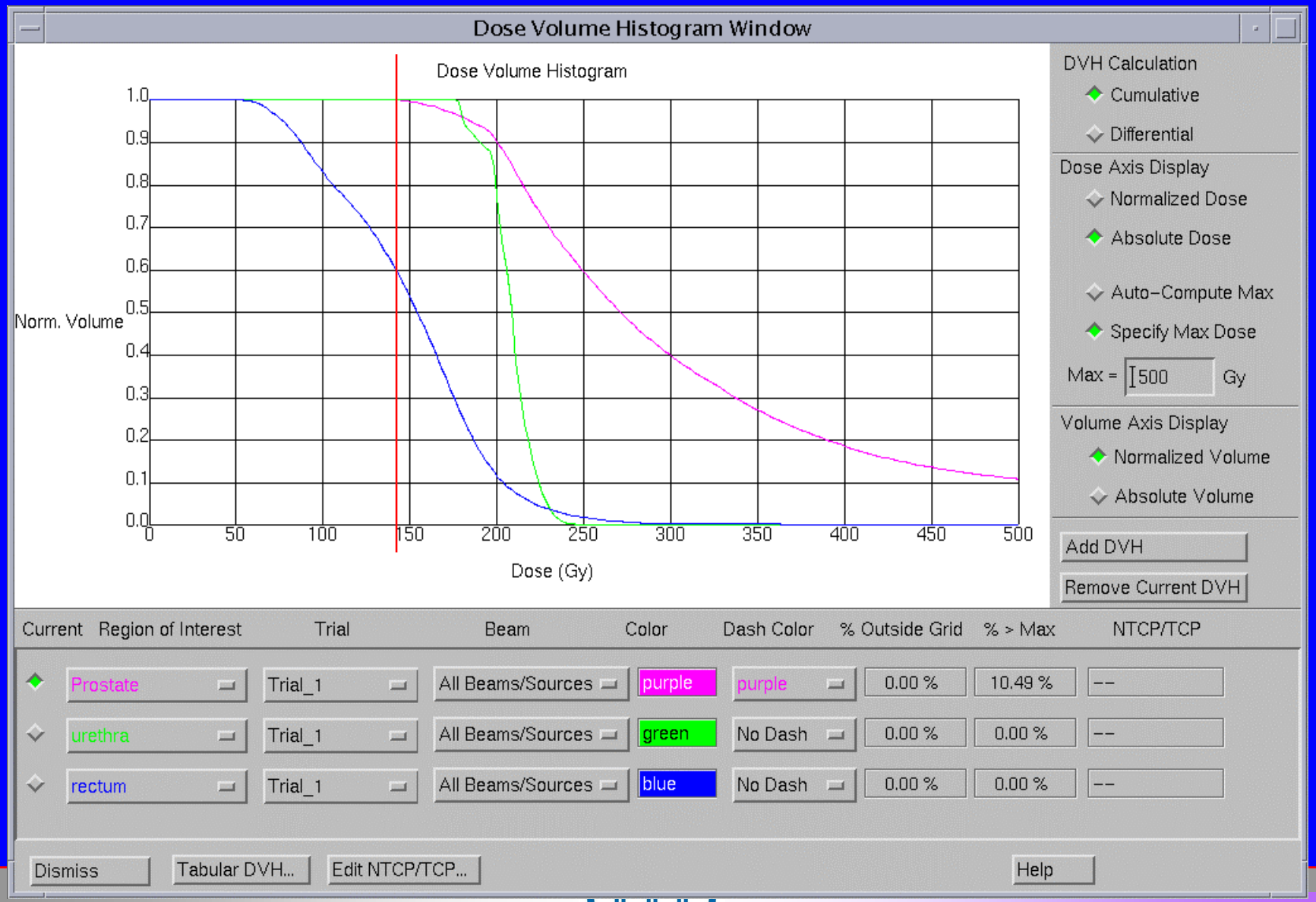
- **Seed placement and plan evaluation (100%, 150% and 200% isodoses displayed)**



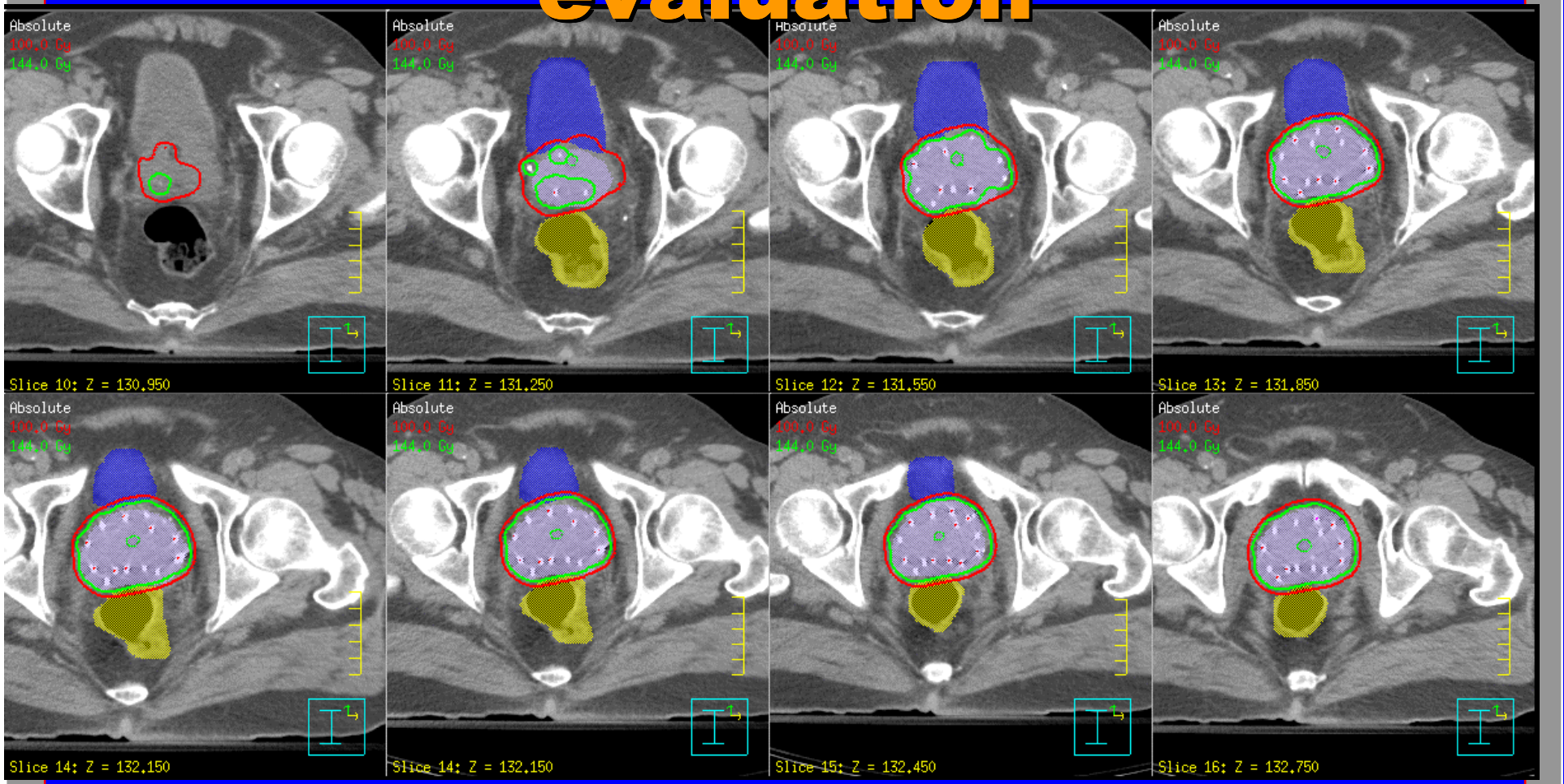



Absolute
300.0 Gy
200.0 Gy
144.0 Gy
PLANNING 6/4/01
U/D SIZE 2.
CM/DIV
Slice 6: Z = 2.500

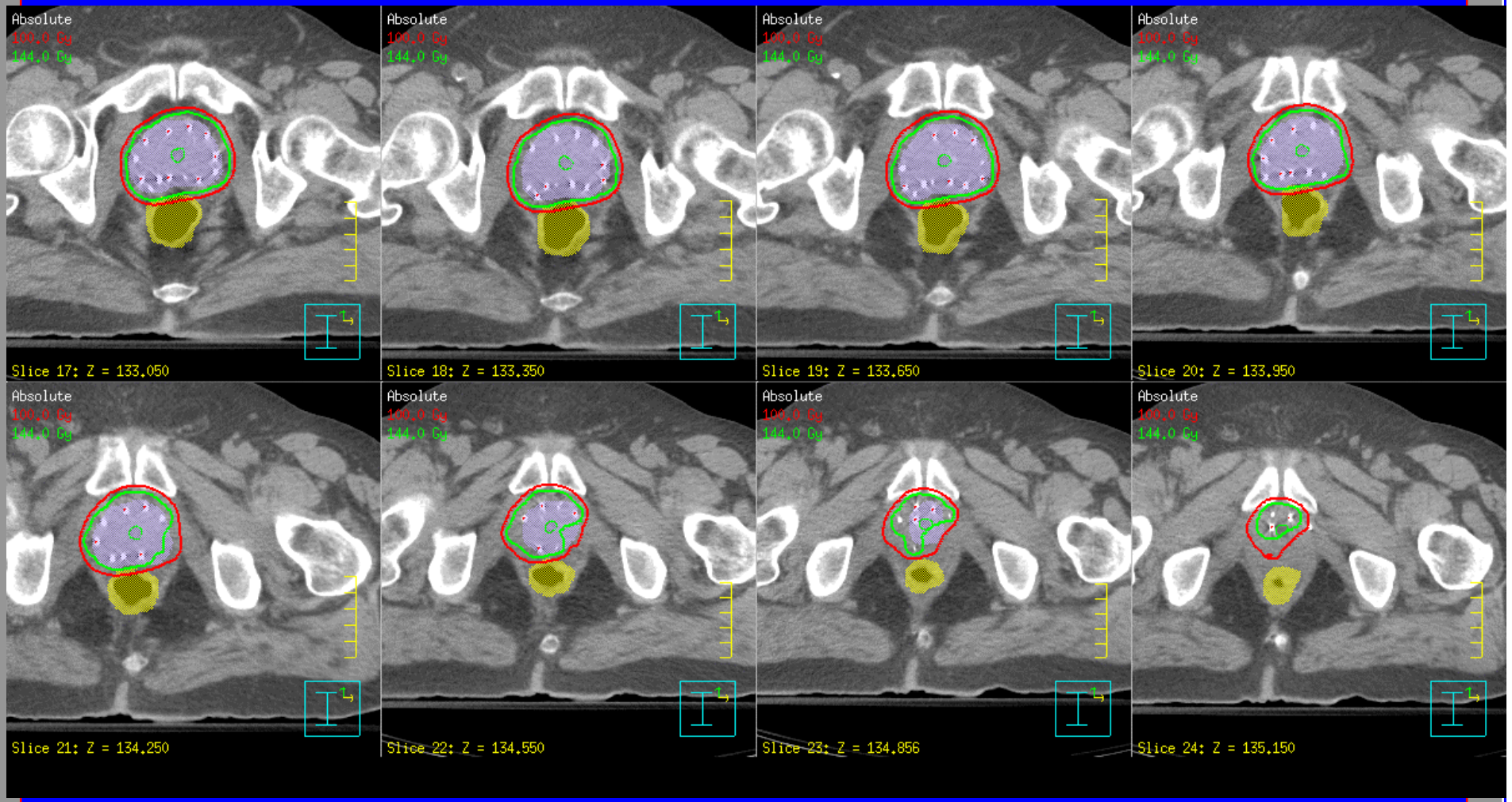
LIJ Pre-implant , TRUS-based, Planned DVH



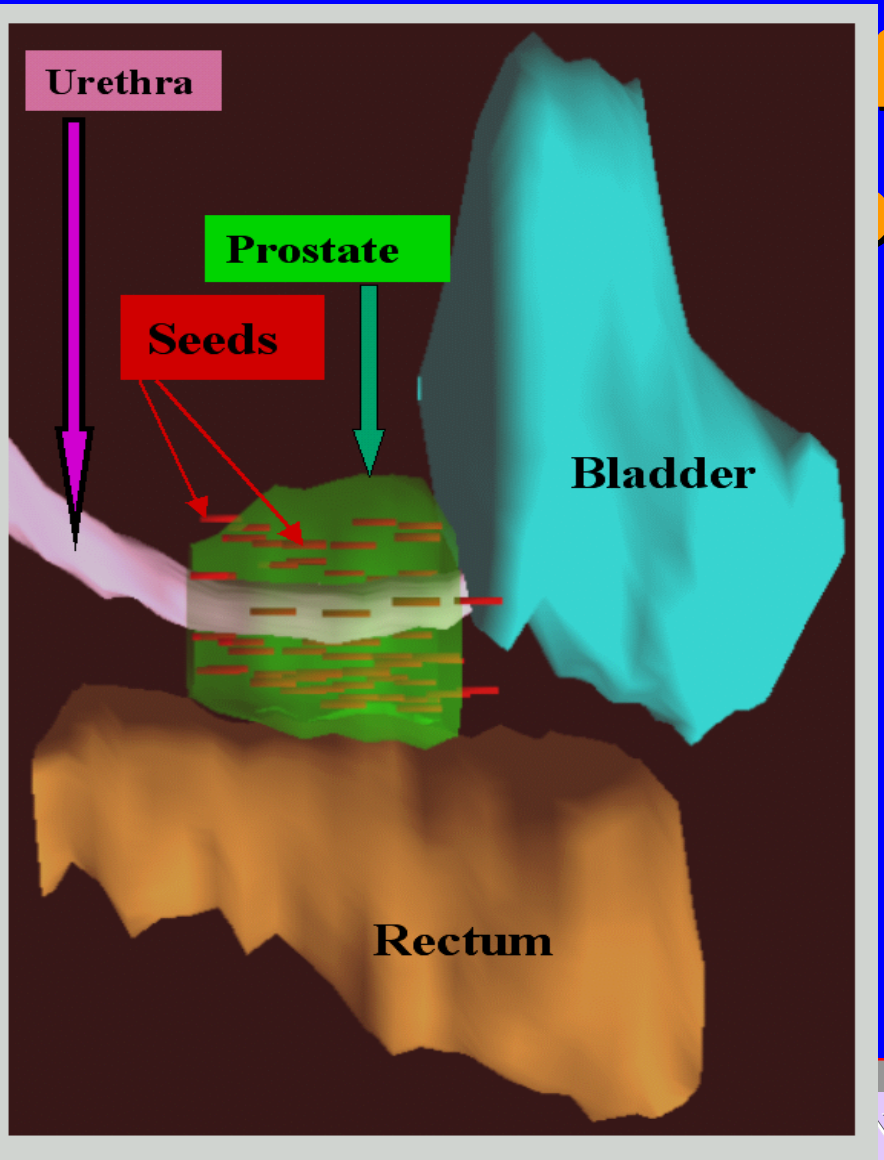
Post-Implant CT-based evaluation

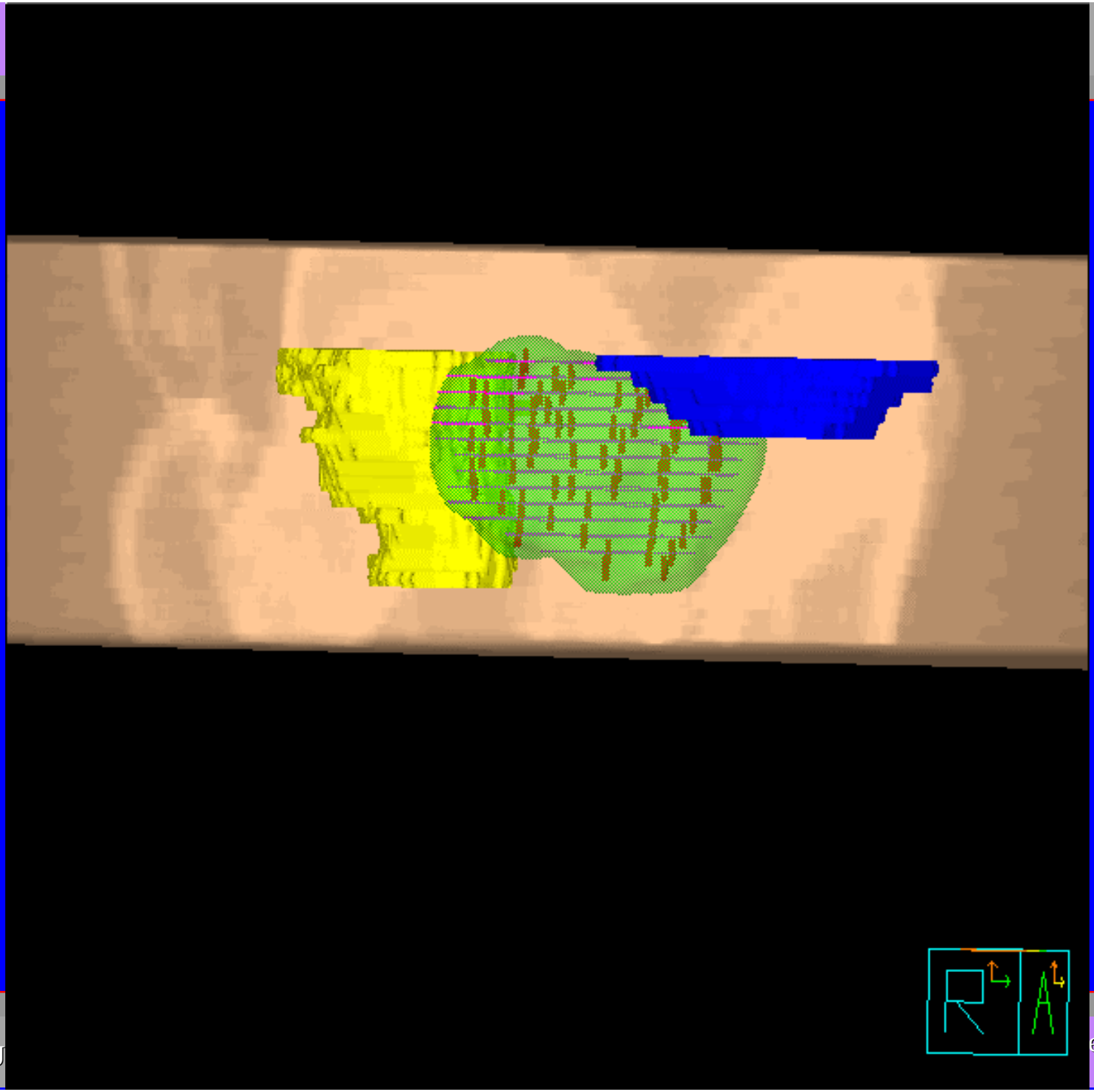


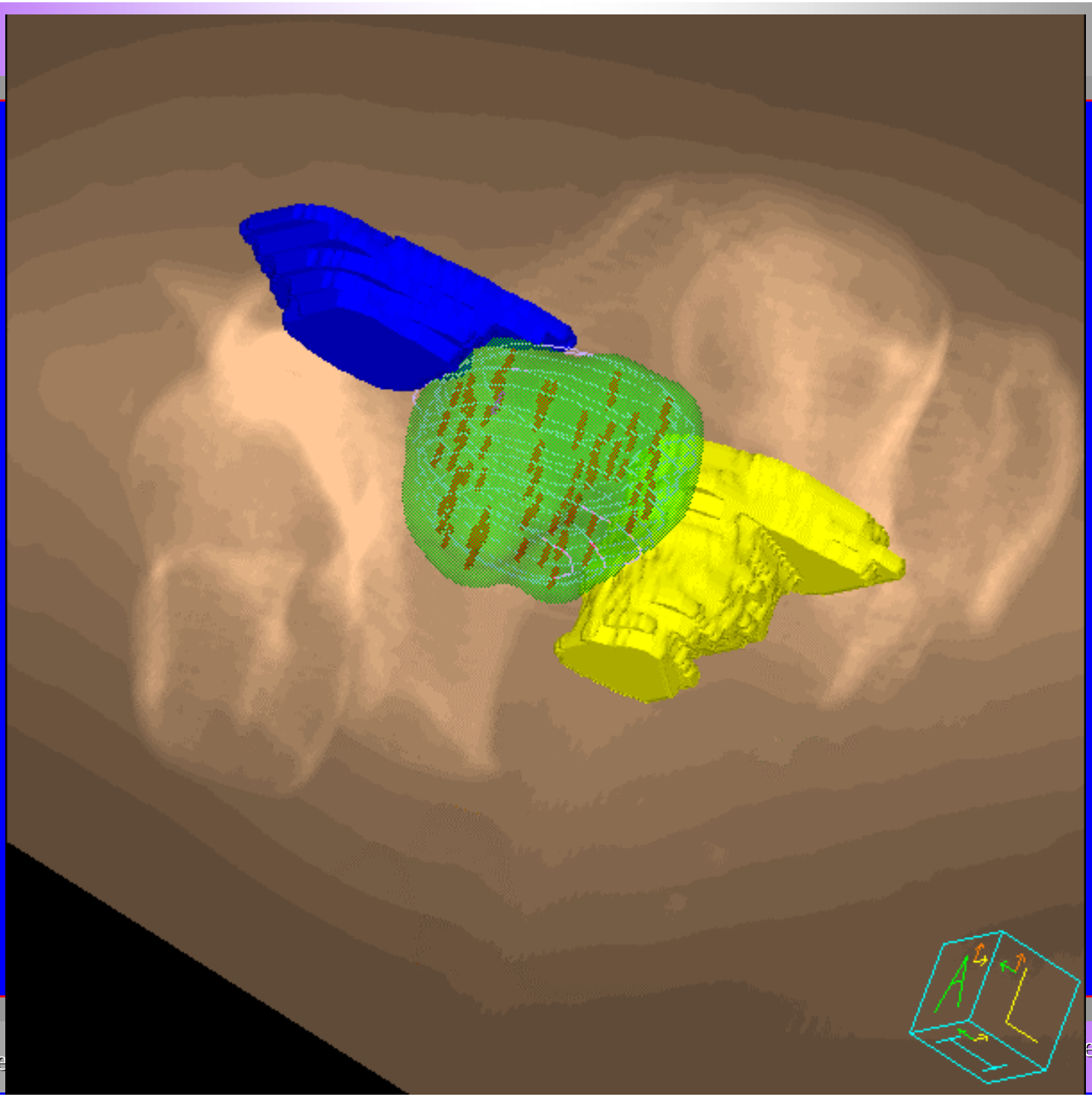
Post-Implant CT-based evaluation



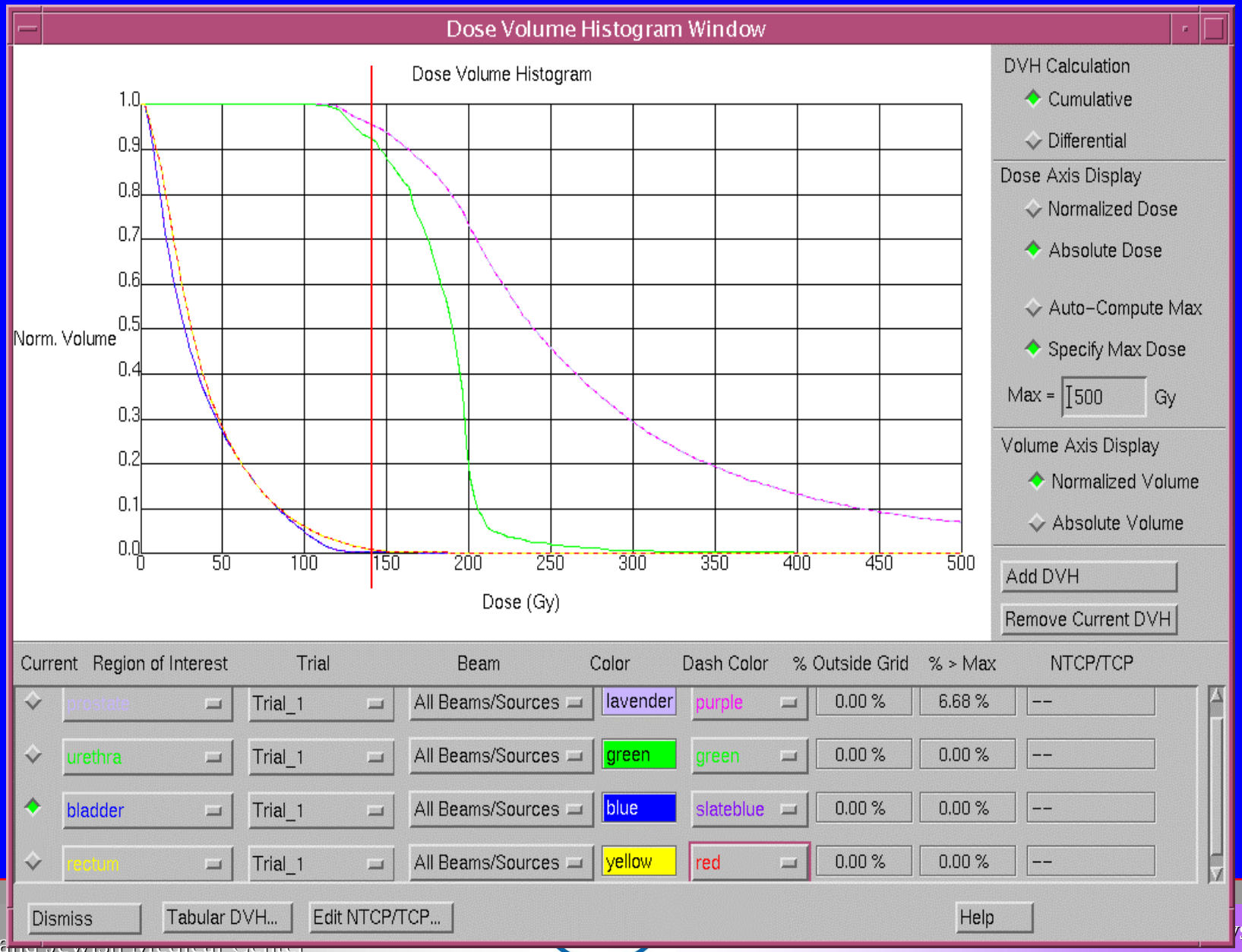
3-D gr f post
im on

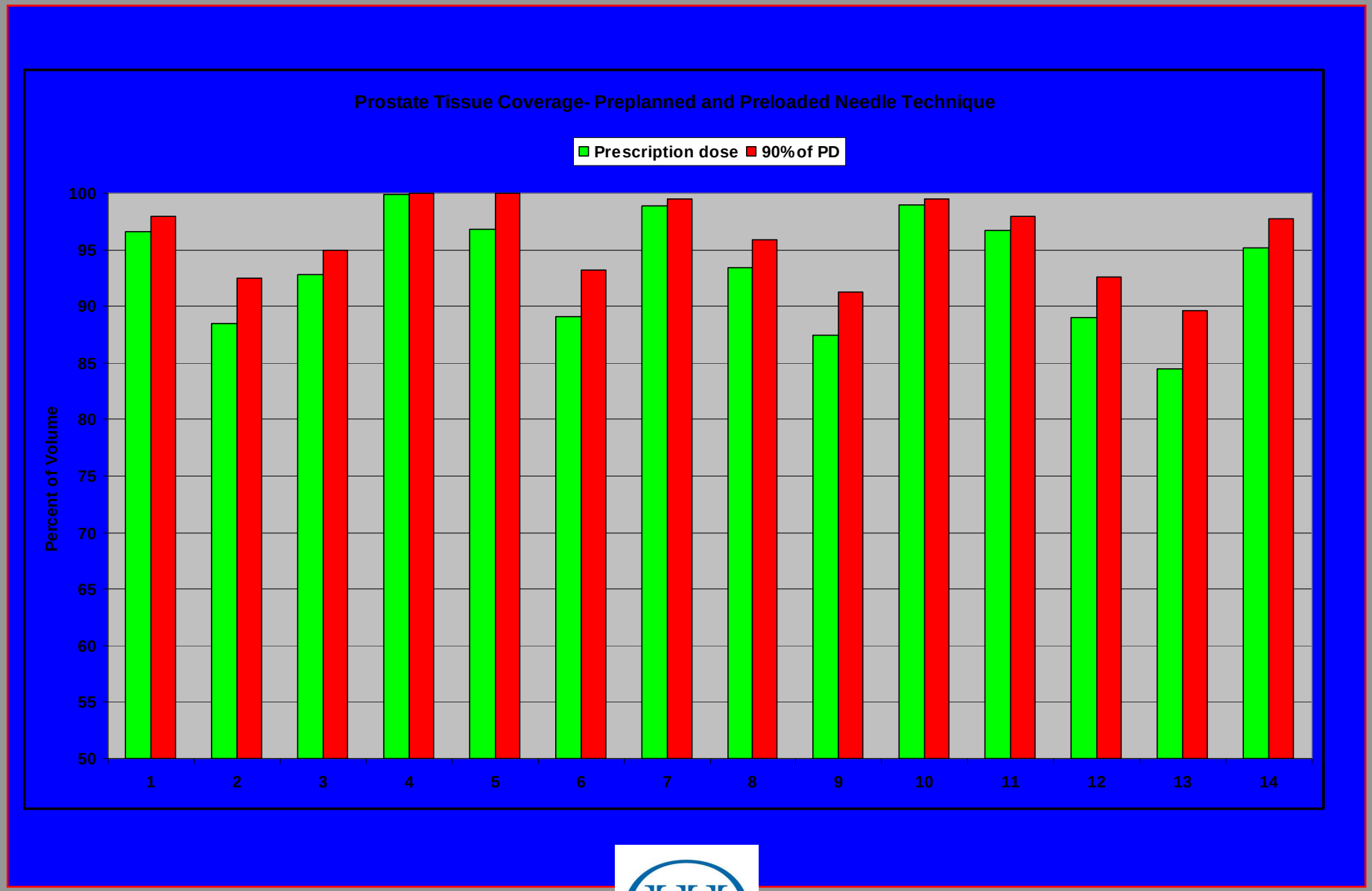


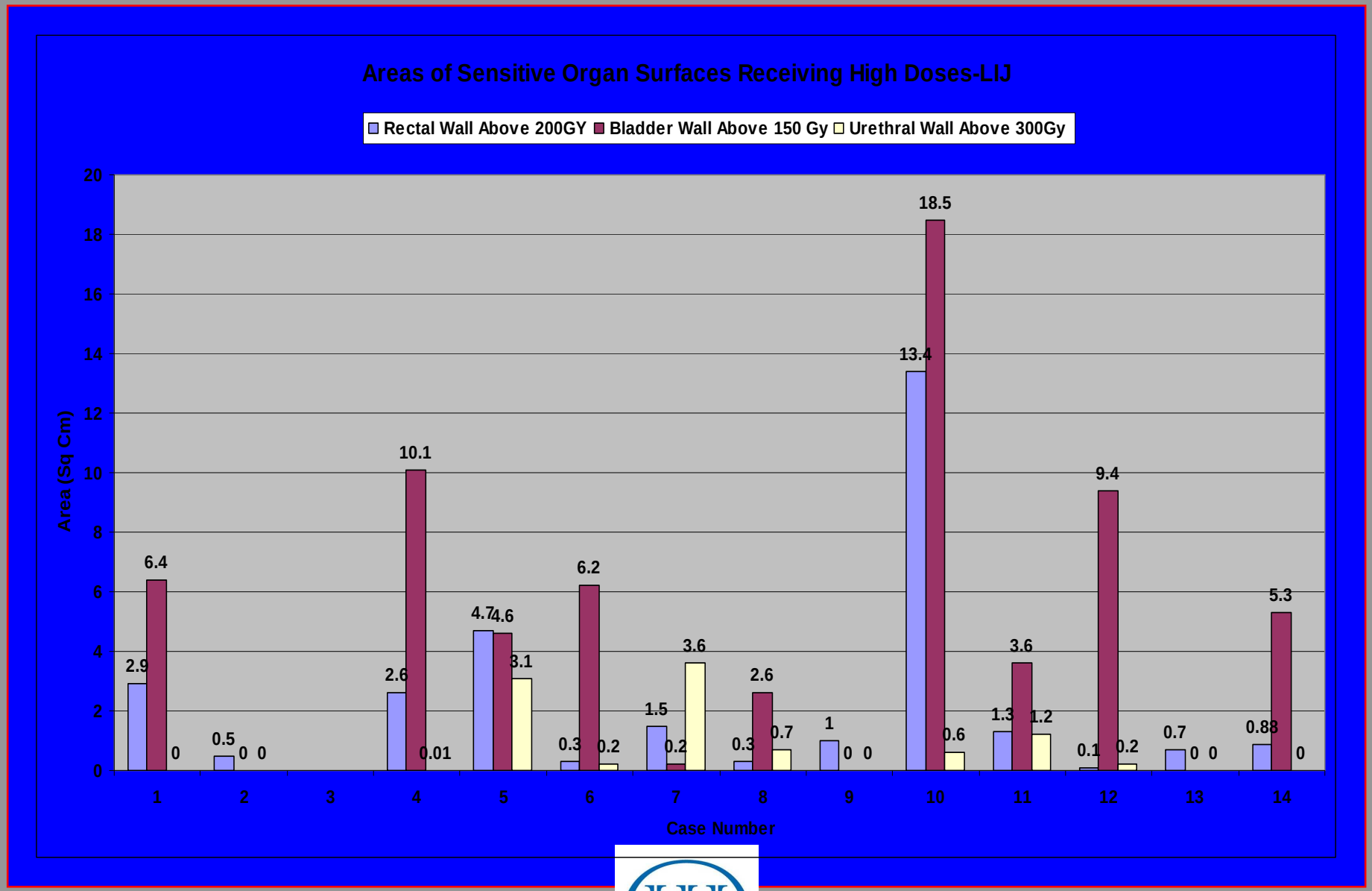


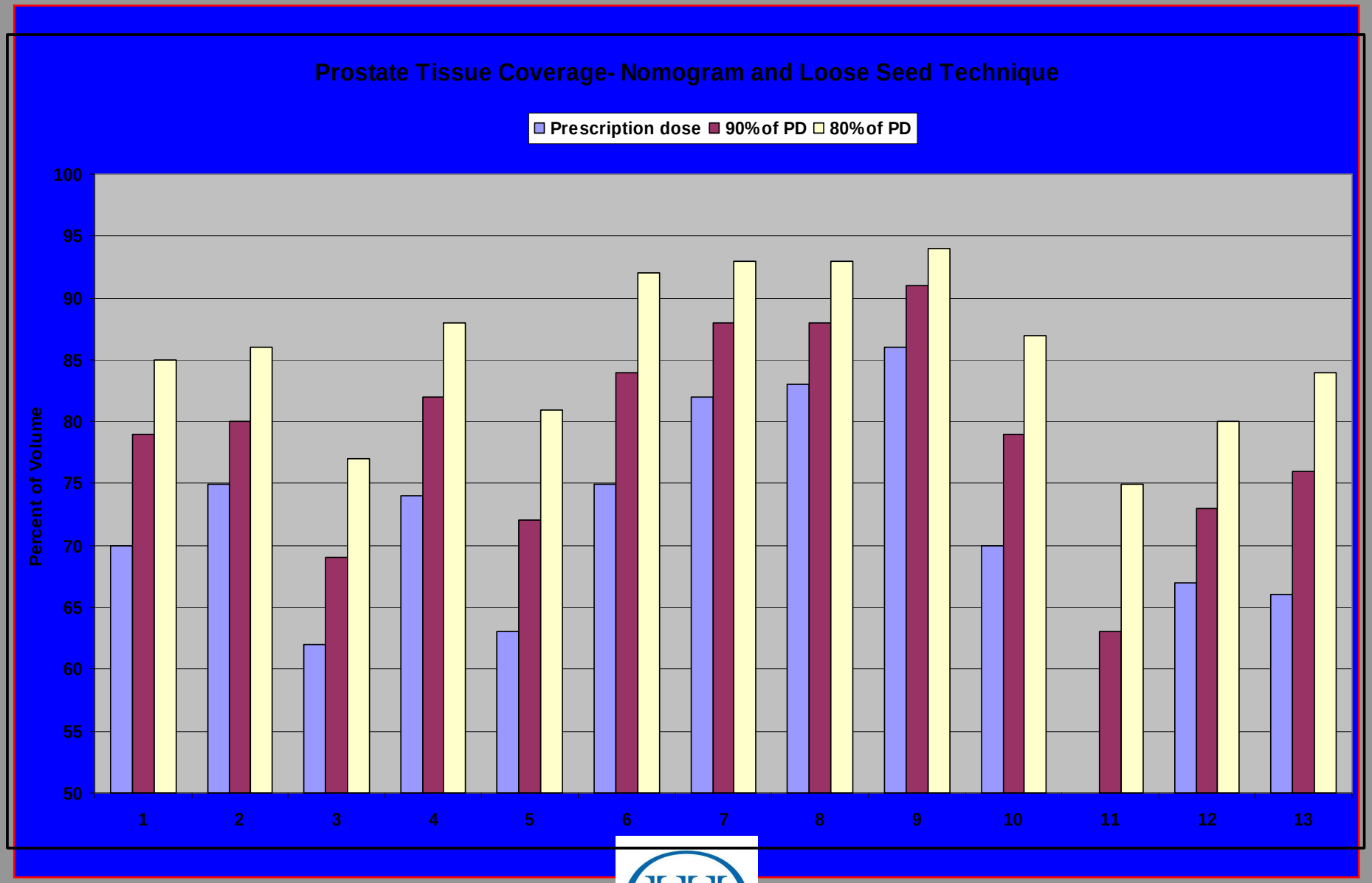


LIJ Post-Implant, Ct-based, DVH Evaluation




Prostate Tissue Coverage- Preplanned and Preloaded Needle Technique
Prescription dose
90% of PD
Percent of Volume
100
95
90
85
80
75
70
65
60
55
50
1
2
3
4
5
6
7
8
9
10
11
12
13
14


Areas of Sensitive Organ Surfaces Receiving High Doses-LIJ
Rectal Wall Above 200GY
Bladder Wall Above 150 Gy
Urethral Wall Above 300Gy
Area (Sq Cm)
Case Number
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
2.9
6.4
0
0.5
0
0
2.6
10.1
0.01
4.7
4.6
3.1
0.3
6.2
0.2
1.5
0.2
3.6
0.3
2.6
0.7
1
0
0
13.4
18.5
0.6
1.3
3.6
1.2
0.1
9.4
0.2
0.7
0
0
0.88
5.3
0


Prostate Tissue Coverage- Nomogram and Loose Seed Technique
Prescription dose
90% of PD
80% of PD
Percent of Volume
100
95
90
85
80
75
70
65
60
55
50
1
2
3
4
5
6
7
8
9
10
11
12
13

Dosimetric Comparison of techniques				
	Preplan + Preload		Nomogram + Loose Seeds	
	AVERAGE	St.Dev.	AVERAGE	St.Dev.
% Prostate Volume Covered by the Prescription Dose	93.4	4.9	71.0	9.8
% Prostate Volume Covered by 90% of the Prescription	95.9	3.5	78.8	8.1
% Prostate Volume Covered by 80% of the Prescription	97.5	2.4	85.8	6.3

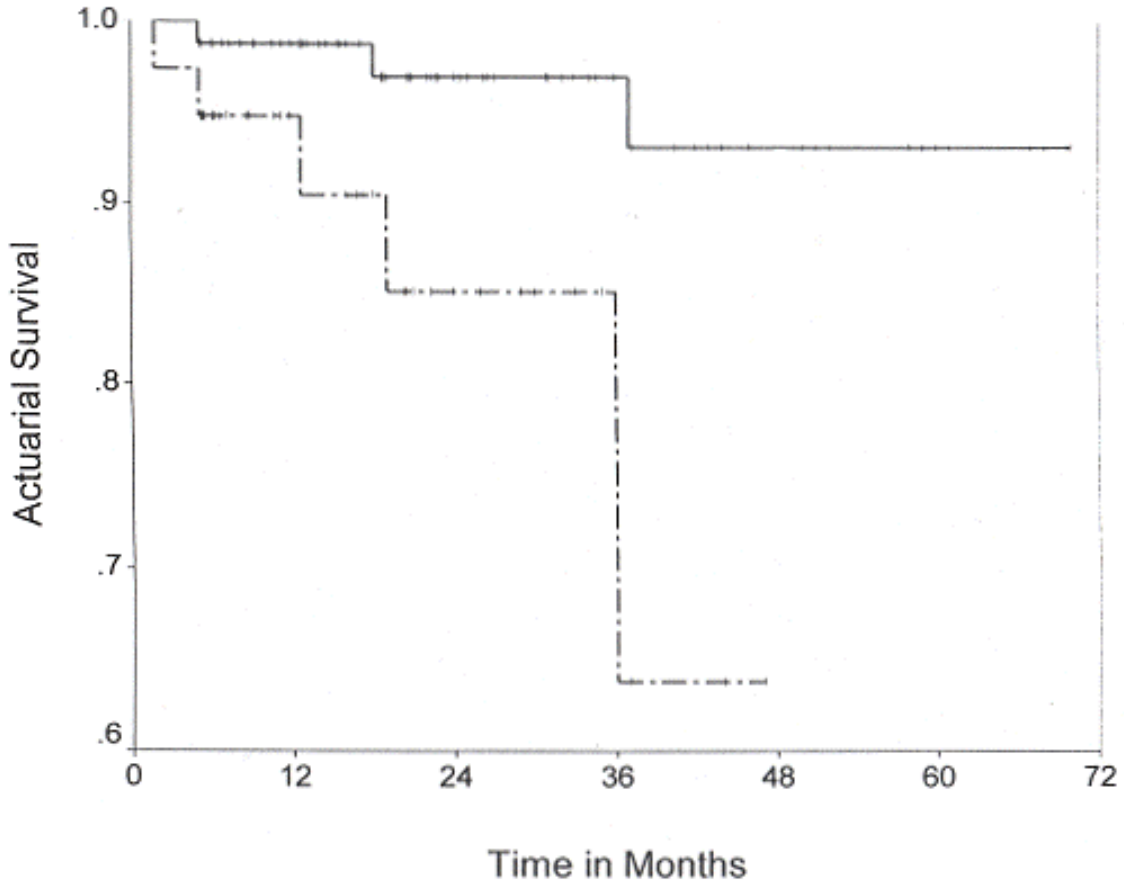


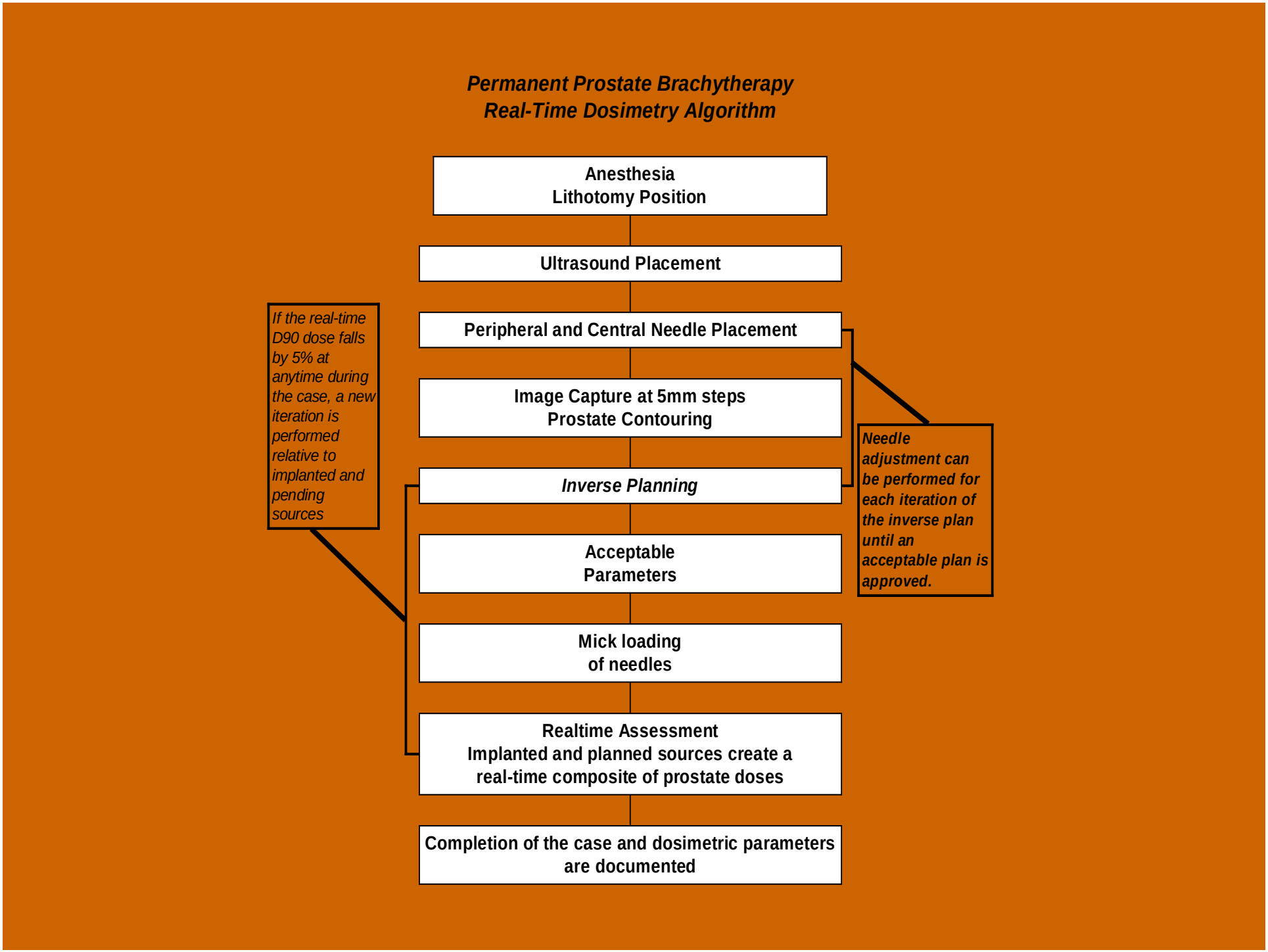
Fig. 3. Actuarial PSA relapse-free survival for patients treated with iodine divided by the dose cutoff value of the D90 dose <90%, ≥90% of the prescribed dose ($p = 0.04$) (Solid line, D90 ≥90% of the prescribed dose; dashed line, D90 <90% of the prescribed dose).

From: L.Potters et. al.: IJROBP 50(3), 605-614, July 2001

Table 6. Actuarial 48-month PSA-RFS comparing the D90 dose <90% or ≥90% of the prescribed dose for Pd-103, I-125, TIPPB as monotherapy, and TIPPB combined with EBT

Factor	D90 dose	4-yr. PSA-RFS	*n*	*p* value
Palladium				.01
	<90	83.4	178	
	≥90	93.3	423	
Iodine				.04
	<90	63.8	38	
	≥90	93.0	80	
No hormones				.001
	<90	81.0	134	
	≥90	93.4	335	
Hormones				.001
	<90	79.3	82	
	≤90	92.5	168	
EBT + TIPPB				.13
	<90	87.9	77	
	≥90	88.23	122	
TIPPB alone				.001
	<90	74.3	136	
	≥90	94.6	384	

From: L.Potters et. al.: IJROBP 50(3), 605-614, July 2001


Permanent Prostate Brachytherapy
Real-Time Dosimetry Algorithm
Anesthesia
Lithotomy Position
Ultrasound Placement
Peripheral and Central Needle Placement
Image Capture at 5mm steps
Prostate Contouring
Inverse Planning
Acceptable
Parameters
Mick loading
of needles
Realtime Assessment
Implanted and planned sources create a
real-time composite of prostate doses
Completion of the case and dosimetric parameters
are documented
If the real-time D90 dose falls by 5% at anytime during the case, a new iteration is performed relative to implanted and pending sources
Needle adjustment can be performed for each iteration of the inverse plan until an acceptable plan is approved.

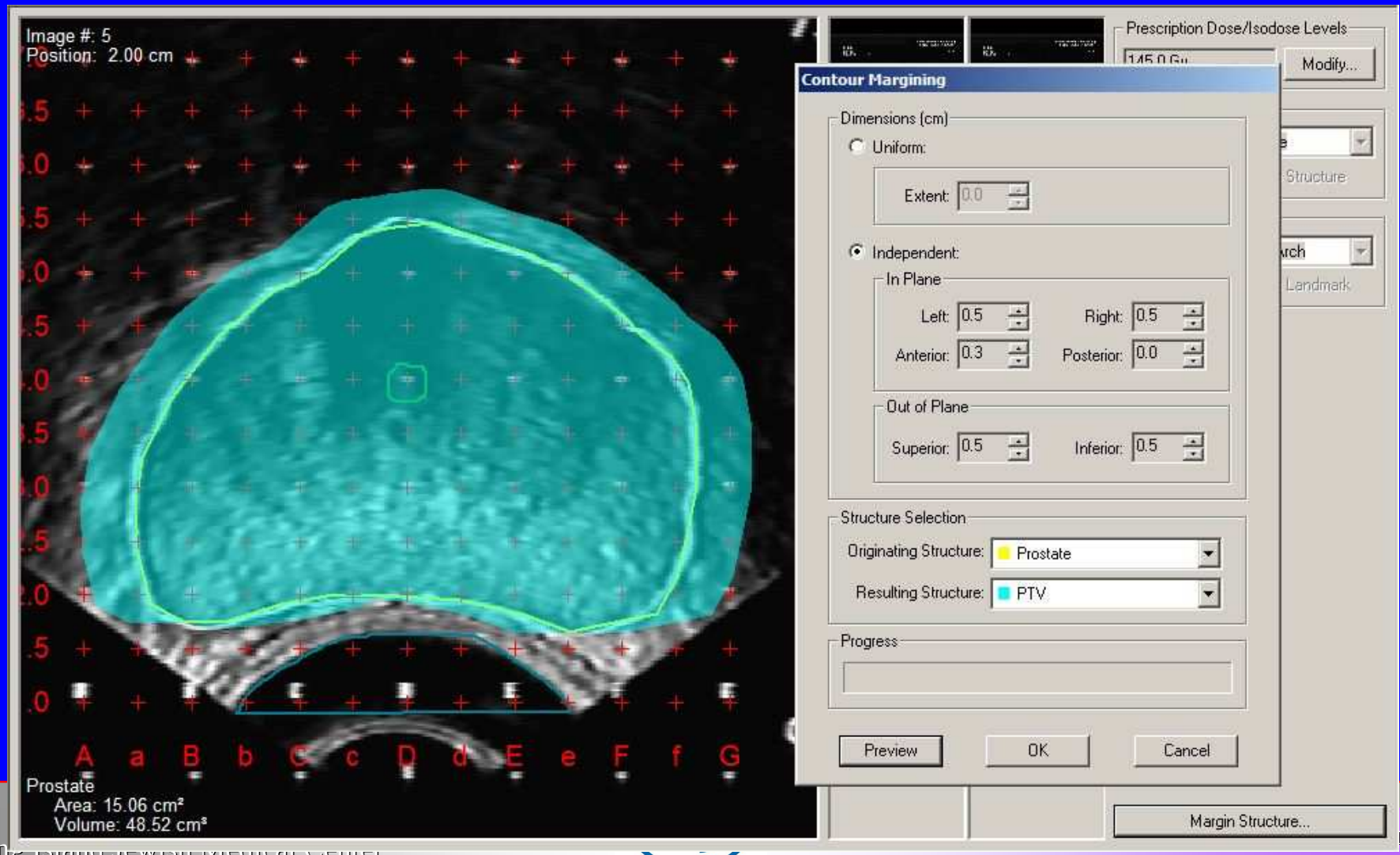
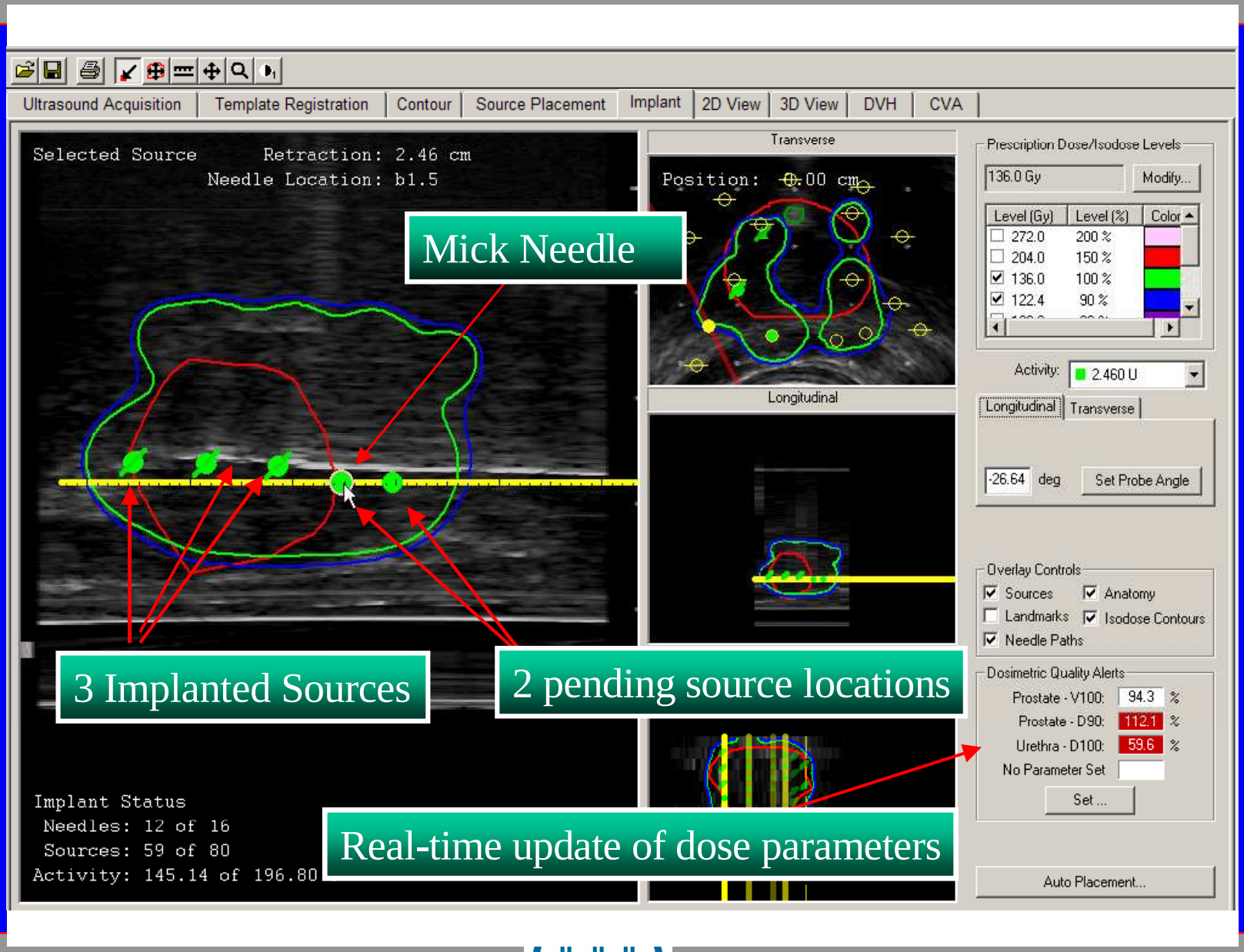
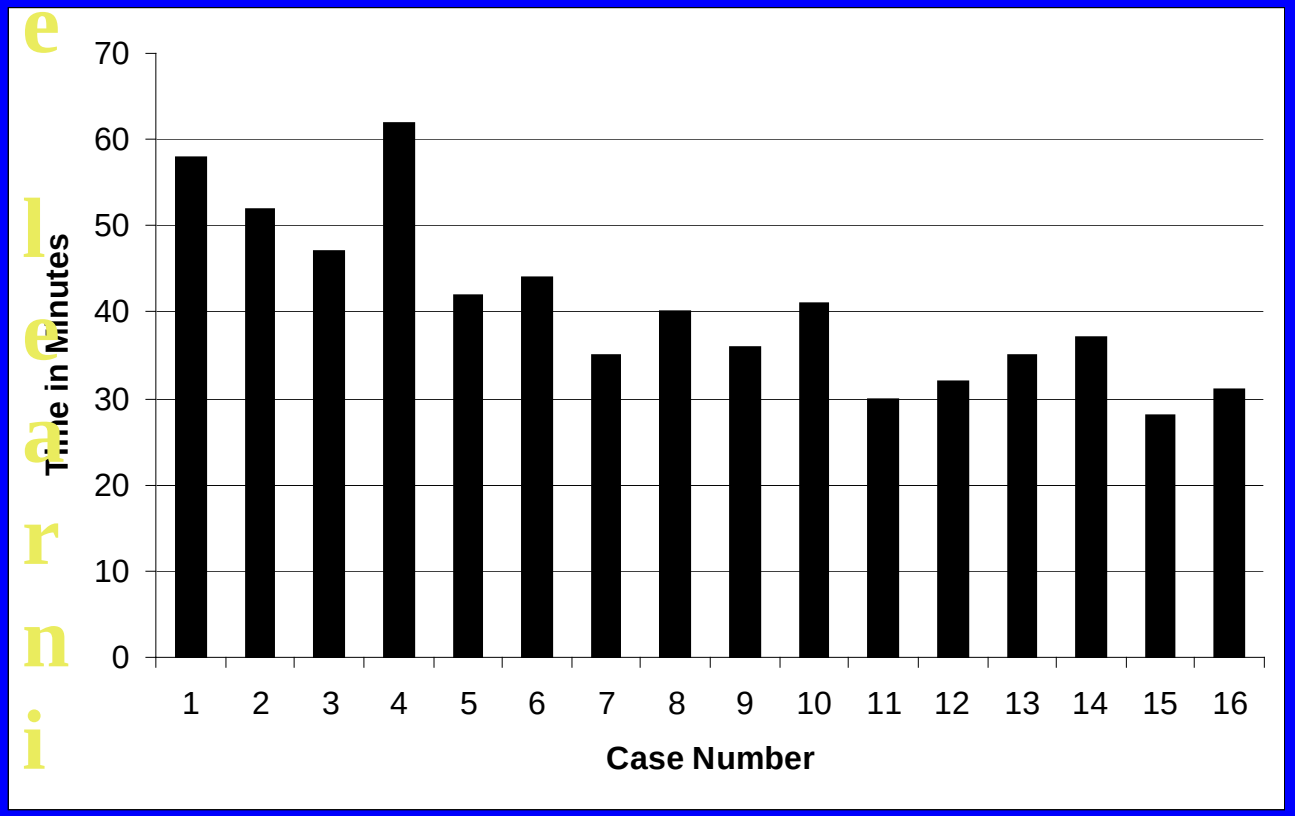


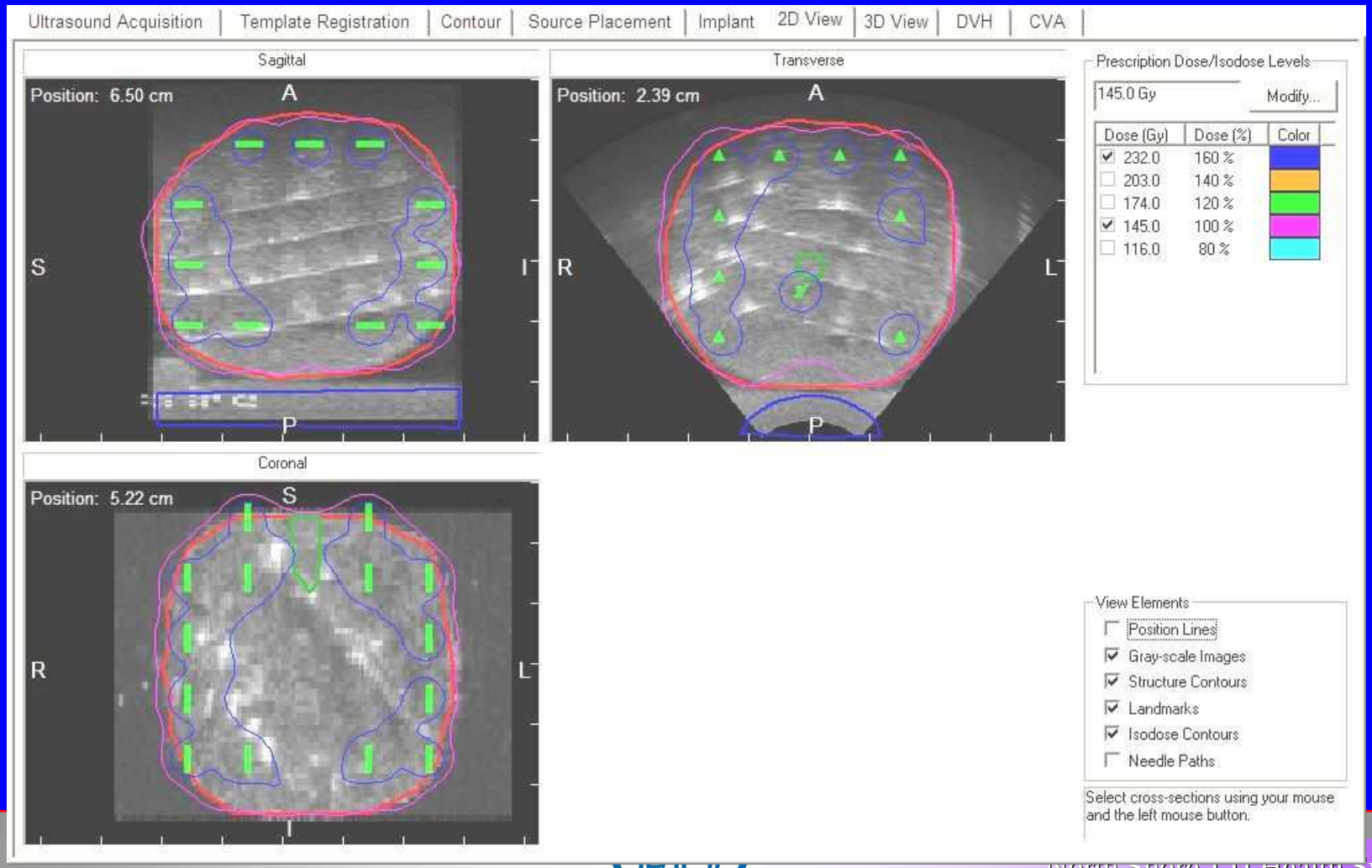
Image #: 5
Position: 2.00 cm
Prostate
Area: 15.06 cm²
Volume: 48.52 cm³
Prescription Dose/Isodose Levels
Modify...
Contour Margining
Dimensions (cm)
Uniform:
Extent: 0.0
Independent:
In Plane
Left: 0.5
Right: 0.5
Anterior: 0.3
Posterior: 0.0
Out of Plane
Superior: 0.5
Inferior: 0.5
Structure Selection
Originating Structure: Prostate
Resulting Structure: PTV
Progress
Preview
OK
Cancel
Margin Structure...


Ultrasound Acquisition
Template Registration
Contour
Source Placement
Implant
2D View
3D View
DVH
CVA
Selected Source
Retraction: 2.46 cm
Needle Location: b1.5
Mick Needle
Transverse
Position: 0.00 cm
Longitudinal
Prescription Dose/Isodose Levels
136.0 Gy
Modify...
Level (Gy)
Level (%)
Color
272.0 200 %
204.0 150 %
136.0 100 %
122.4 90 %
Activity:
2.460 U
Longitudinal
Transverse
-26.64 deg
Set Probe Angle
Overlay Controls
Sources
Anatomy
Landmarks
Isodose Contours
Needle Paths
Dosimetric Quality Alerts
Prostate - V100: 94.3 %
Prostate - D90: 112.1 %
Urethra - D100: 59.6 %
No Parameter Set
Set ...
Auto Placement...
3 Implanted Sources
2 pending source locations
Implant Status
Needles: 12 of 16
Sources: 59 of 80
Activity: 145.14 of 196.80
Real-time update of dose parameters

The learning curve...

The learning




Ultrasound Acquisition
Template Registration
Contour
Source Placement
Implant
2D View
3D View
DVH
CVA
Sagittal
Position: 6.50 cm
A
S
I
P
Transverse
Position: 2.39 cm
A
R
L
P
Coronal
Position: 5.22 cm
S
R
L
I
Prescription Dose/Isodose Levels
145.0 Gy
Modify...
Dose (Gy)
Dose (%)
Color
232.0 160 %
203.0 140 %
174.0 120 %
145.0 100 %
116.0 80 %
View Elements
Position Lines
Gray-scale Images
Structure Contours
Landmarks
Isodose Contours
Needle Paths
Select cross-sections using your mouse and the left mouse button.

Report of needle loading

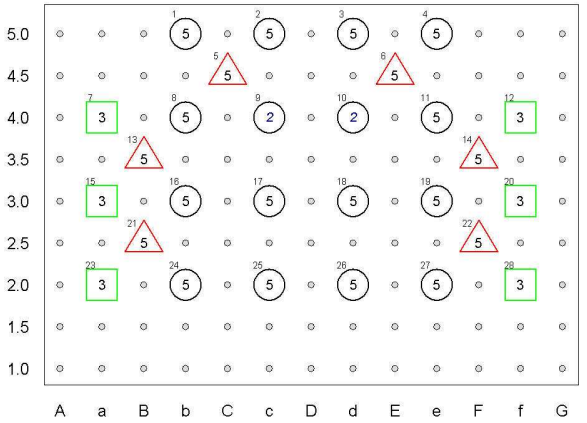
VariSeed: Needle Loading Report [Page 1]

5/29/2003 1:44:39 PM

Name: **Demo Studies** PID: **Demo** Dept. ID:	Study: **Pre/I-125/Primary/US Video 1** Variation: **Default** Images: **10** Template: **B & K Standard** Shift: **X = 0.00cm Y = 1.00cm**	Source: **I-125 (6711) [NIST 99]** Comment: Sources: **122** Anisotropy: **Constant (Point Model) [0.930]** Source Activity: **0.432 U [0.340 mCi]**
Procedure Date: **N/A**	Prescription Dose: **145.0 Gy**	Total Activity: **52.704 U [41.499 mCi]**

Needle Number	Retraction (cm)	Hole Location	Number Seeds
1	0.00	b5.0	5
2	0.00	c5.0	5
3	0.00	d5.0	5
4	0.00	e5.0	5
5	0.50	C4.5	5
6	0.50	E4.5	5
7	1.00	a4.0	3
8	0.00	b4.0	5
● *9*	*0.00*	*c4.0*	*2*
● *10*	*0.00*	*d4.0*	*2*
11	0.00	e4.0	5
12	1.00	f4.0	3
13	0.50	B3.5	5
14	0.50	F3.5	5
15	1.00	a3.0	3
16	0.00	b3.0	5
17	0.00	c3.0	5
18	0.00	d3.0	5
19	0.00	e3.0	5
20	1.00	f3.0	3
21	0.50	B2.5	5
22	0.50	F2.5	5
23	1.00	a2.0	3
24	0.00	b2.0	5
25	0.00	c2.0	5
26	0.00	d2.0	5
27	0.00	e2.0	5
28	1.00	f2.0	3

● = *Special loading*



Retraction Legend					
Plane 0	Plane 1	Plane 2	Plane 3	Plane 4	Special
0.00 cm	0.50 cm	1.00 cm	1.50 cm	2.00 cm	Other

Number of Needles	Seeds per needle
2	2
6	3
20	5

Plan Summary	
Total Activity [U]	52.70
Total Activity [mCi]	41.50
Total Needles	28
Total Seeds	122
Extra Seeds	
Total Seeds to Order	

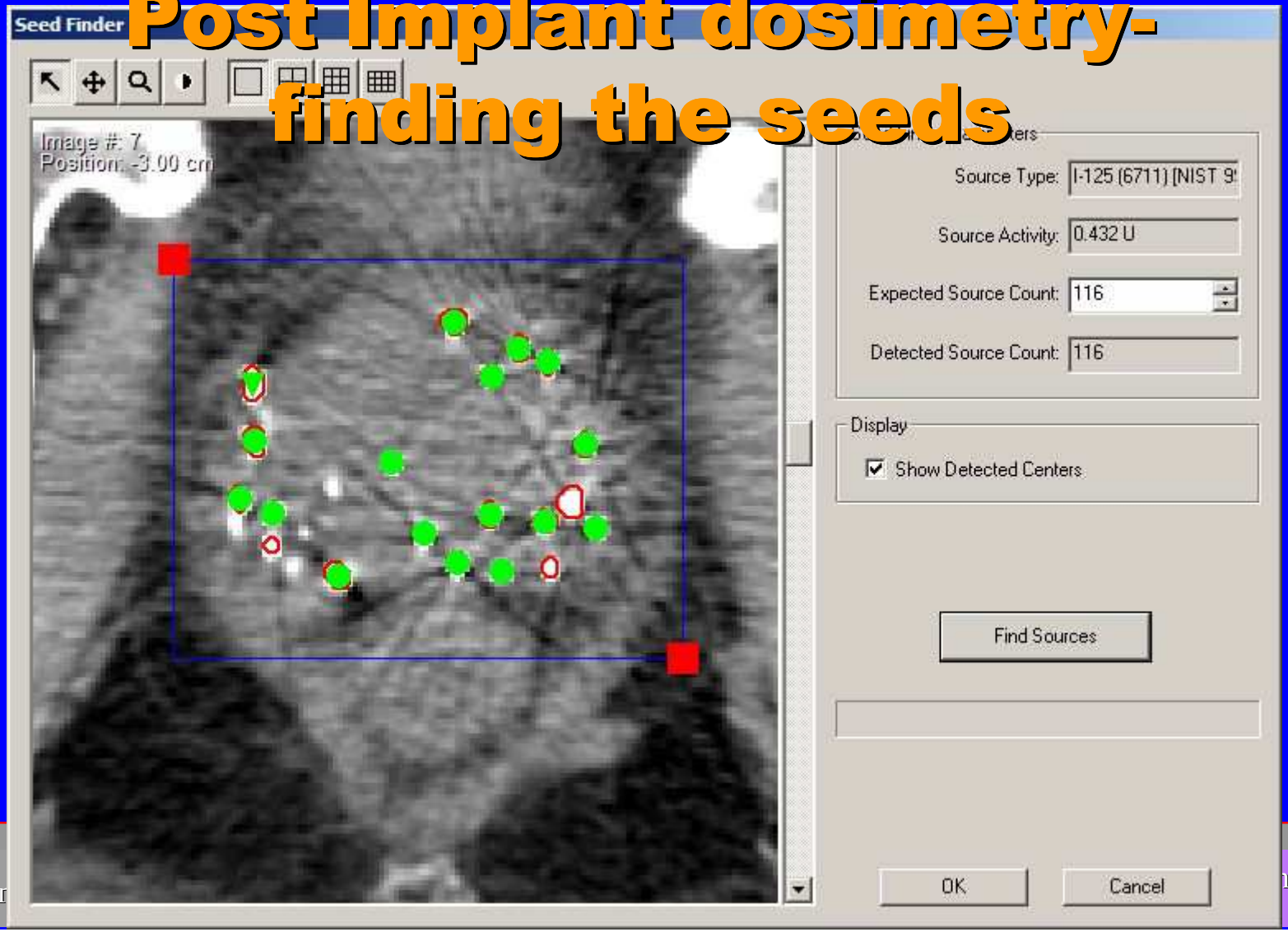
Study Created by _____

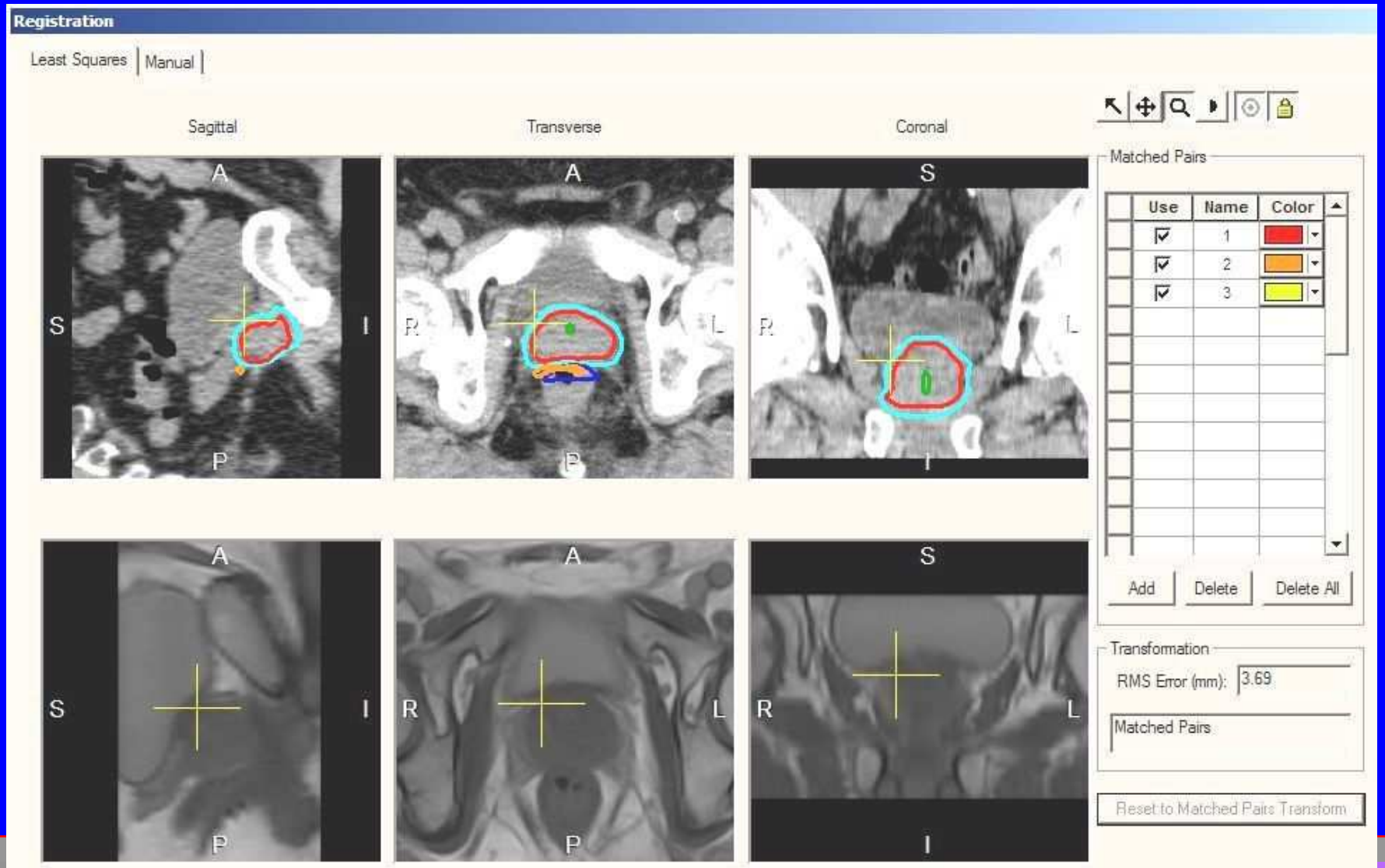
Study Approved by _____

VariSeed 7.1 (Build 2340)

D41F C194 5159 1839 9A62 AE25 a8

Post Implant dosimetry- finding the seeds



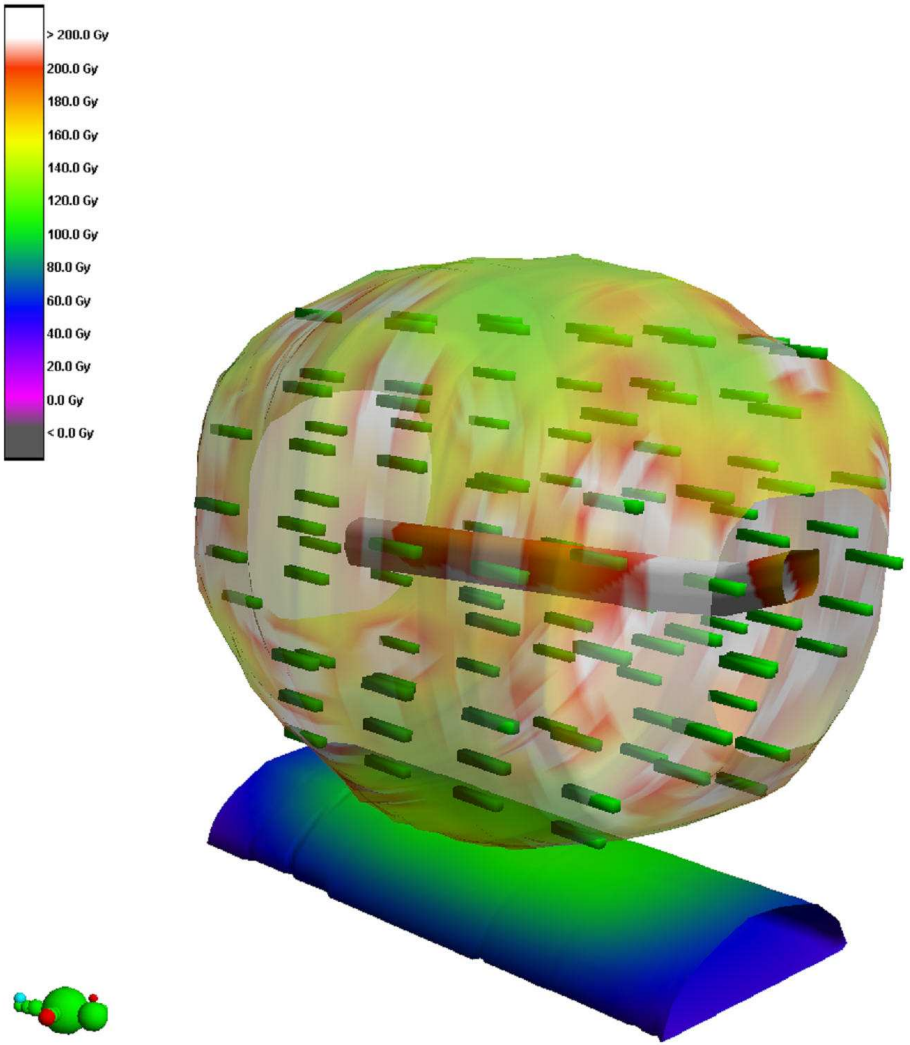

Registration
Least Squares
Manual
Sagittal
Transverse
Coronal
A
S
I
P
R
L
Matched Pairs
Use
Name
Color
1
2
3
Add
Delete
Delete All
Transformation
RMS Error (mm):
3.69
Matched Pairs
Reset to Matched Pairs Transform

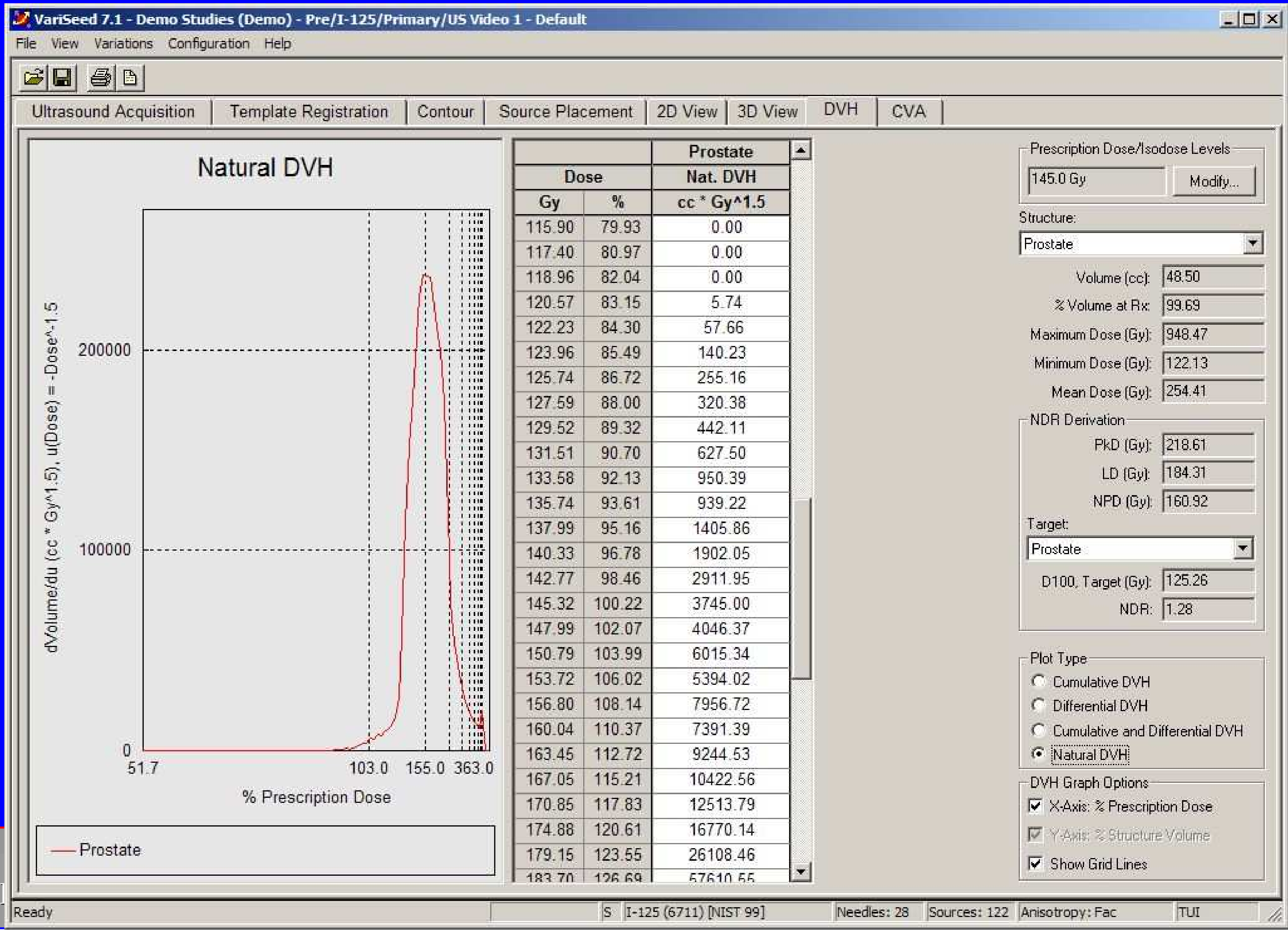
Dose display for evaluation and reporting

VariSeed: 3D View Report [Page 1]

5/29/2003 1:50:56 PM

Name: **Demo Studies** PID: **Demo** Dept. ID:	Study: **Intra-Op** Variation: **Default** Images: **56** Template: **B & K Standard**	Source: **I-125 (6733) [NIST 00]** Comment: Sources: **100** Anisotropy: **Factors (Point Model)** Source Activity: **0.432 U [0.340 mCi]**
Procedure Date: **5/29/2003**	Prescription Dose: **145.0 Gy**	Total Activity: **43.200 U [34.016 mCi]**




VariSeed 7.1 - Demo Studies (Demo) - Pre/I-125/Primary/US Video 1 - Default
File View Variations Configuration Help
Ultrasound Acquisition
Template Registration
Contour
Source Placement
2D View
3D View
DVH
CVA
Natural DVH
dVolume/du (cc * Gy^1.5), u(Dose) = -Dose^-1.5
200000
100000
0
51.7
103.0
155.0
363.0
% Prescription Dose
Prostate
Prostate
Dose
Nat. DVH
Gy
%
cc * Gy^1.5
115.90 79.93 0.00
117.40 80.97 0.00
118.96 82.04 0.00
120.57 83.15 5.74
122.23 84.30 57.66
123.96 85.49 140.23
125.74 86.72 255.16
127.59 88.00 320.38
129.52 89.32 442.11
131.51 90.70 627.50
133.58 92.13 950.39
135.74 93.61 939.22
137.99 95.16 1405.86
140.33 96.78 1902.05
142.77 98.46 2911.95
145.32 100.22 3745.00
147.99 102.07 4046.37
150.79 103.99 6015.34
153.72 106.02 5394.02
156.80 108.14 7956.72
160.04 110.37 7391.39
163.45 112.72 9244.53
167.05 115.21 10422.56
170.85 117.83 12513.79
174.88 120.61 16770.14
179.15 123.55 26108.46
Prescription Dose/Isodose Levels
145.0 Gy
Modify...
Structure:
Prostate
Volume (cc): 48.50
% Volume at Rx: 99.69
Maximum Dose (Gy): 948.47
Minimum Dose (Gy): 122.13
Mean Dose (Gy): 254.41
NDR Derivation
PkD (Gy): 218.61
LD (Gy): 184.31
NPD (Gy): 160.92
Target:
Prostate
D100, Target (Gy): 125.26
NDR: 1.28
Plot Type
Cumulative DVH
Differential DVH
Cumulative and Differential DVH
Natural DVH
DVH Graph Options
X-Axis: % Prescription Dose
Y-Axis: % Structure Volume
Show Grid Lines
Ready
S
I-125 (6711) [NIST 99]
Needles: 28
Sources: 122
Anisotropy: Fac
TUI

HDR Brachytherapy for Prostate

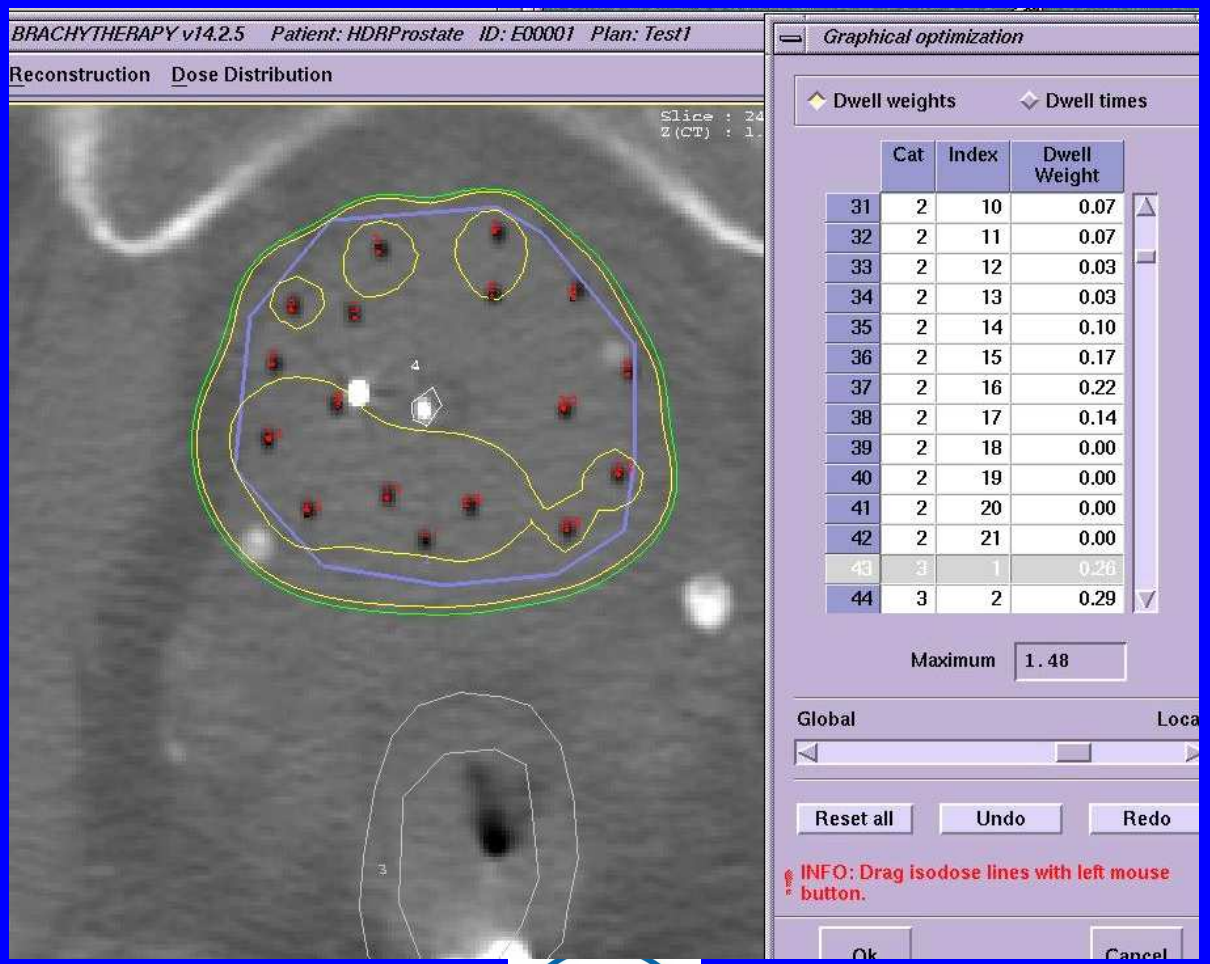
- Used as boost to 45 Gy EBRT
- HDR dose given in 2 fractions of 8 Gy each
- EBRT given after HDR
- Gold markers placed at base and at apex

Dose equivalence for complete RT course

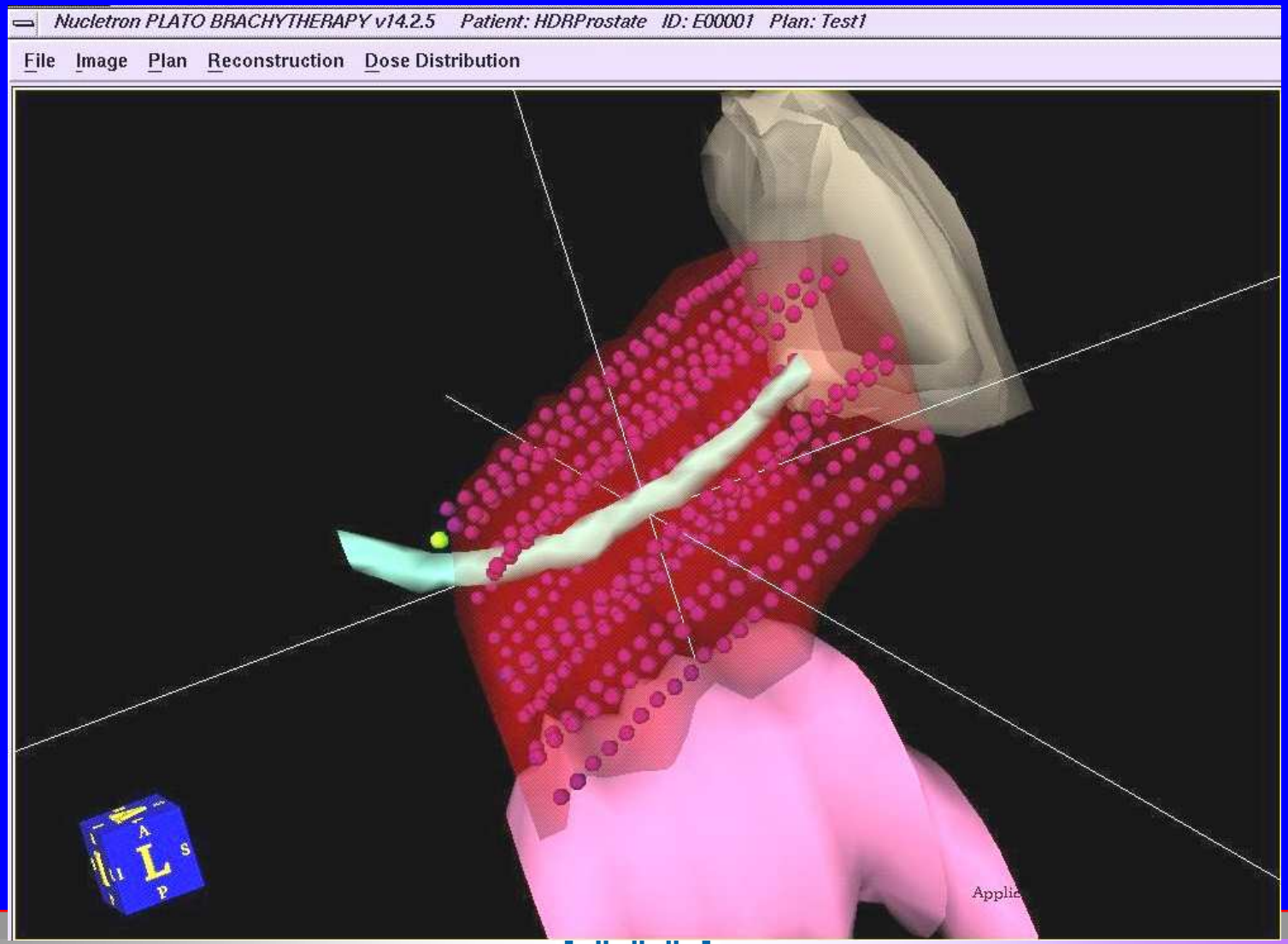
- ERD=d{1+d/(α/β)}
- for (α/β)=1.5
- ERD(HDR)=8{1+8/1.5}=50 Gy
- Total dose= 2x50+45=145 Gy (similar to seed implant with I-

Planning Procedure

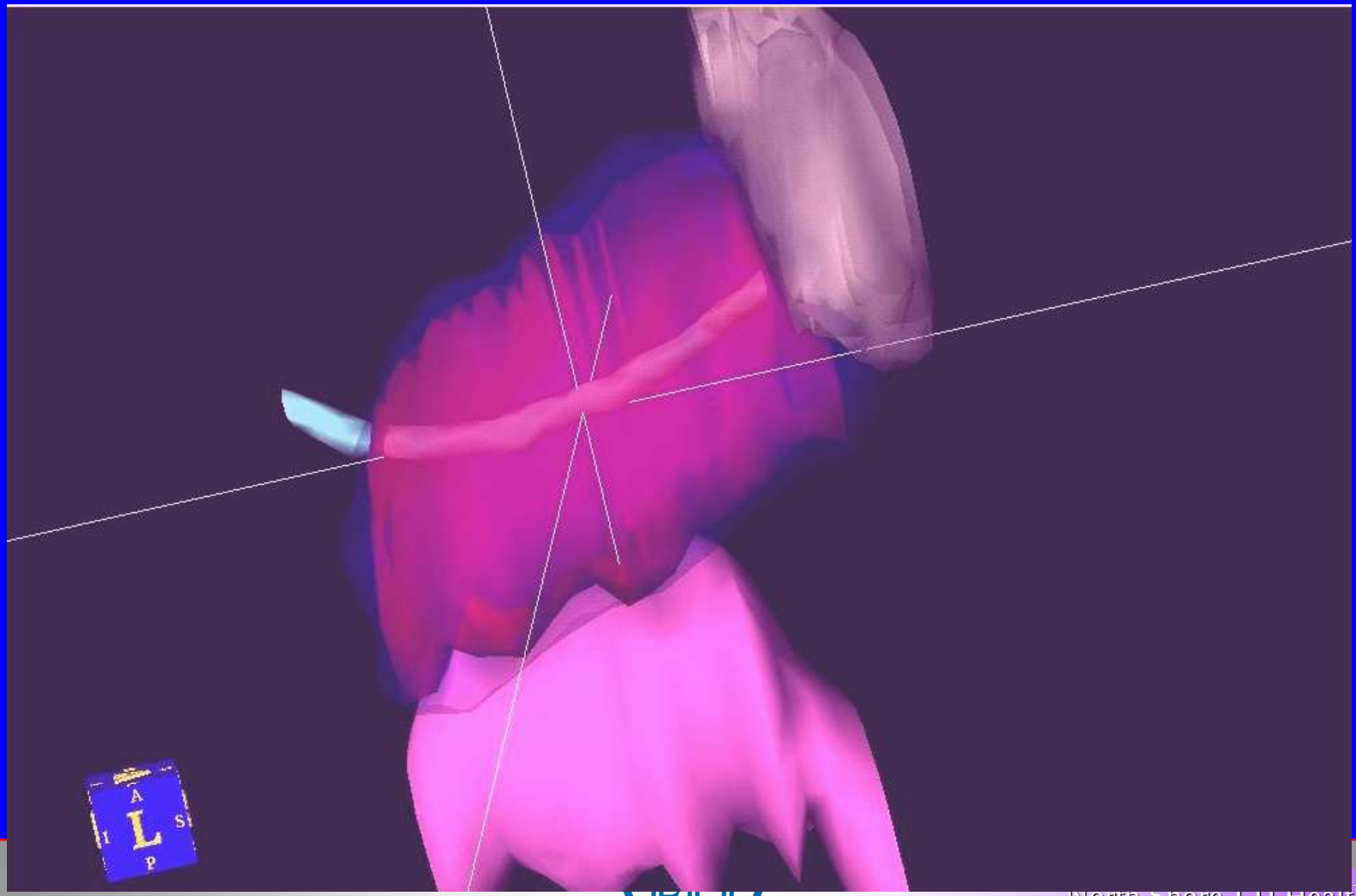
- CT based anatomy delineation
- Catheter tracking
- Inverse planning
- Review and adjustment of Isodose distribution


BRACHYTHERAPY v14.2.5 Patient: HDRProstate ID: E00001 Plan: Test1
Reconstruction Dose Distribution
Graphical optimization
Dwell weights
Dwell times
Cat Index Dwell Weight
31 2 10 0.07
32 2 11 0.07
33 2 12 0.03
34 2 13 0.03
35 2 14 0.10
36 2 15 0.17
37 2 16 0.22
38 2 17 0.14
39 2 18 0.00
40 2 19 0.00
41 2 20 0.00
42 2 21 0.00
44 3 2 0.29
Maximum 1.48
Global
Reset all
Undo
Redo
INFO: Drag isodose lines with left mouse button.
Ok
Cancel

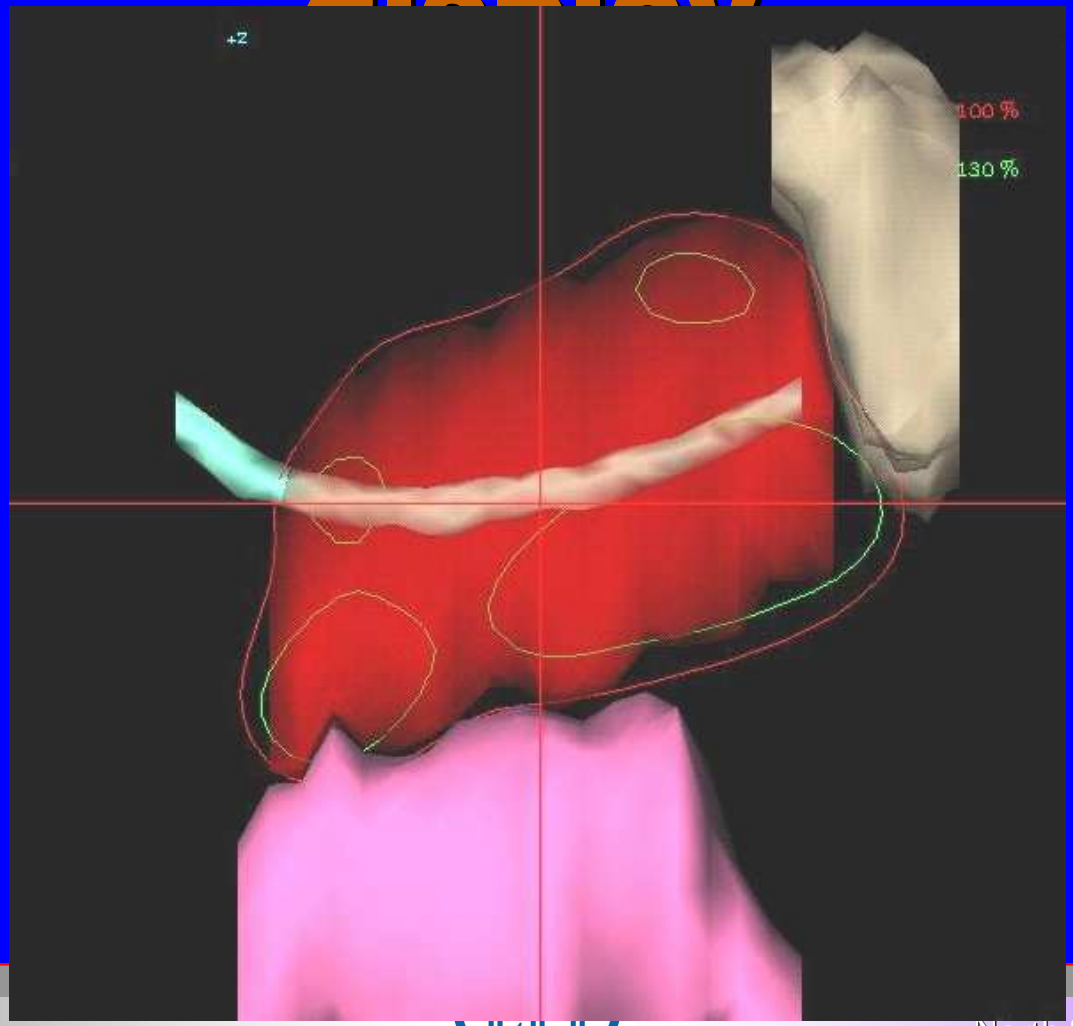
Catheter tracks with prospective dwell positions

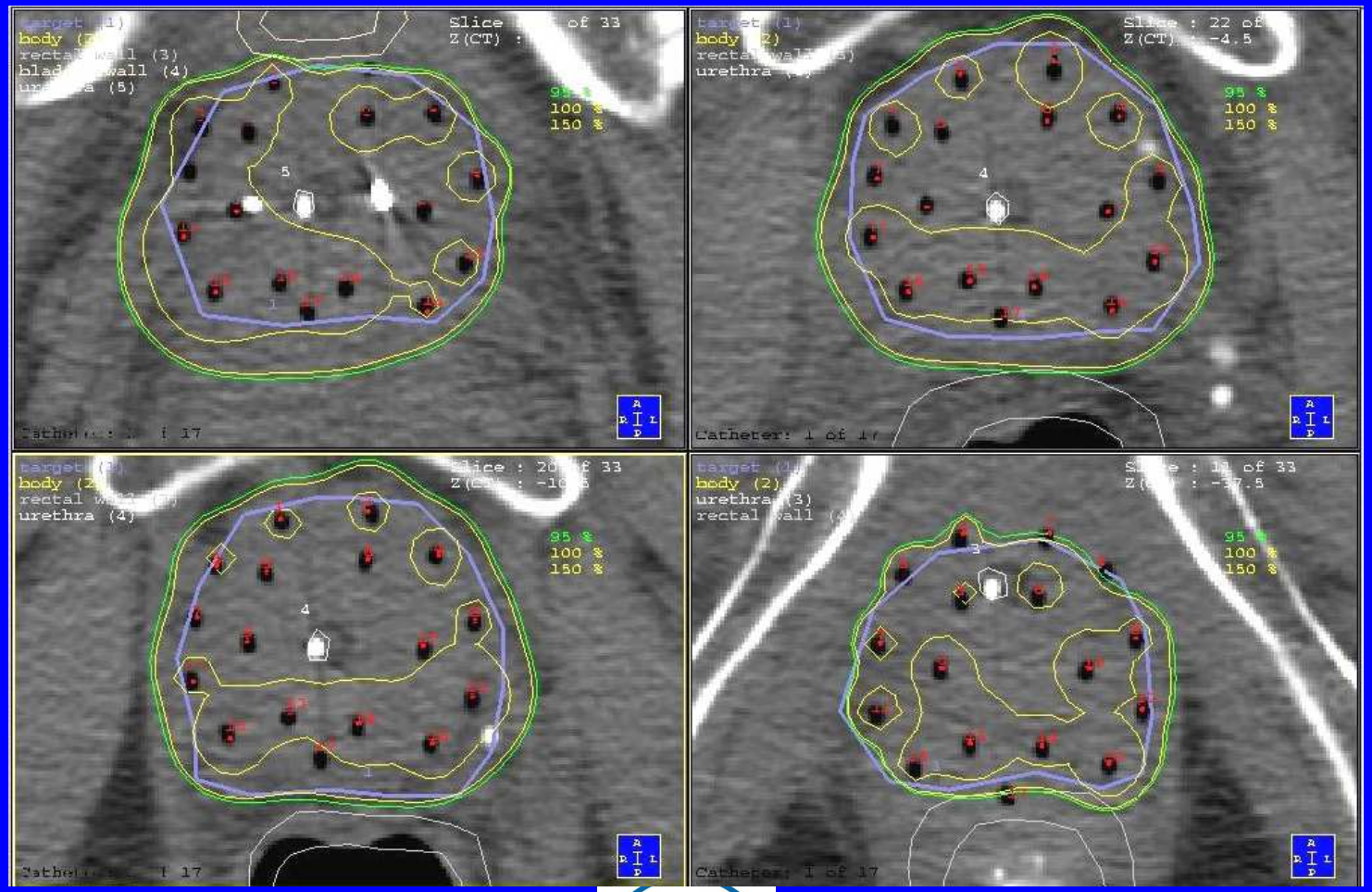


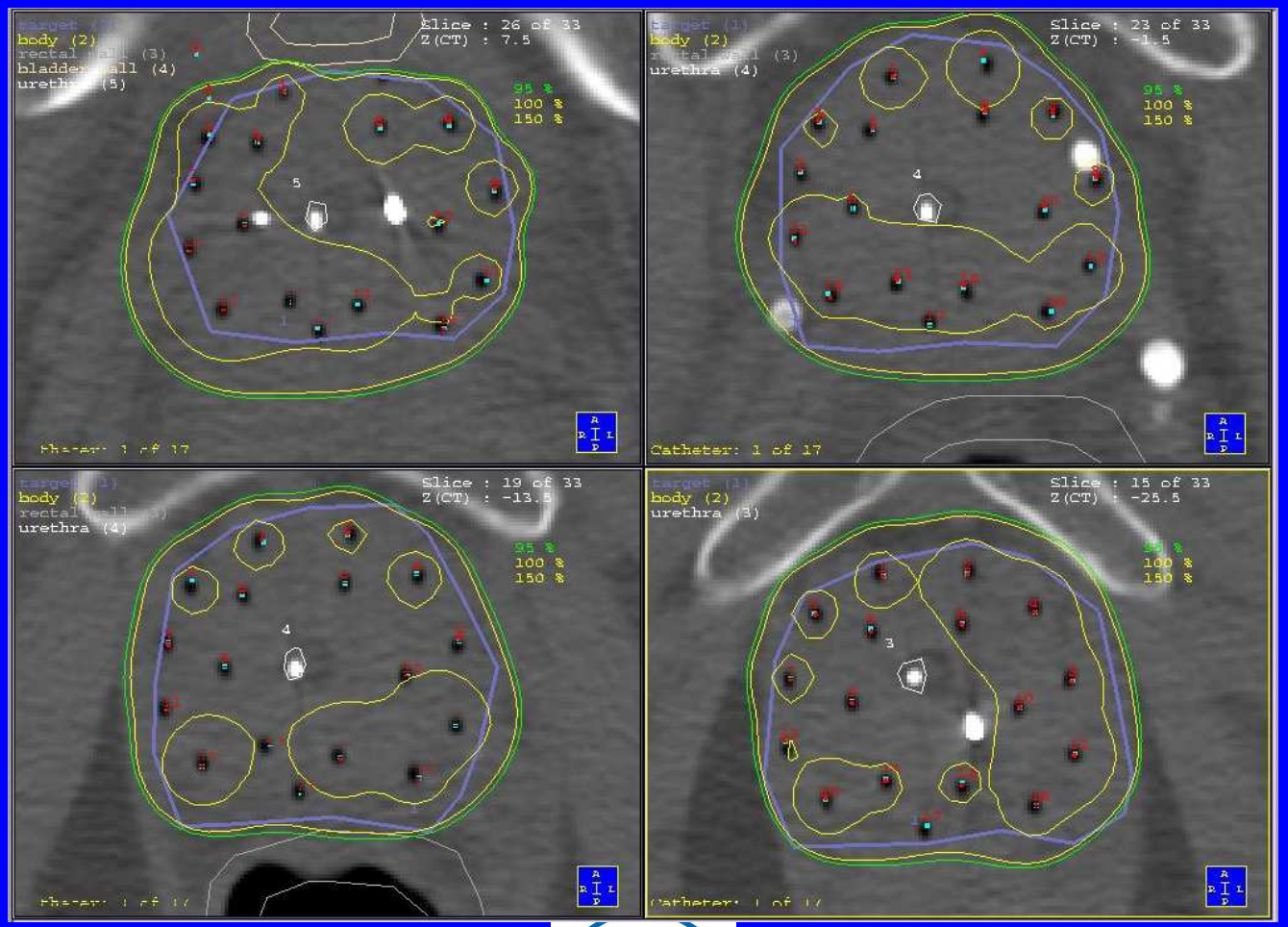
Dose cloud at 8 Gy covers the Prostate tightly The Rectum and Bladder are



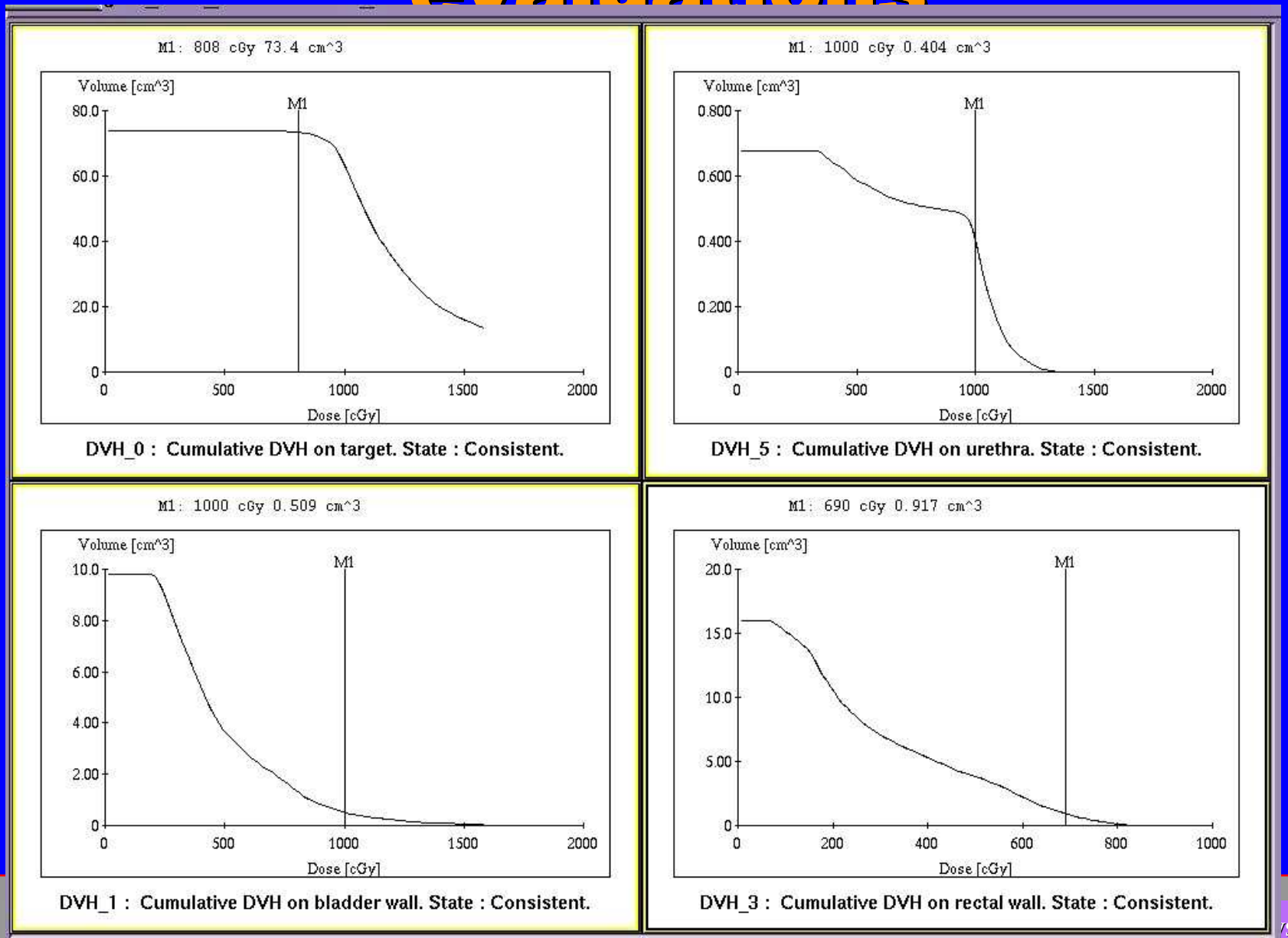
2-D dose distribution display



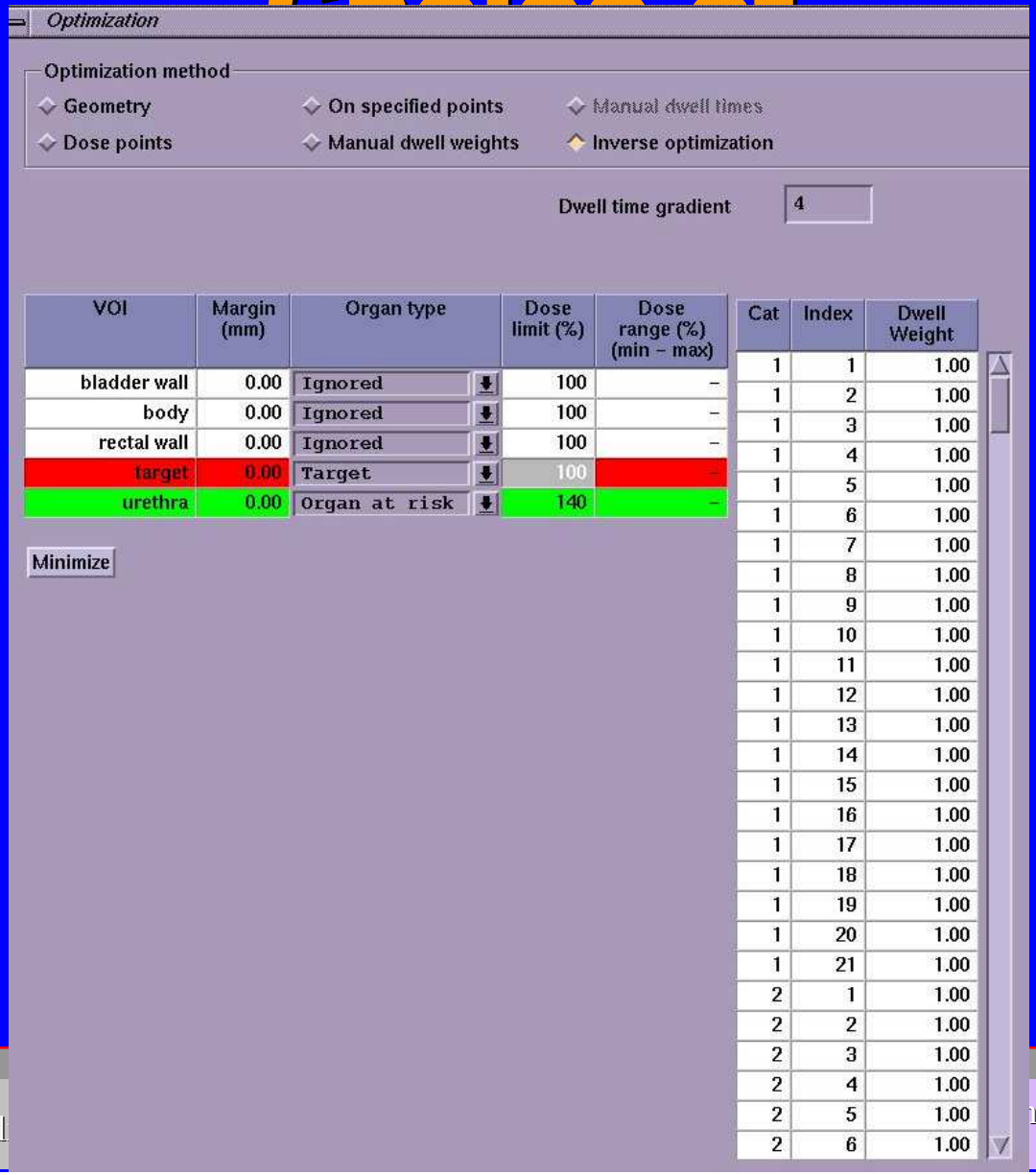

body (2)
rectal wall (3)
urethra (4)
95 %
100 %
150 %
Catheter: 1 of 17


body (2)
bladder wall (4)
urethra (5)
Slice : 26 of 33
Z(CT) : 7.5
95 %
100 %
150 %
5
body (2)
urethra (4)
Slice : 23 of 33
Z(CT) : -1.5
95 %
100 %
150 %
4
Catheter: 1 of 17
body (2)
urethra (4)
Slice : 19 of 33
Z(CT) : -13.5
95 %
100 %
150 %
4
body (2)
urethra (3)
Slice : 15 of 33
Z(CT) : -25.5
95 %
100 %
150 %
3

Pre-implant plan DVH evaluations

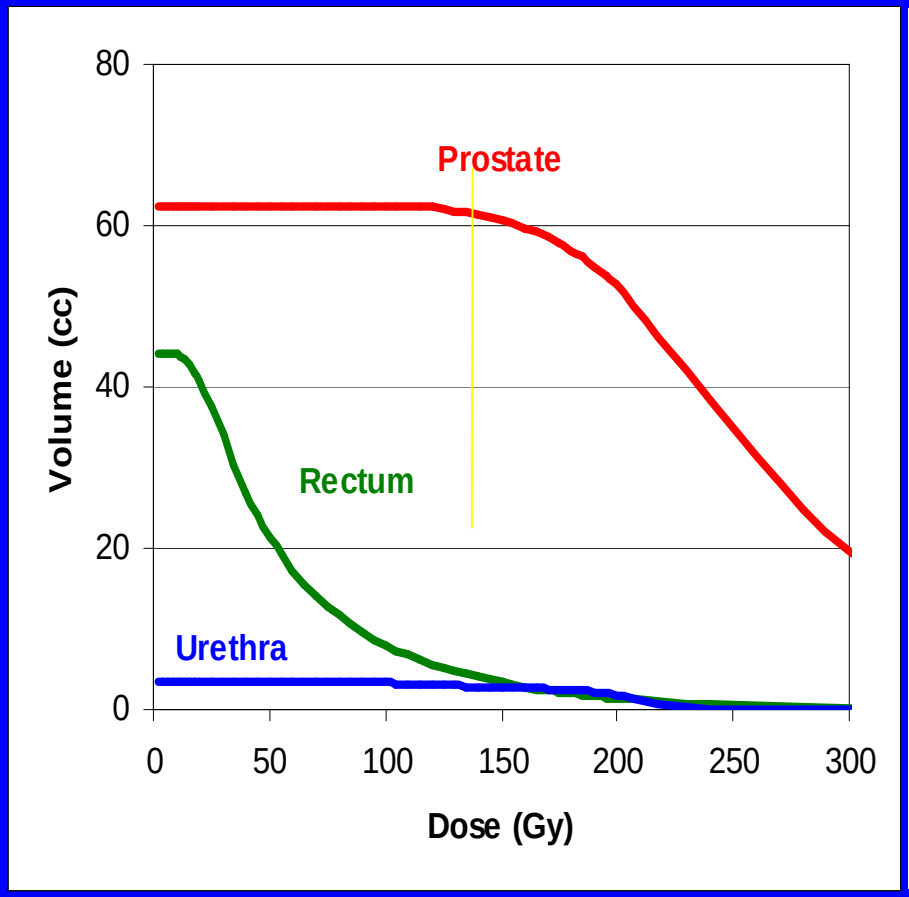


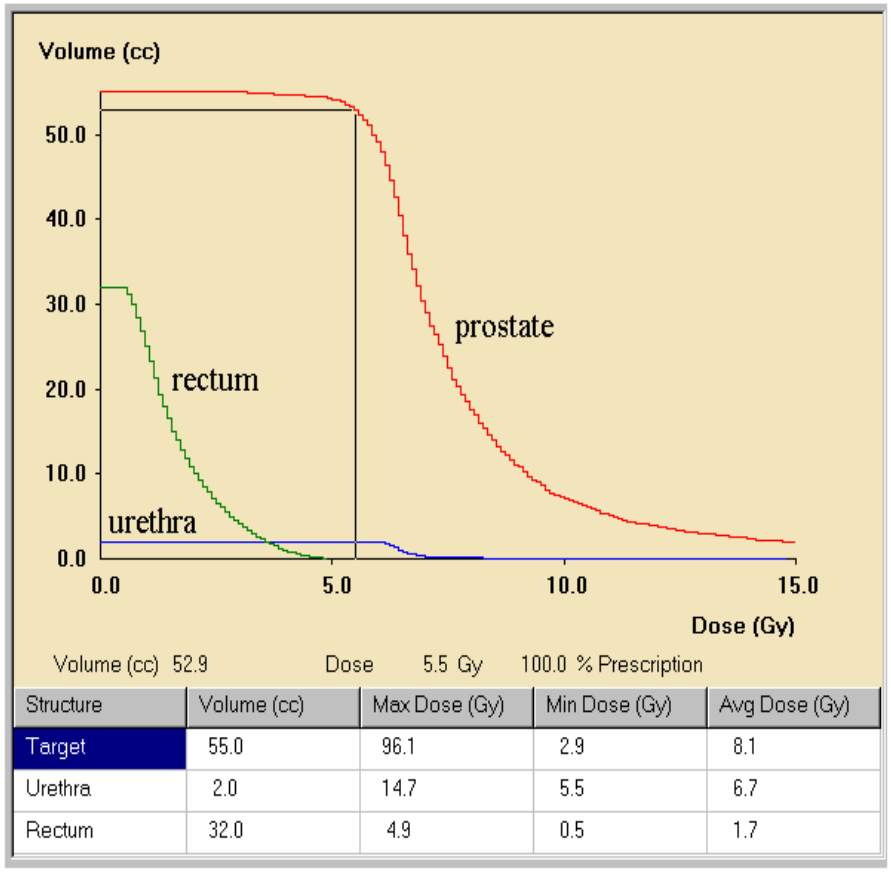
Choice of


Optimization
Optimization method
Geometry
On specified points
Manual dwell times
Dose points
Manual dwell weights
Inverse optimization
Dwell time gradient
4
VOI
Margin (mm)
Organ type
Dose limit (%)
Dose range (%) (min – max)
bladder wall 0.00 Ignored 100 –
body 0.00 Ignored 100 –
rectal wall 0.00 Ignored 100 –
target 0.00 Target 100 –
urethra 0.00 Organ at risk 140 –
Minimize
Cat
Index
Dwell Weight
1 1 1.00
1 2 1.00
1 3 1.00
1 4 1.00
1 5 1.00
1 6 1.00
1 7 1.00
1 8 1.00
1 9 1.00
1 10 1.00
1 11 1.00
1 12 1.00
1 13 1.00
1 14 1.00
1 15 1.00
1 16 1.00
1 17 1.00
1 18 1.00
1 19 1.00
1 20 1.00
1 21 1.00
2 1 1.00
2 2 1.00
2 3 1.00
2 4 1.00
2 5 1.00
2 6 1.00

Large number of source Dwell positions offers great flexibility for Optimizing the Dose

Prostate Brachytherapy
DVH evaluation





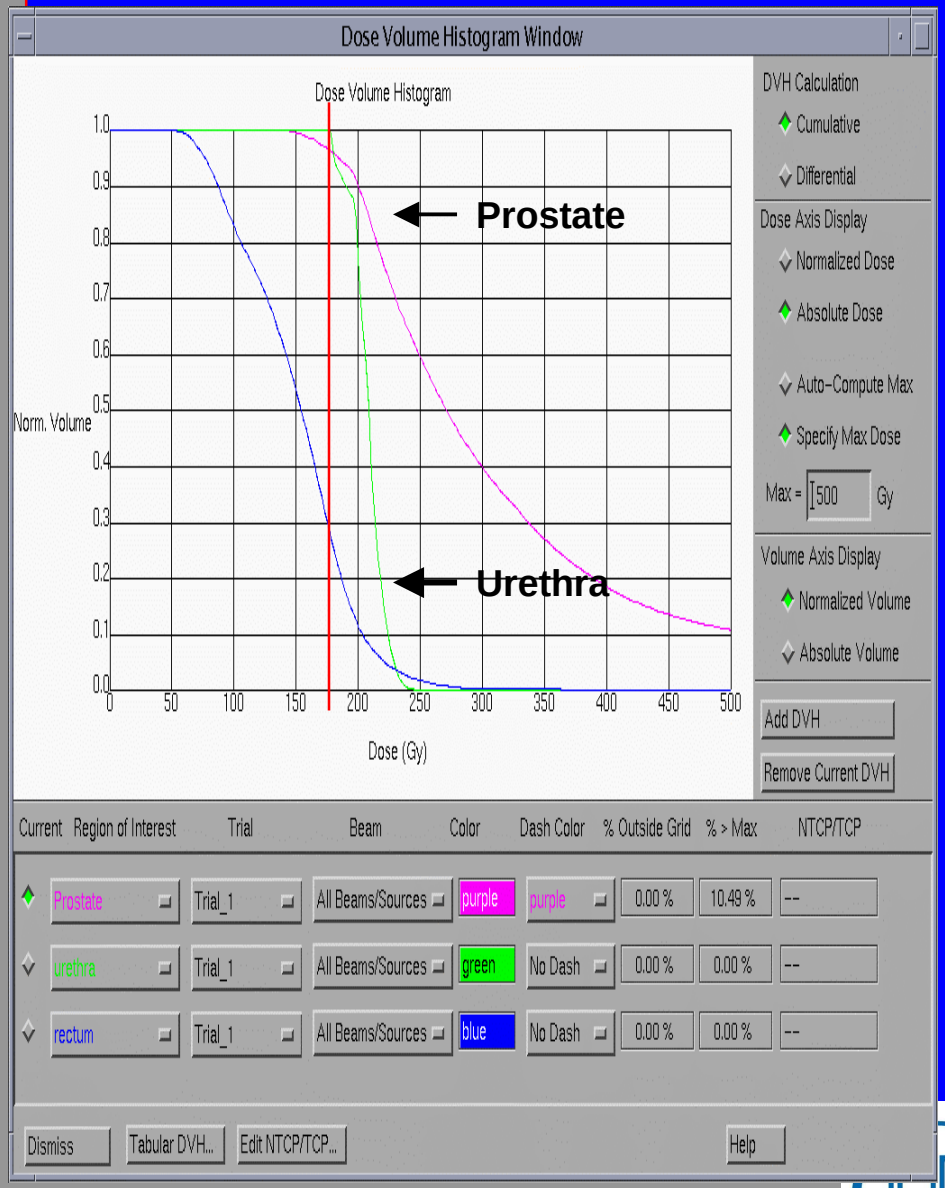
Volume (cc) 52.9 Dose 5.5 Gy 100.0 % Prescription

Structure	Volume (cc)	Max Dose (Gy)	Min Dose (Gy)	Avg Dose (Gy)
Target	55.0	96.1	2.9	8.1
Urethra	2.0	14.7	5.5	6.7
Rectum	32.0	4.9	0.5	1.7

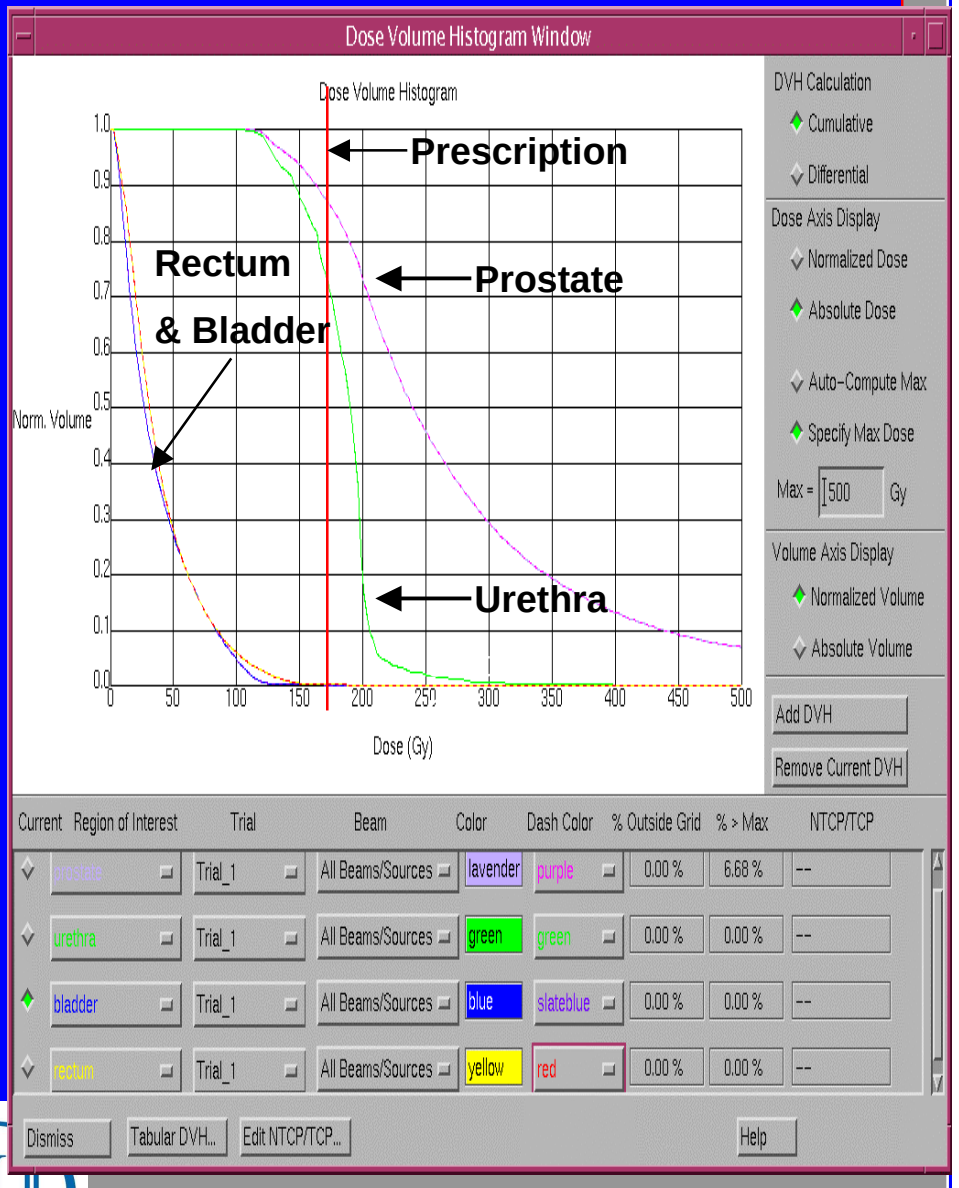
Permanent seed implant
LDR

HDR with remote afterloader

Pre-implant , TRUS-based, Planned DVH



Post-Implant, Ct-based, DVH Evaluation



Comparison of Biological Effectiveness for all Four Modalities

Modality	Fractionation	Total Dose (Gy)	BED (Gy)
I-125	1 x 144	144.0	123
EBRT	44 x 1.8	79.2	170
EBRT	25 x 1.8	45.0	99
I-125	1 x 115	115.0	98
EBRT + I-125			197
EBRT	25 x 1.8	45.0	99
HDR	2 x 8	16.0	101
EBRT + HDR			200