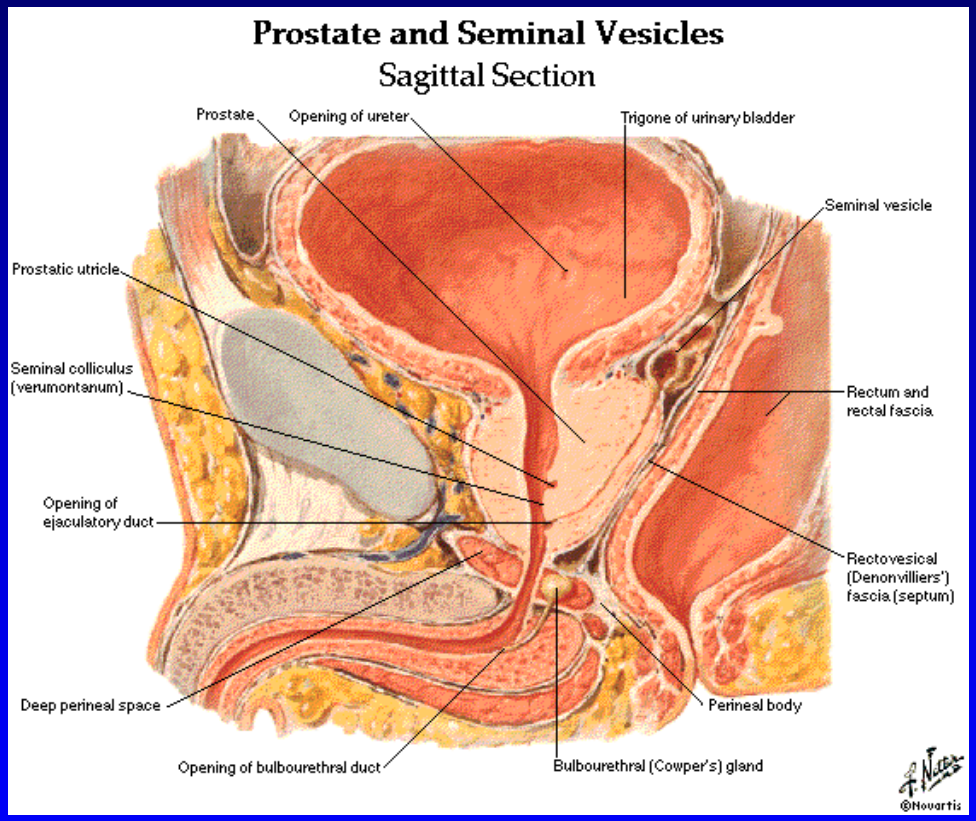
# Brachytherapy Physics

## Prostate

# Prostate Brachytherapy



# Permanent Seed Prostate Brachytherapy (LDR)

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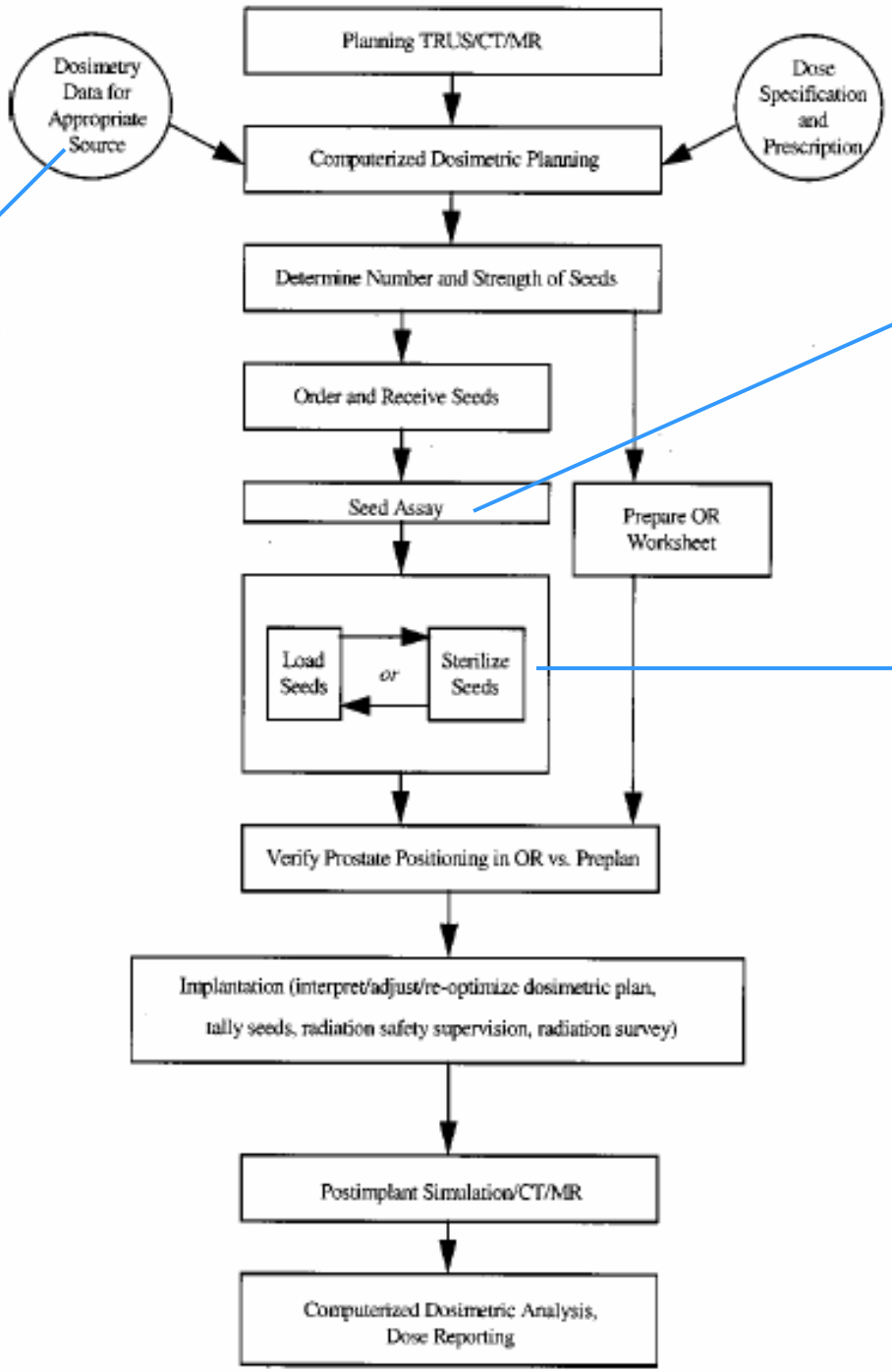



Physics guidelines require 10% seed assay

Needle types

- Loose Seeds loaded manually into needles
- Mick Application
- RapidStrand (I-125) or stranded needles

# Prescribed Dose

| | Previous | Current* |
|---|---|---|
| **I-125** | | |
| **Monotherapy** | **160 Gy** | **145 Gy** |
| **+ 45 Gy EBRT** | **120 Gy** | **108 Gy** |
| **Pd 103** | | |
| **Monotherapy** | **115 Gy** | **120 Gy** |
| **+ 45 Gy EBRT** | **90 Gy** | **95 Gy** |

***Current prescriptions require seeds to be calibrated to current national standards and have current dosimetric data**

Recommendations of the American Association of Physicists in Medicine regarding the Impact of Implementing the 2004 Task Group 43 Report on Dose Specification for $^{103}$Pd and $^{125}$I Interstitial Brachytherapy

**It is important to keep and eye on the prescribed dose and the dosimetric data used to calculate such prescribed dose. *Especially for PD-103***

# TRUS Prostate Implants

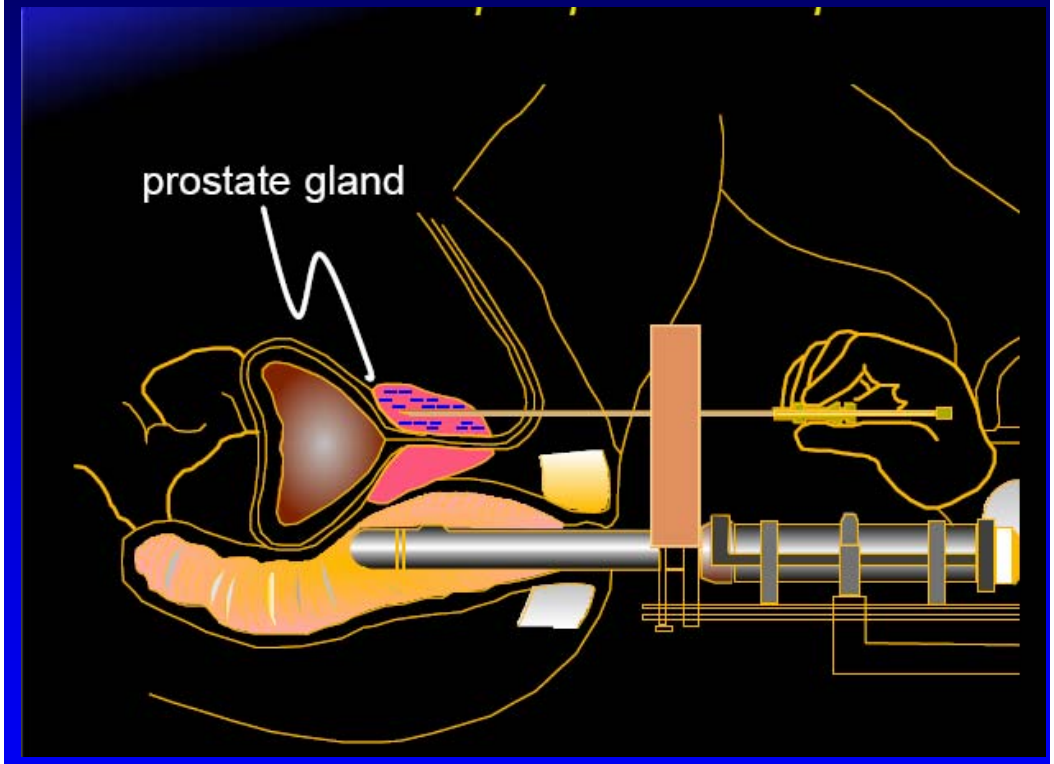



TABLE I. Equipment requirement for the prostate seed implant program.

| Mick applicator technique | Pre-loaded needle technique |
|---|---|
| **Capital equipment** | |
| Well-type ionization chamber | Well-type ionization chamber |
| GM or scintillation detector | GM or scintillation detector |
| Ion chamber survey meter | Ion chamber survey meter |
| Computer treatment planning system | Computer treatment planning system |
| Ultrasound unit | Ultrasound unit |
| Stabilization device/attachment | Stabilization device/attachment |
| Fluoroscopy unit | Fluoroscopy unit |
| Mick applicator | |
| **Supplies and consumables** | |
| Loading block, cartridges | Needle box, (optional) needle loading device |
| Seed carrier | Seed sterilization container |
| Mick-compatible needles | Needles |
| (Optional) stabilization needles | (Optional) stabilization needles |
| Reverse action tweezers | Reverse action tweezers |
| Radioactive seeds | Radioactive seeds |
| | Spacers and bone wax |

# Patient Selection- Definitive Treatment

- Primary
  - Gleason Score <= 6
  - PSA <= 10 ng/mL
  - Stage <= T2a
- Secondary
  - 3 or fewer cores
  - No positive seminal vesicles or distant mets.
  - Prostate volume <= 60 cc
    - Pubic arch intereference
    - Urinary retention
  - TURP discouraged
  - disease limited to the gland
  - Expected life >5 yrs

# Sources

## I-125

- Advantages
  - Well Characterized dosimetry
  - Long term use
- Disadvantages
  - Relatively long half life
  - Rounded seed ends makes them mobile
  - Very anisotropic dose distribution

## Pd-103

- Advantages
  - Short Half Life
  - Cupped seed ends tend to anchor seeds
- Disadvantages
  - Dosimetry based on only two studies
  - Activity decays 4% a day
  - Edema not resolved for 30 days, may cause issues with implants

-- Both are NIST traceable and have rapid strands available

# Characteristics of $^{125}I$

- Energy of emitted photons -keV (number of photons per decay):

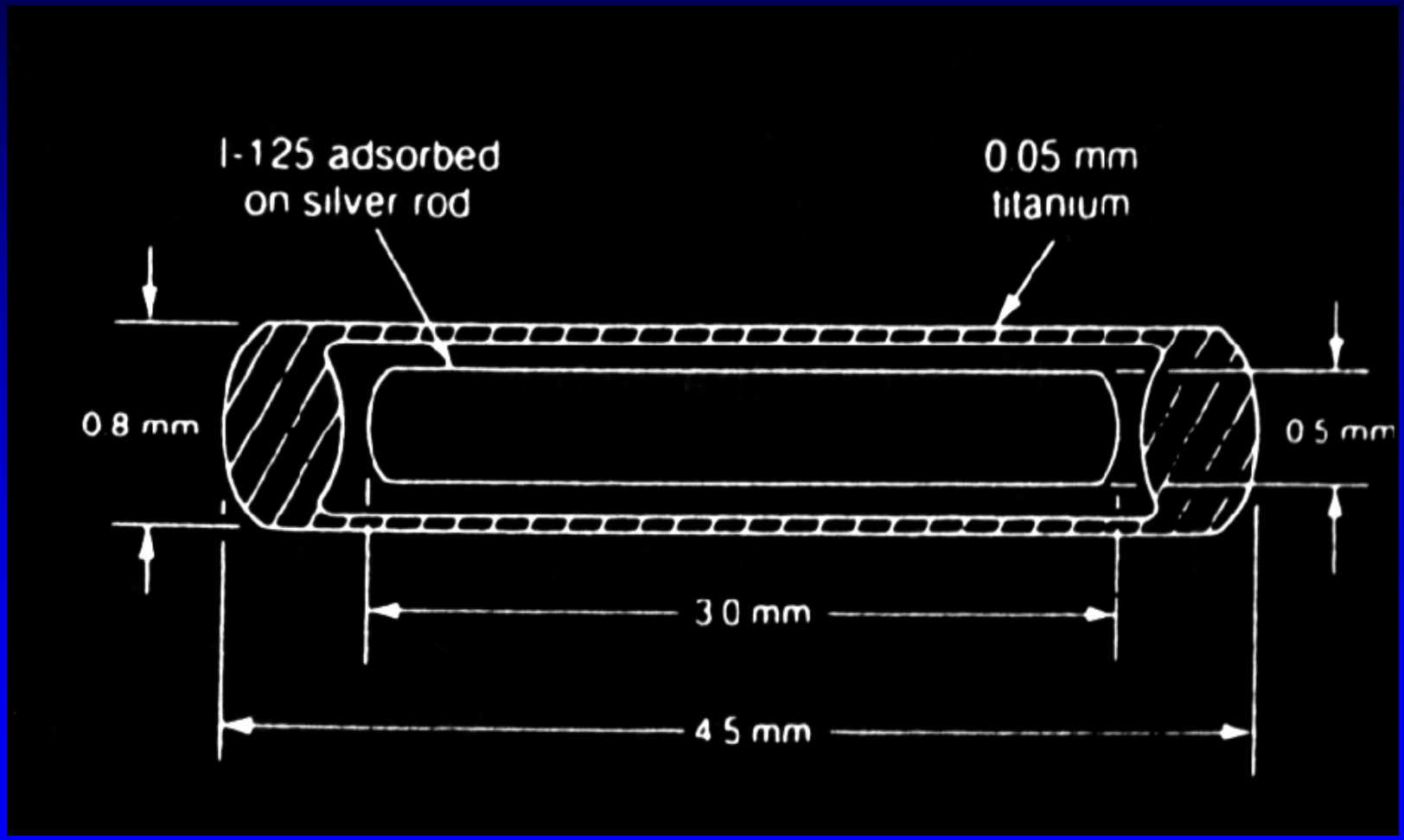
  27.4 (1.15), 31.4 (0.25), 35.5 (0.067)
- Outer Dimension: 4.5 mm x 0.8 mm
- Half Life: 59.4 Days
- Typical Prescription 145 Gy

  (160 Gy using 1985 dosimetry standards)
- Initial dose rate = 7.0 cGy/hr
- 90% of total dose delivered in 197 days
- HVL in tissue = 1.8 cm
- Exposure rate at 1 m from the patient < 0.3 mR/hr

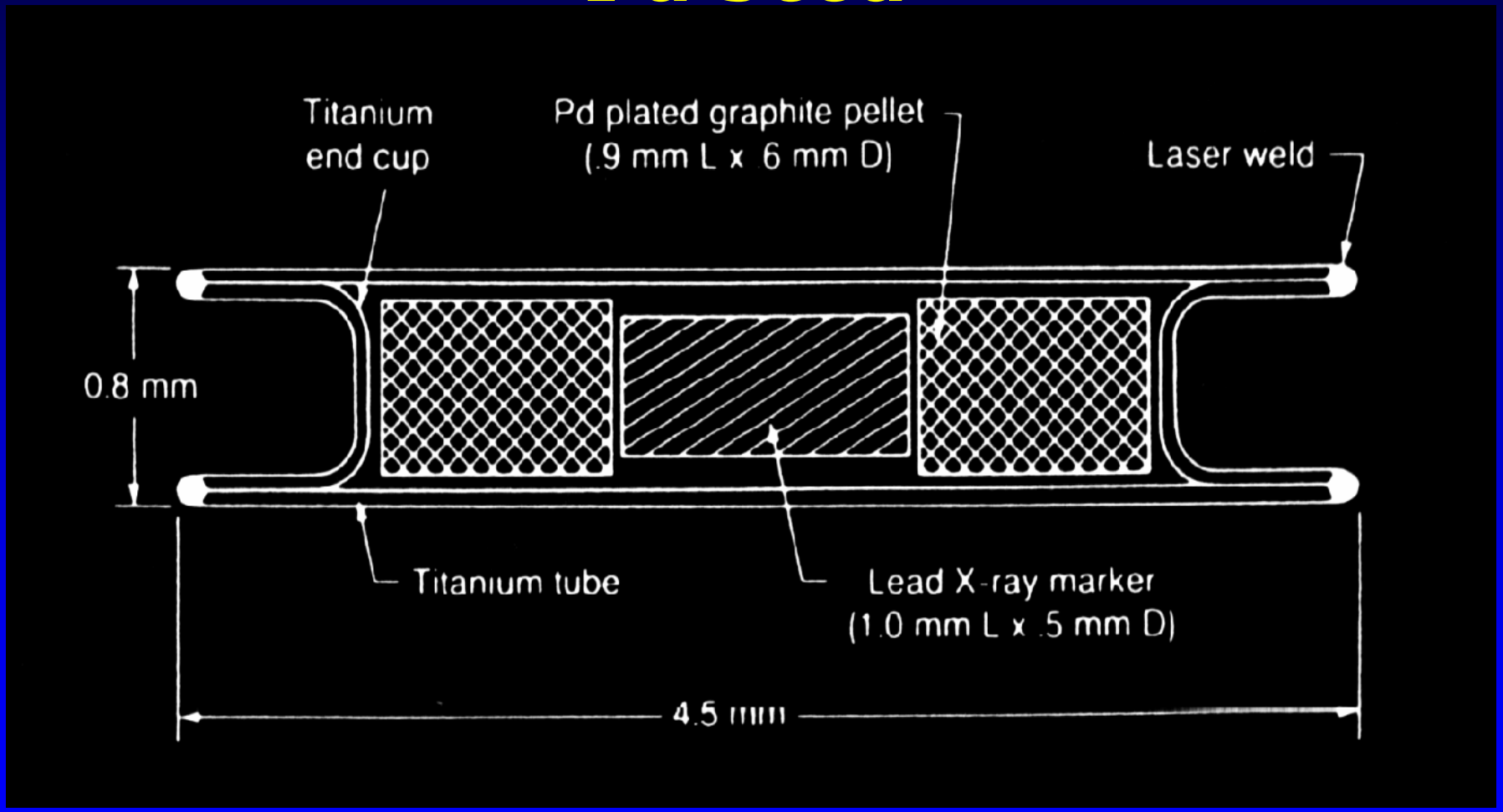
# Characteristics of $^{103}Pd$

- Energy of principal emitted photons -keV (number of photons per decay): 20.1 (0.656), 23.0 (.125)
- Outer Dimension: 4.5 mm x 0.81 mm
- Half Life: 16.97 Days
- Typical prescription 120 Gy
- Initial dose rate = 19.6 cGy/hr
- 90% of total dose delivered in 56 days
- HVL in tissue = 1.1 cm
- Exposure rate at 1 m from the patient < 0.15 mR/hr

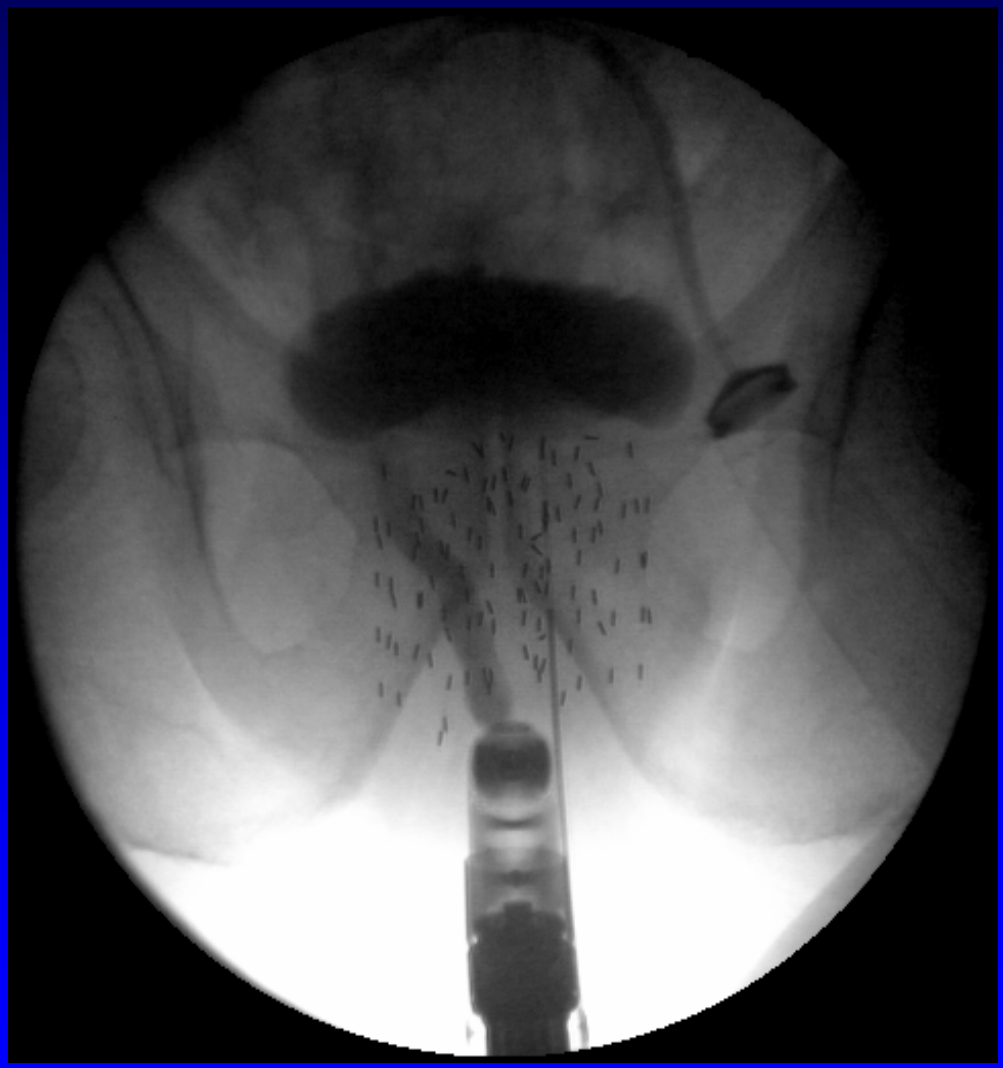
# Schematic Diagram of $^{125}I$ 6711 Seed



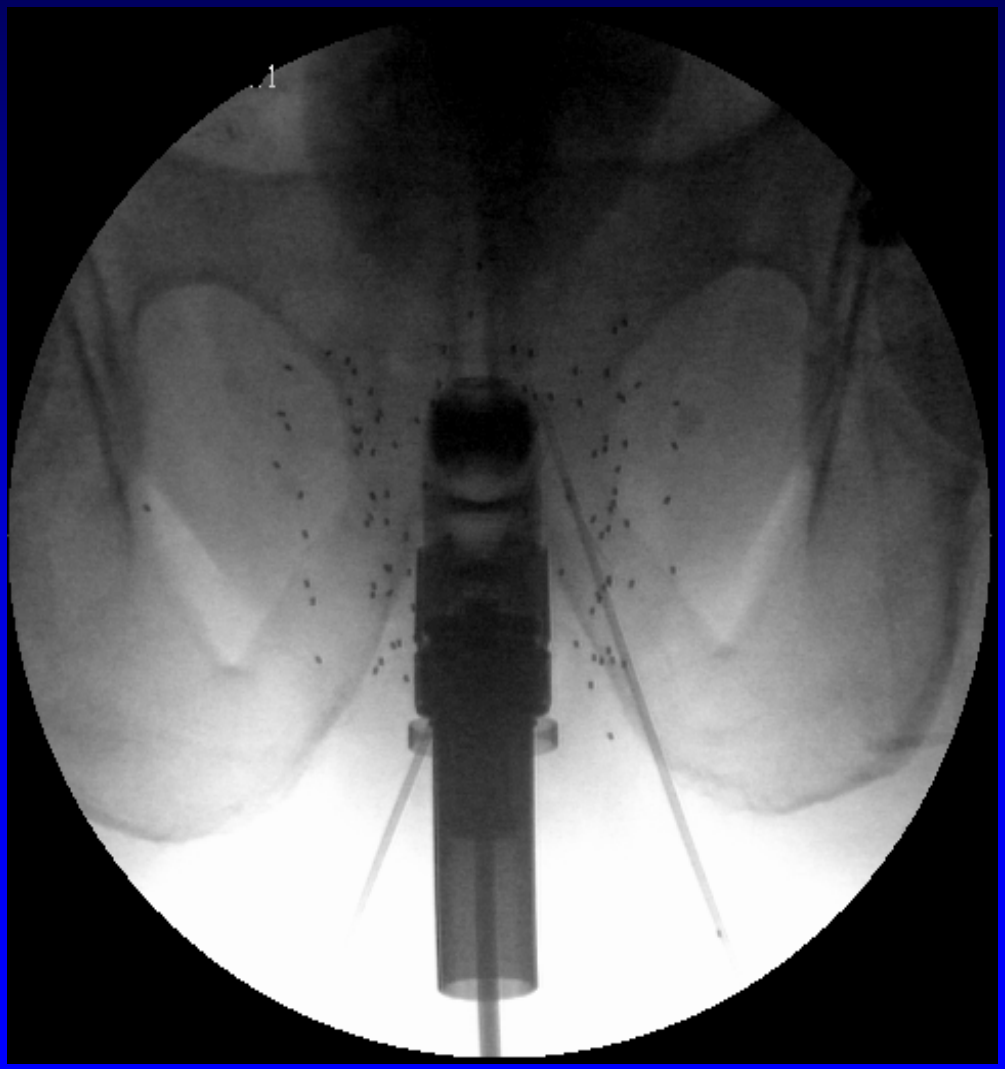
# Schematic Diagram of $^{103}$Pd Seed



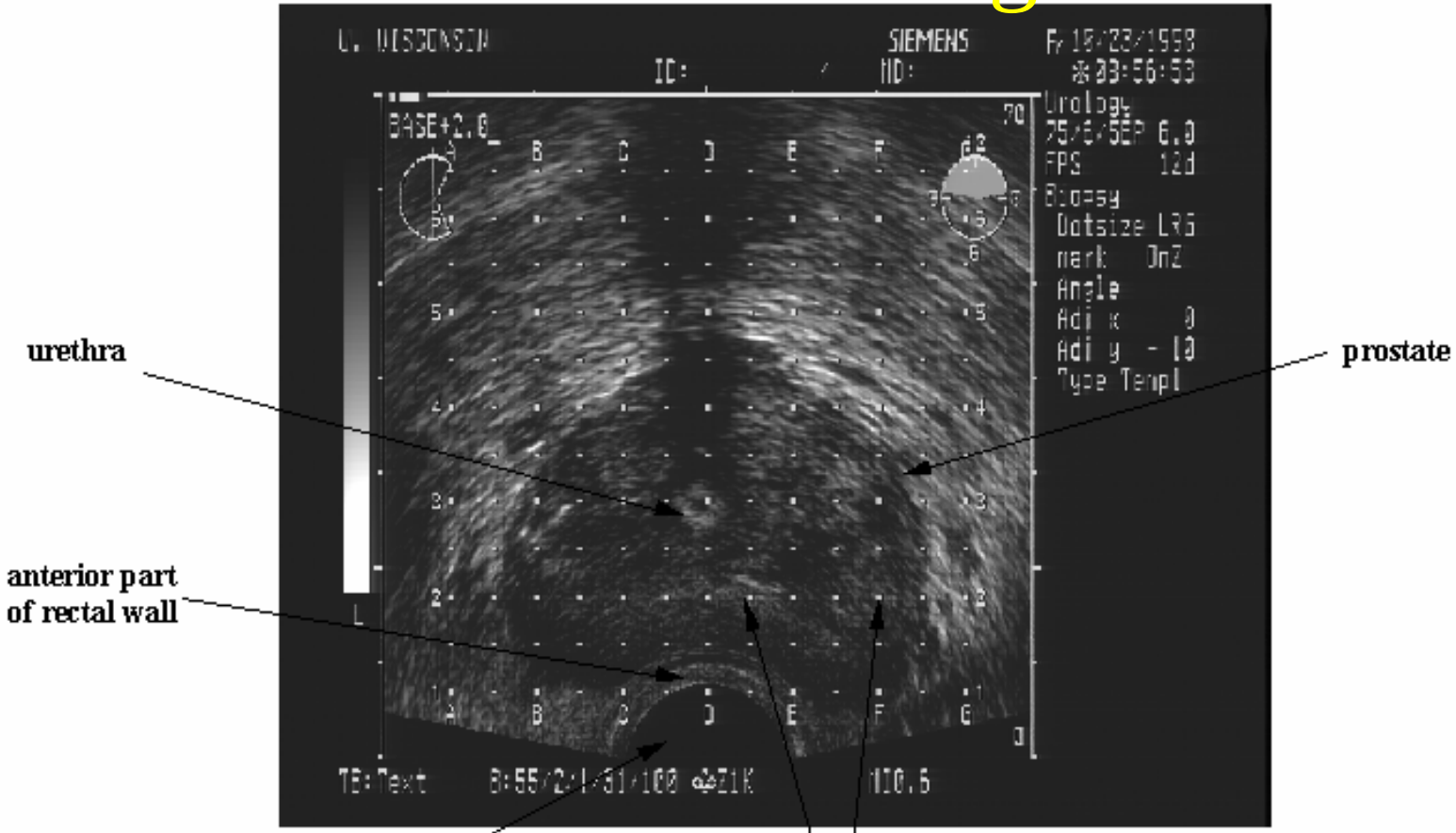
# $^{125}$I 6711 Seed Prostate Implant Radiograph



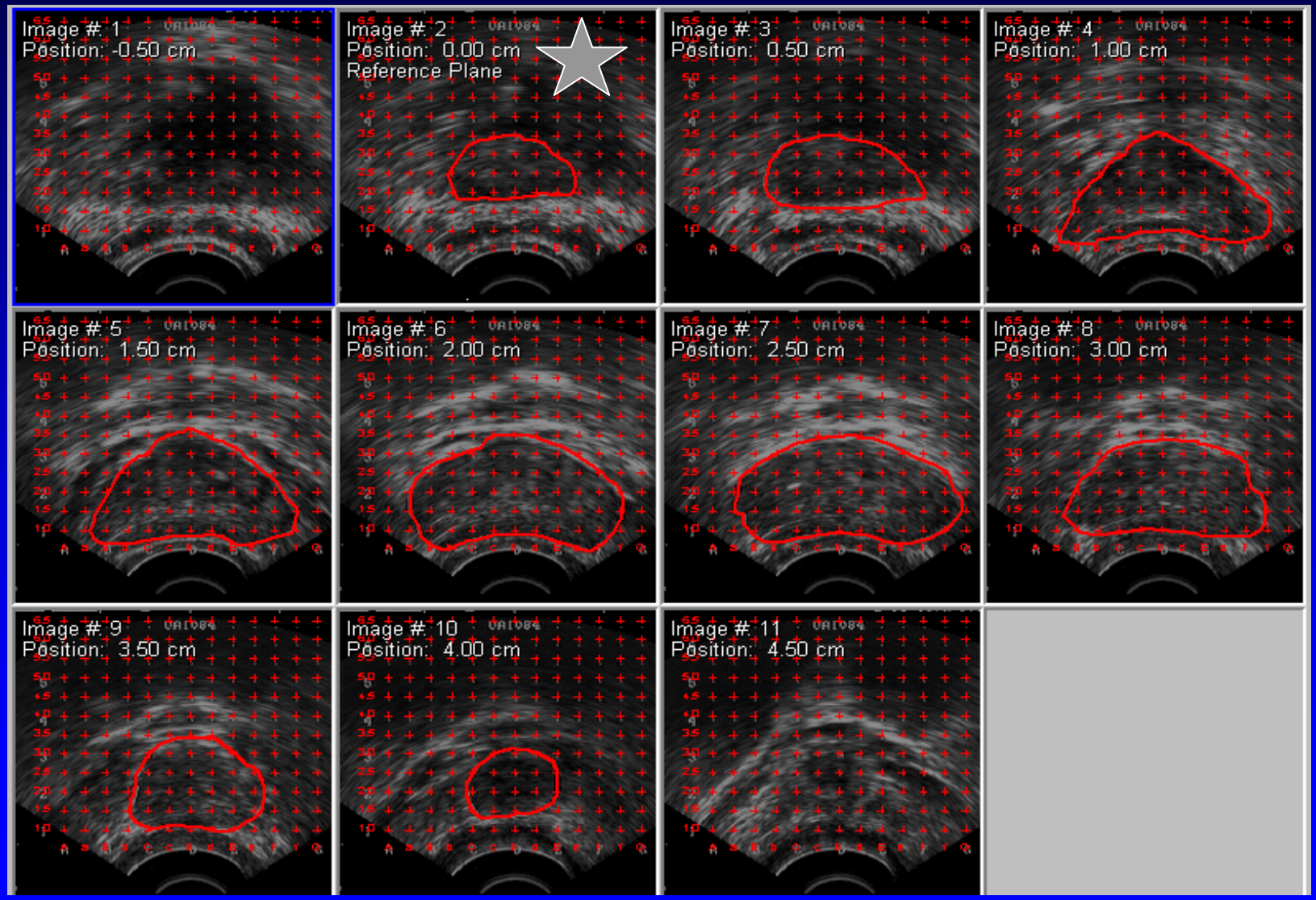
# $^{103}$Pd Prostate Implant Radiograph



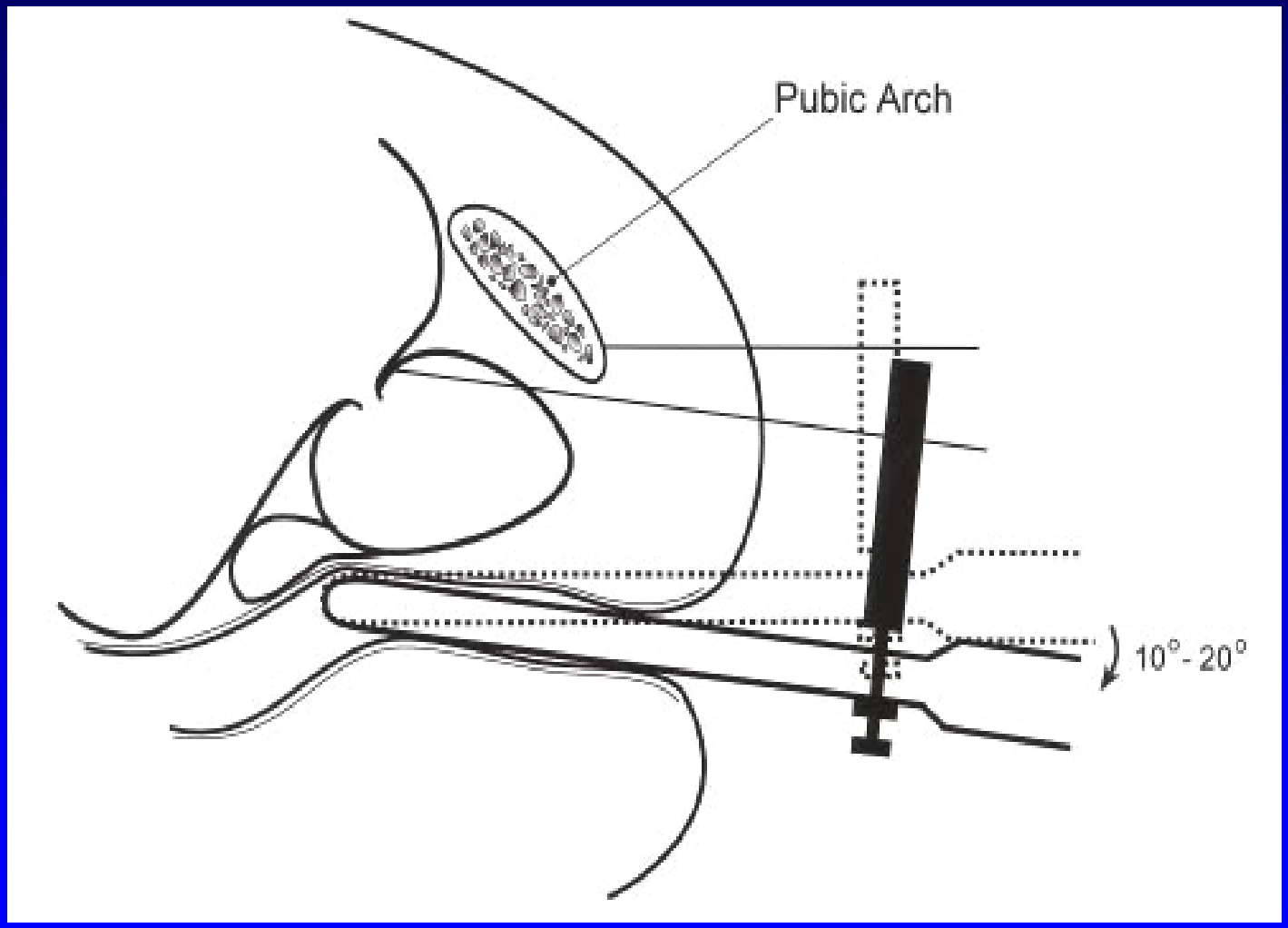
# Ultrasound images



# Ultrasound images



# Avoiding the pubic arch: change probe angle or hyper-extend legs



# Treatment Planning Goals

- Provide coverage of the entire target volume
- Limit rectal and urethral doses to acceptable limits
- Minimize dose inhomogeneity
- Plan for possible pubic arch interference
- Design the implant as technically simple as possible

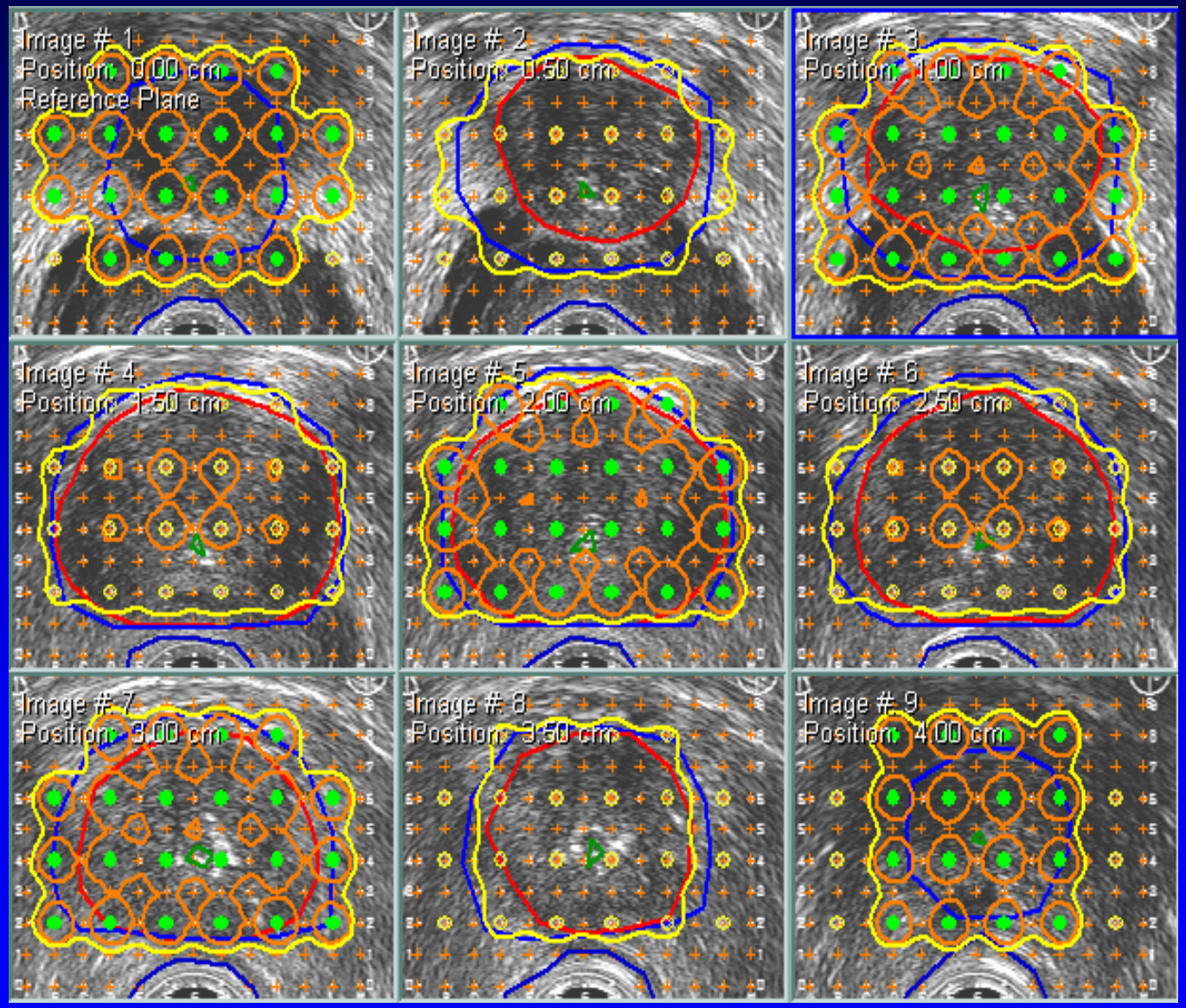
# Seed Distribution

- Uniform Loading
- Peripheral Loading
- Modified Peripheral Loading

# Uniform Loading

- Classic approach of spacing seeds 1 cm apart throughout the prostate
- Requires a higher number of lower strength seeds
  - 0.30 to 0.39 mCi/seed for $^{125}I$
  - 0.93 to 1.16 mCi/seed for $^{103}Pd$
- Relatively high doses in the center of the prostate

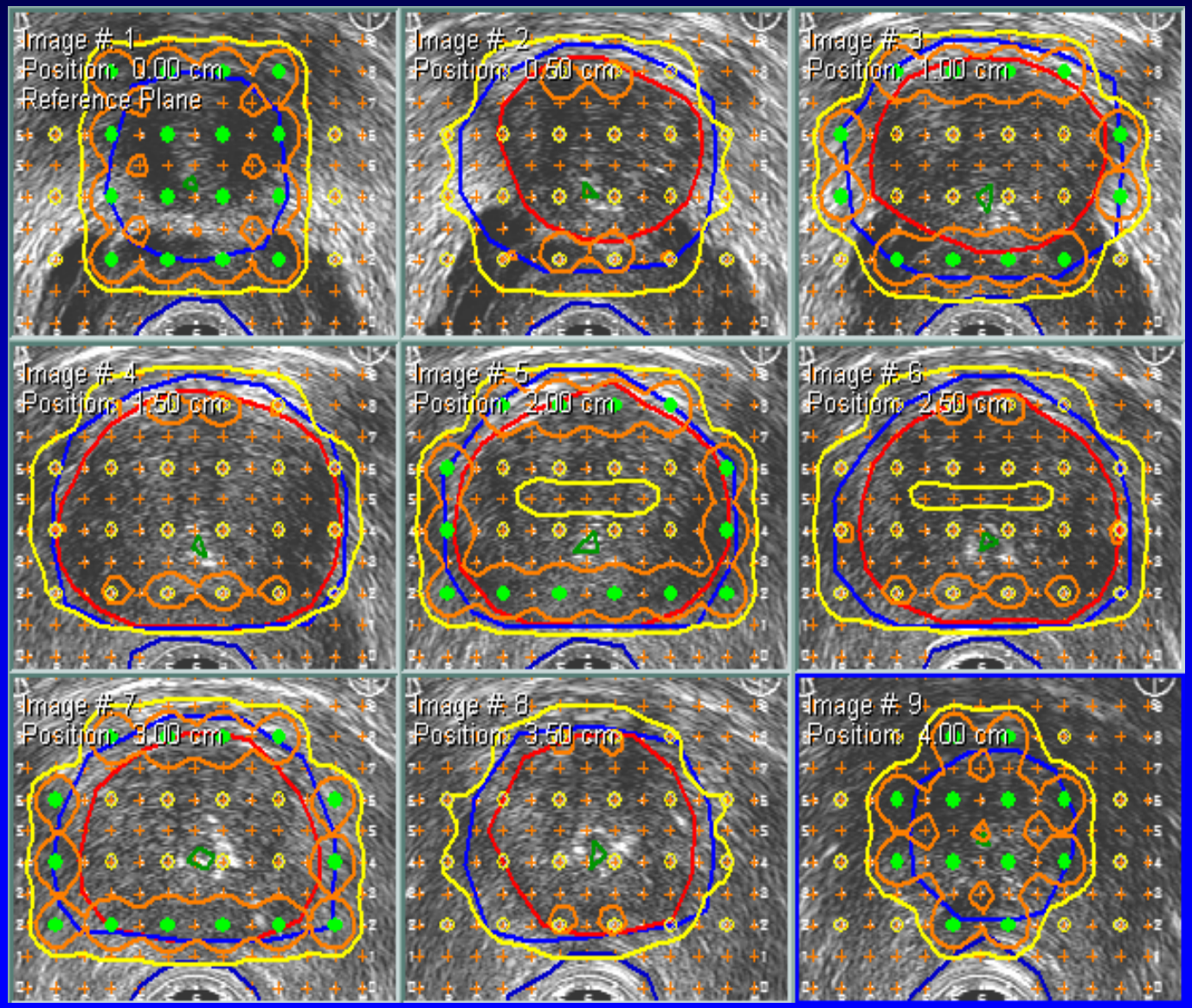
# Uniform Loading



# Peripheral Loading

- An alternative approach in which seeds are preferentially limited to the periphery of the prostate
- Requires a substantial increase in seed strength
  - 0.60 to 0.80 mCi/seed for $^{125}I$
  - 1.5 mCi/seed or higher for $^{103}Pd$
- The end result is to produce a dose minimum, instead of a dose maximum, at the location of urethra

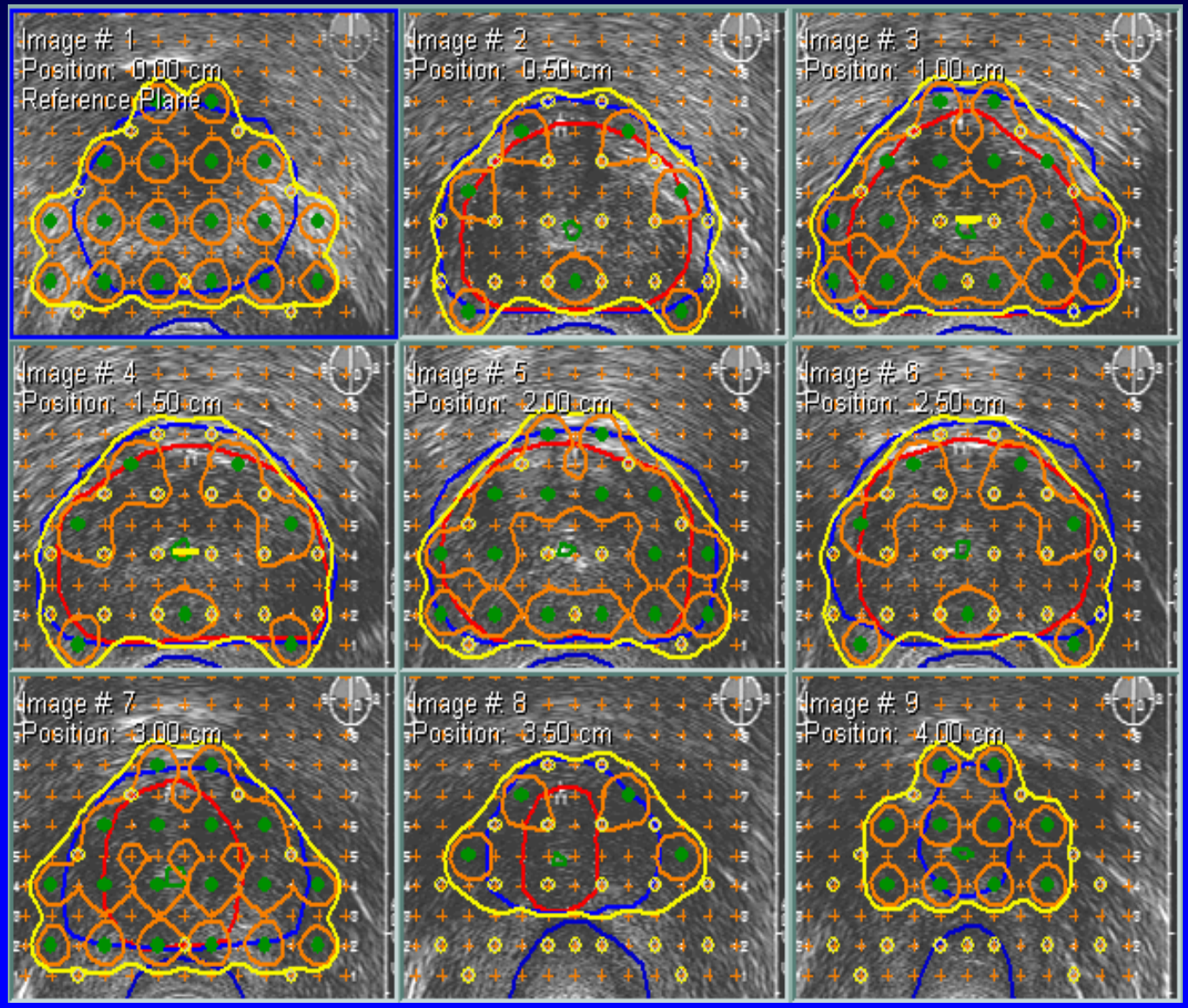
# Peripheral Loading



# Modified Peripheral Loading

- Some seeds in the central portion of a uniformly loaded implant are deleted to reduce central dose
- Strength/seed higher than with uniform loading

# Modified Peripheral Loading



# Critical Structures

- Seeds should not be placed in close proximity to urethra
- The aim should be to cover the entire prostate while keeping the dose to the rectal wall as small as possible
- Rectal dose can be high, especially if peripheral loading is employed using higher activity seeds

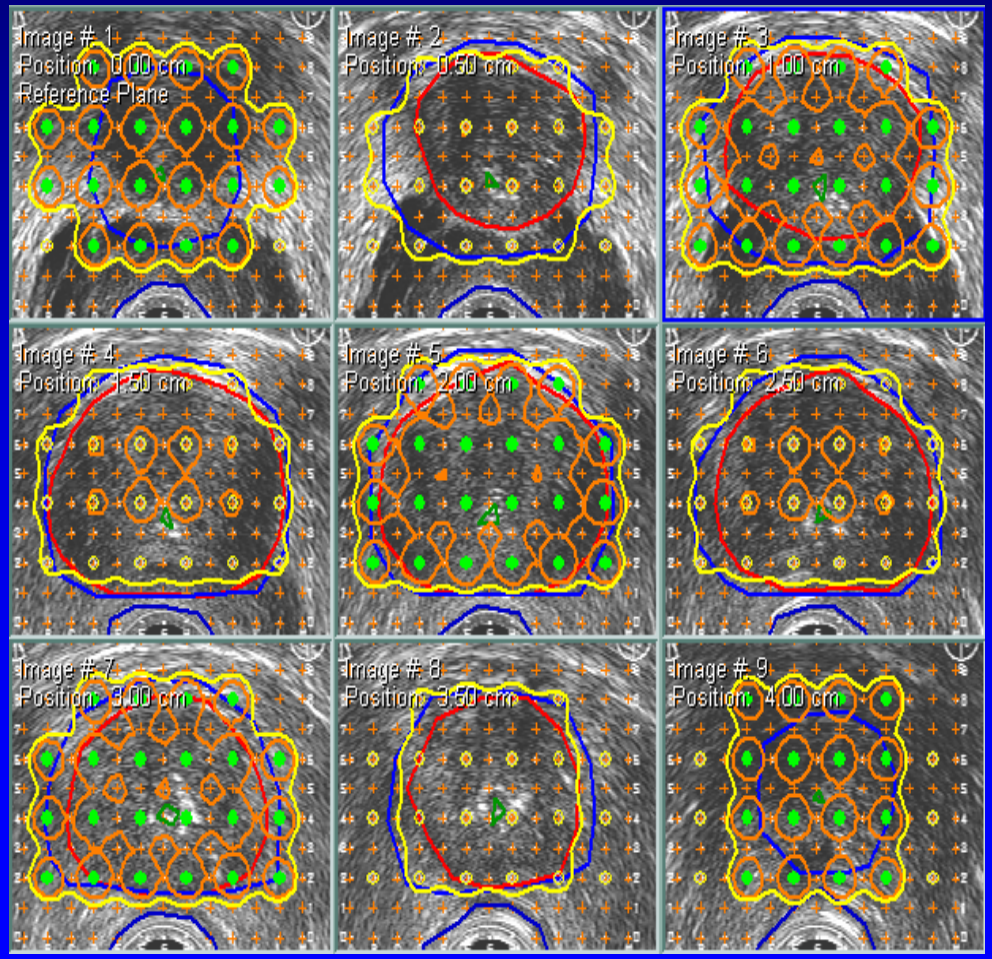
# Dose Reporting Parameters

- $D_{100}$, $D_{90}$, $D_{80}$ - dose to 100%, 90%, 80% of the target volume for dosimetric evaluation
- $V_{200}$, $V_{100}$, $V_{90}$, $V_{80}$ - (fractional) volume of the prostate target that received 200%, 100%, 90%, 80% of the prescribed minimum peripheral dose
- DVH

# Treatment Volumes
# MIR and Seattle

- GTV = Prostate(MIR) and/or P and SV(Seattle)
- PTV = GTV + 3-5mm(R,L,A) and 0-3mm post

PTV use encouraged to cover for possible extra capsular disease



# Acceptable Dose Distribution

**PTV:**

**V 100 > 95%**

**V 150 < 40%**

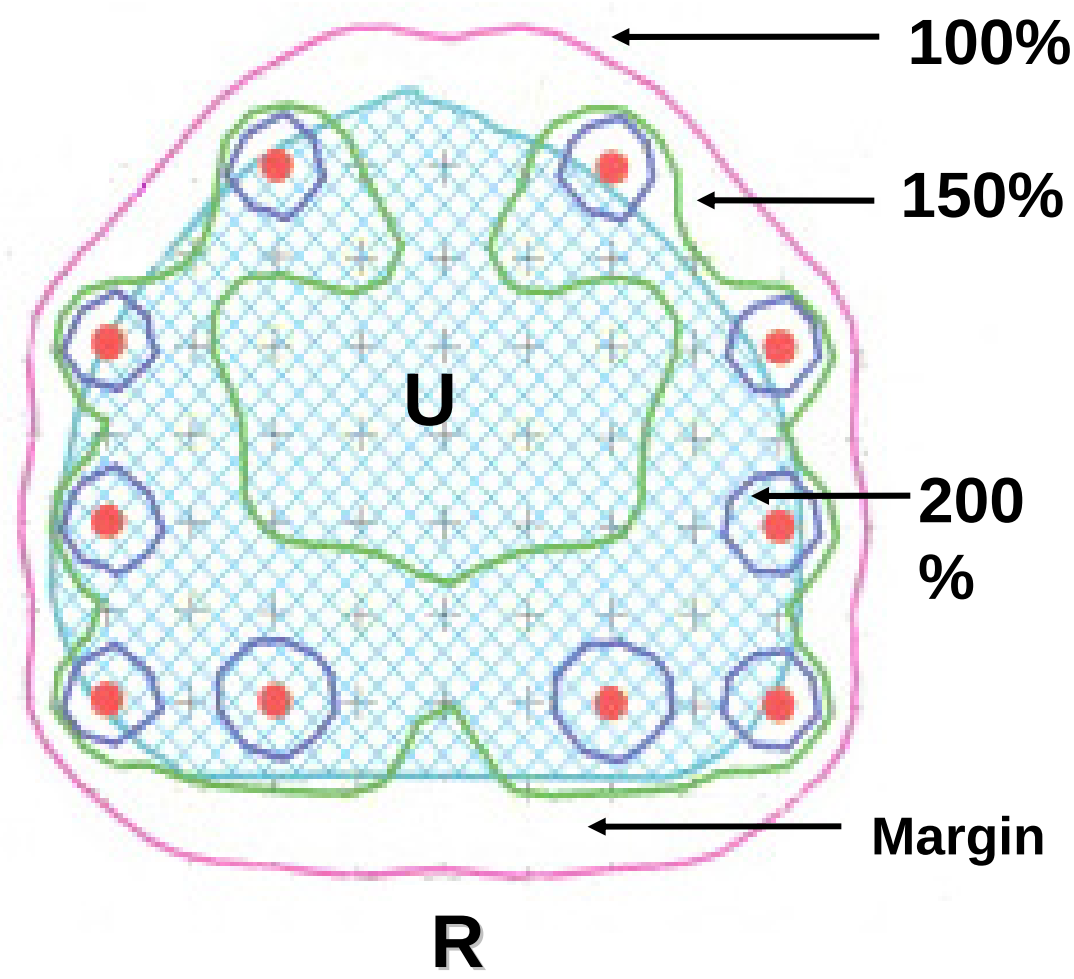
**V 200 < 20%**

**Prostate:**

**V 100 > 99%**

**Urethra Point: 100-125% KEEP<150%**

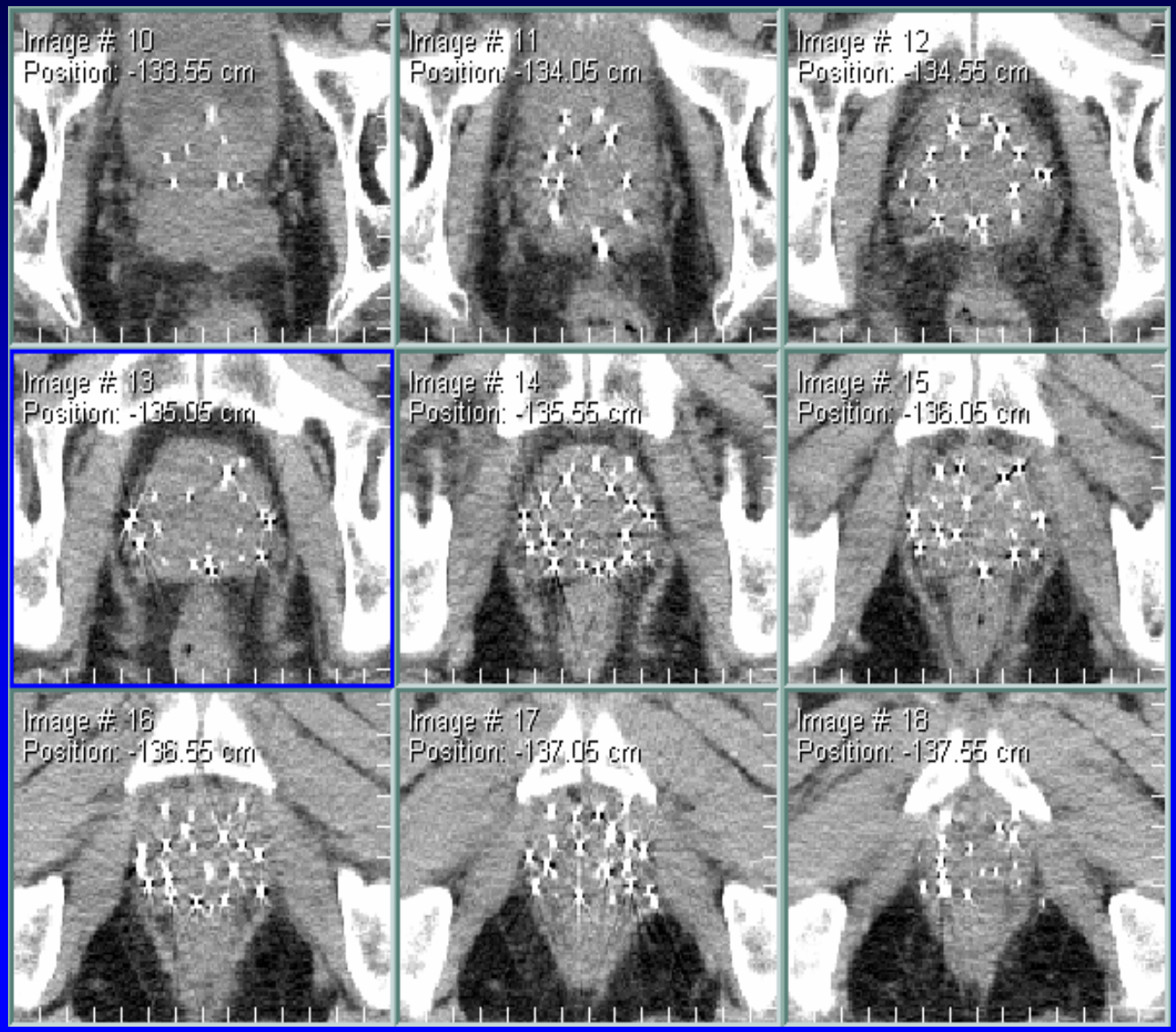
**Rectum Point: <100%**



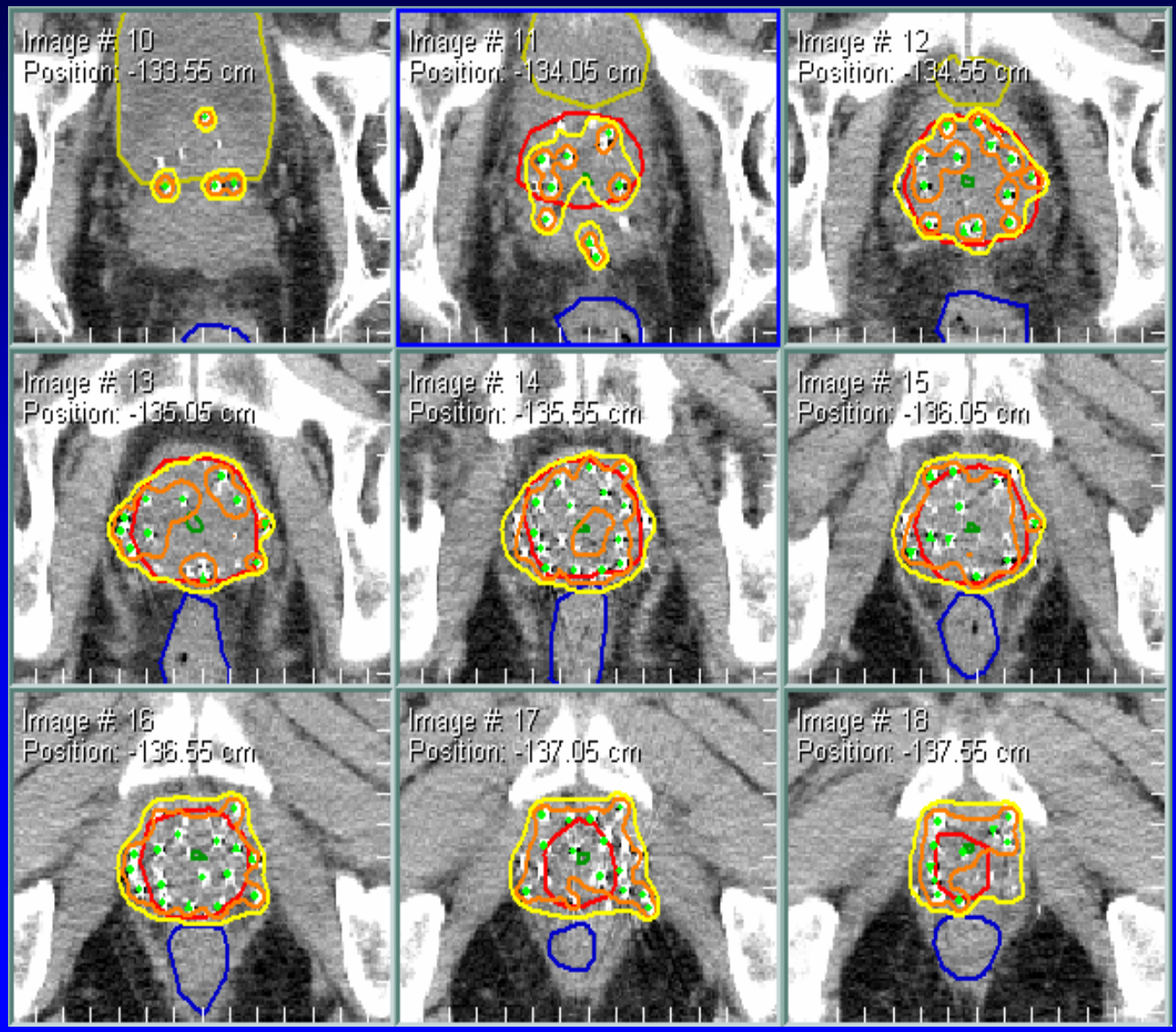
# Post-Implant Dosimetry Evaluation

- CT-Based Dosimetry:
  - Current standard of practice
  - Allows quantitative evaluation (DVH, mPD, *etc*)
  - Operator dependence can be minimized
  - Allows quick identification of inadequate implants (for example systematically missing the base of prostate in seed insertion)
  - Allows secondary dosimetric effects to be considered (anisotropy)
  - Allows inhomogeneity correction

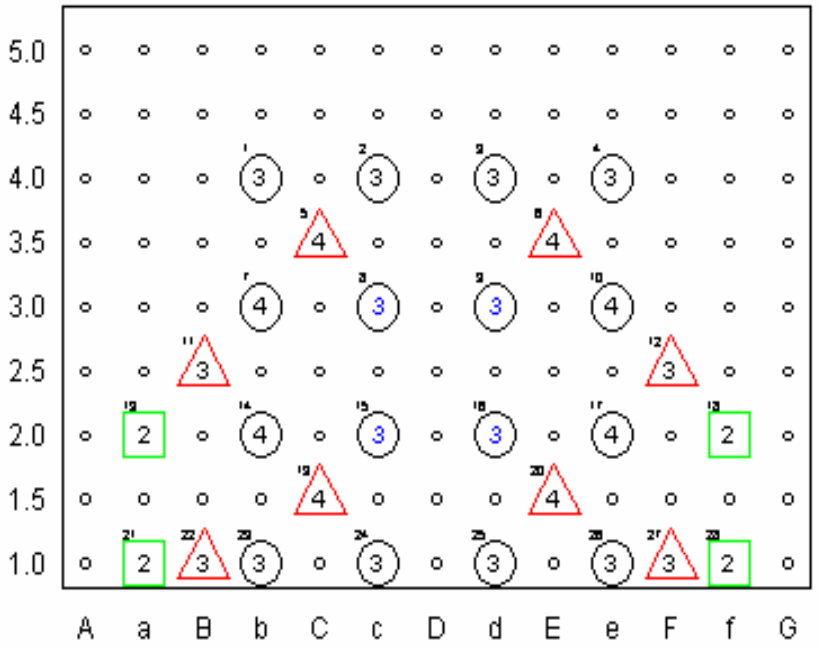
# Postimplant Dosimetry



# Postimplant Dosimetry



| Needle Number | Retraction (cm) | Hole Location | Number Seeds |
|---|---|---|---|
| 1 | 0.00 | b4.0 | 3 |
| 2 | 0.00 | c4.0 | 3 |
| 3 | 0.00 | d4.0 | 3 |
| 4 | 0.00 | e4.0 | 3 |
| 5 | 0.50 | C3.5 | 4 |
| 6 | 0.50 | E3.5 | 4 |
| 7 | 0.00 | b3.0 | 4 |
| 8 | 0.00 | c3.0 | 3 |
| 9 | 0.00 | d3.0 | 3 |
| 10 | 0.00 | e3.0 | 4 |
| 11 | 0.50 | B2.5 | 3 |
| 12 | 0.50 | F2.5 | 3 |
| 13 | 1.00 | a2.0 | 2 |
| 14 | 0.00 | b2.0 | 4 |
| 15 | 0.00 | c2.0 | 3 |
| 16 | 0.00 | d2.0 | 3 |
| 17 | 0.00 | e2.0 | 4 |
| 18 | 1.00 | f2.0 | 2 |
| 19 | 0.50 | C1.5 | 4 |
| 20 | 0.50 | E1.5 | 4 |
| 21 | 1.00 | a1.0 | 2 |
| 22 | 0.50 | B1.0 | 3 |
| 23 | 0.00 | b1.0 | 3 |
| 24 | 0.00 | c1.0 | 3 |
| 25 | 0.00 | d1.0 | 3 |
| 26 | 0.00 | e1.0 | 3 |
| 27 | 0.50 | F1.0 | 3 |
| 28 | 1.00 | f1.0 | 2 |



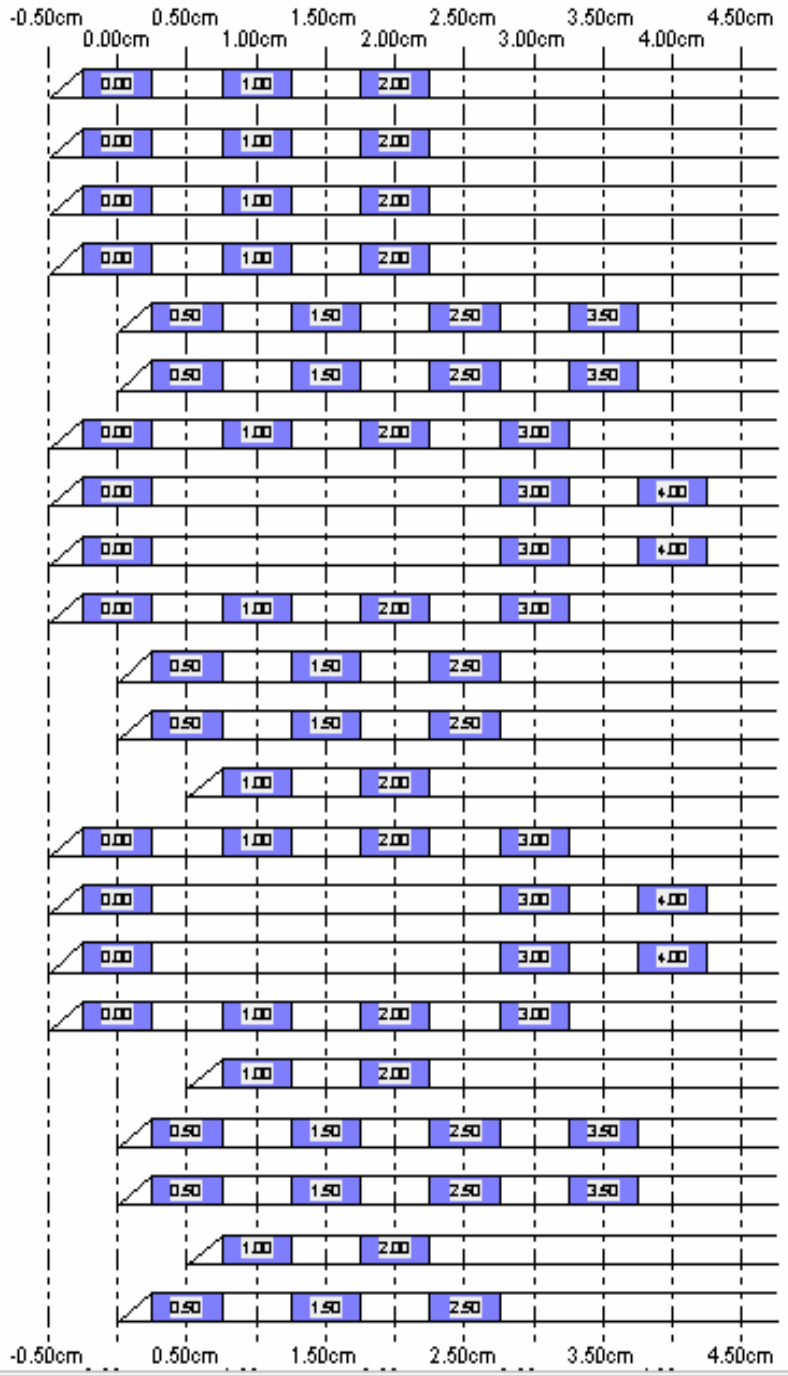

| Retraction Legend | | | | | |
|---|---|---|---|---|---|
| Plane 0 | Plane 1 | Plane 2 | Plane 3 | Plane 4 | Special |
| 0.00 cm | 0.50 cm | 1.00 cm | 1.50 cm | 2.00 cm | other |

| Number of Needles | Seeds per needle |
|---|---|
| 4 | 2 |
| 16 | 3 |
| 8 | 4 |

| Plan Summary | |
|---|---|
| Total Activity [U] | 43.74 |
| Total Activity [mCi] | 34.44 |
| Total Needles | 28 |
| Total Seeds | 88 |
| Extra Seeds | |
| **Total Seeds to Order** | |

| Needle Number | Retraction (cm) | Hole Location | Number Seeds |
|---|---|---|---|
| 1 | 0.00 | b4.0 | 3 |
| 2 | 0.00 | c4.0 | 3 |
| 3 | 0.00 | d4.0 | 3 |
| 4 | 0.00 | e4.0 | 3 |
| 5 | 0.50 | C3.5 | 4 |
| 6 | 0.50 | E3.5 | 4 |
| 7 | 0.00 | b3.0 | 4 |
| *8* | *0.00* | *c3.0* | *3* |
| *9* | *0.00* | *d3.0* | *3* |
| 10 | 0.00 | e3.0 | 4 |
| 11 | 0.50 | B2.5 | 3 |
| 12 | 0.50 | F2.5 | 3 |
| 13 | 1.00 | a2.0 | 2 |
| 14 | 0.00 | b2.0 | 4 |
| *15* | *0.00* | *c2.0* | *3* |
| *16* | *0.00* | *d2.0* | *3* |
| 17 | 0.00 | e2.0 | 4 |
| 18 | 1.00 | f2.0 | 2 |
| 19 | 0.50 | C1.5 | 4 |
| 20 | 0.50 | E1.5 | 4 |
| 21 | 1.00 | a1.0 | 2 |
| 22 | 0.50 | B1.0 | 3 |

= Special loading



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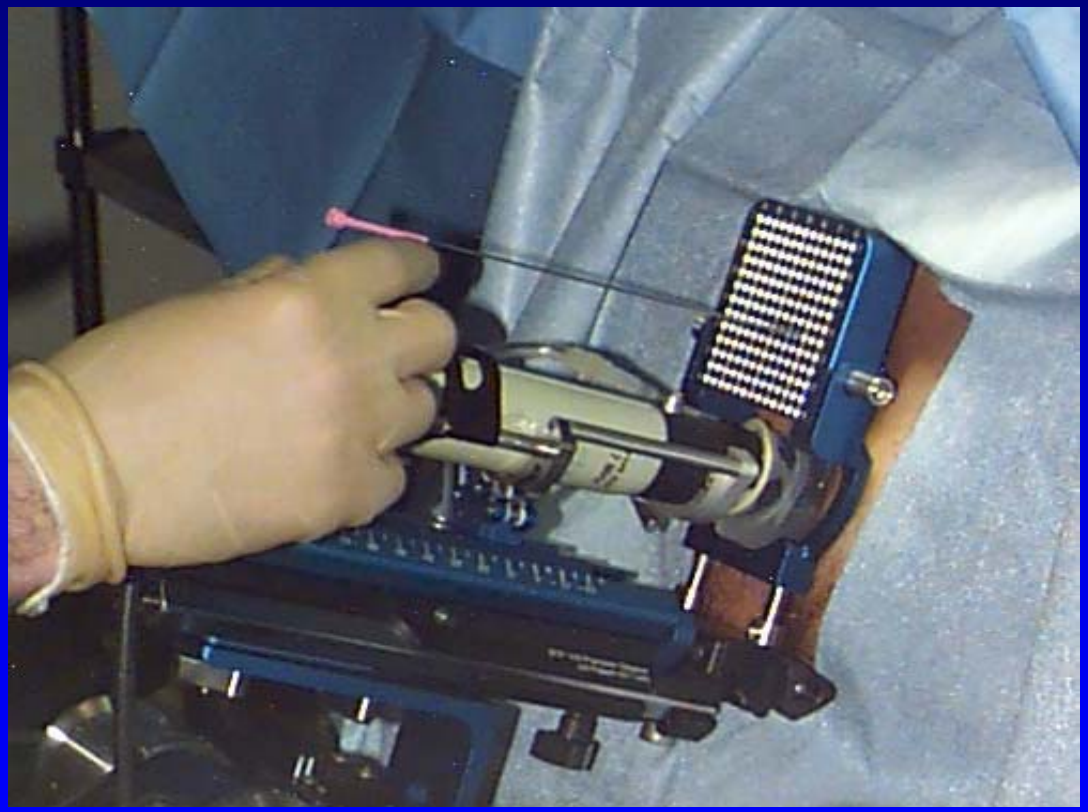
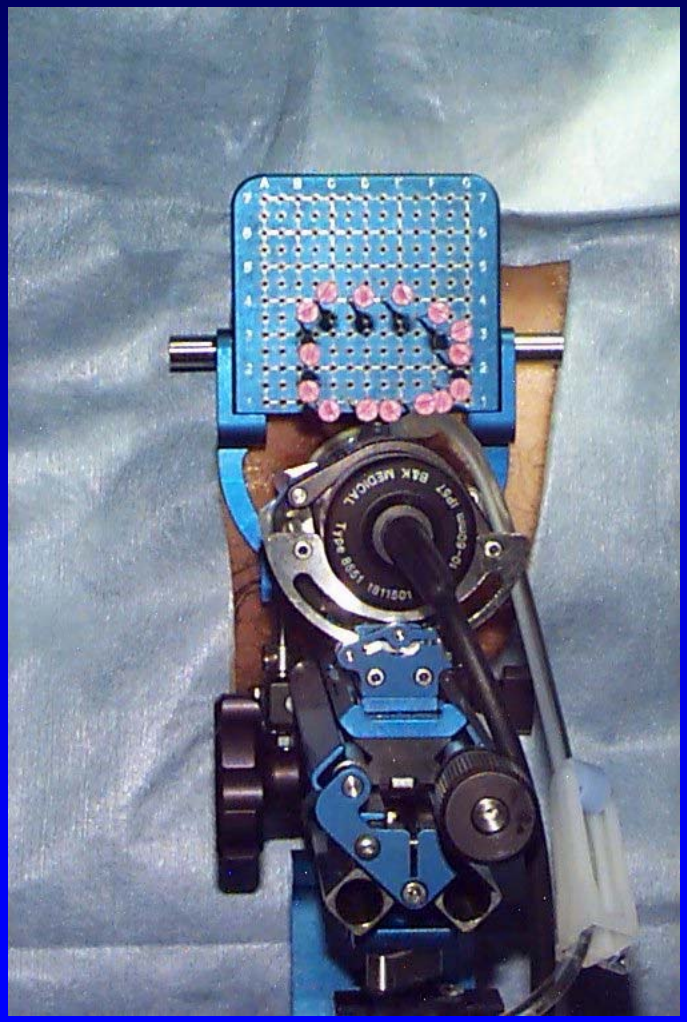


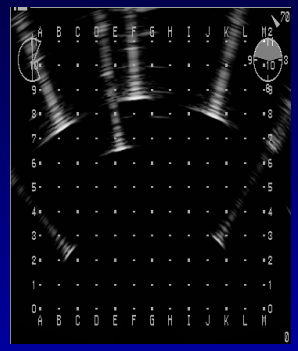


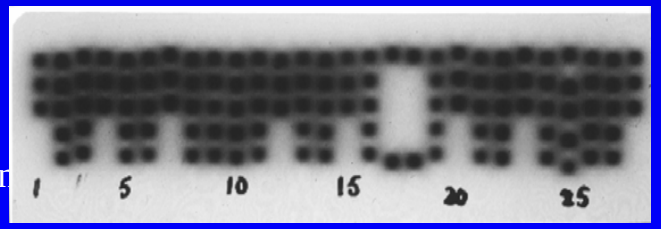
# Sources of Dosimetric Uncertainties

- Seed displacement
  - source-to-source spacing differences
  - needle placement errors
  - seed splaying
- Prostate edema postimplantation
- Difficulty in defining the target volume based on CT
- Patient positioning reproducibility (volume study and operating room)
  - ONLY BENEFIT OF ONLINE PLANNING
- Prostate volume changes between volume study and implant
  - -especially important in the case of hormones therapy
- Prostate movement during implantation, even with stabilizing needles in place

# Pre Plan-Prostate LDR QA

- Treatment Planning System QA
  - Study data input geometric accuracy
  - Accuracy of Dosimetric Data of Sources
  - Dose Calculation Accuracy against manual TG43
    - Single and dual source configurations
- QA on instrumentation for Data Acquisition and implantation
  - Ultrasound QA
    - Transverse Positional Accuracy
    - Saggital Positional Accuracy
    - Image Quality (TGC) and effects on positional accuracy
  - Appropriate template selection
- Plan Evaluation QA
  - Appropriate Data set used and registered to template
  - Appropriate Prescription and source selection
  - Appropriate needle, source and Dose Distributions based on guidelines
- Plan Loading QA
  - Source Strength Verification
    - NIST Calibrated source to determine Well Chamber Calibration Factors
    - Assay 10% of sources
  - Source Tracking During sterilization
  - Needle Loading
    - Autoradiograph of needles compared against plan data
    - Procedures for Source Accountability storage and recordkeepin
- Post Implantation QA
  - Seed Accountability
  - Radiation Safety : Patient and Area Survey





# HDR Prostate Brachytherapy

# HDR Prostate - Seattle

- Mate *et al*, IJROBP 1998 41(3): 525-533
  - HDR brachytherapy at 3.0 Gy – 4.0 Gy x 4, followed by 50.4 Gy external beam treatments
  - Ultrasound guided-needle insertion
  - CT-based optimization of HDR dwell times
    - CT gantry tilted to be orthogonal to needle paths
  - Peripherally weighted dose distribution
    - Less than 120% dose to urethra

# HDR Prostate – William Beaumont Hospital

- HDR boost treatment
  - Kini *et al*, IJROBP 1999 43(3): 571-578
  - 50 Gy external beam
  - 2 factions HDR brachytherapy at 9.5 Gy/fx given at 1st and 3rd week of external beam treatments
- HDR alone treatment
  - Martinez *et al*, IJROBP 2001 49(1): 61-69
  - 36 Gy in 4 fractions
  - BID in two days
  - Considered to be equivalent to 76.4 Gy external beam dose