

# Brachytherapy Planning and Quality Assurance

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- ◆ Classical implant systems
- ◆ Most common clinical applications and modern dosimetry methods
- ◆ Quality assurance

# Classical implant systems

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- ◆ Manchester (Paterson-Parker)
- ◆ Quimby
- ◆ Paris
- ◆ With the advent of computerized treatment planning these are little used today with the possible exception of the Manchester System for cervix cancer treatments

# The Manchester System

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- ◆ Aims at producing as uniform a dose as possible within the treatment volume
- ◆ Sources of variable strength used
- ◆ Rules provided for placement of sources of different strengths
- ◆ Tables provided to determine treatment time
- ◆ Originally devised for Ra-226 but later extended to Cs-137

# The Quimby System

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- ◆ Developed by Edith Quimby at Memorial Hospital, New York
- ◆ Required uniform distribution of same strength sources
- ◆ Produced non-uniform dose distributions
- ◆ Tables provided to determine treatment times
- ◆ Originally devised for Ra-226 and Rn-222 seeds but later extended to Ir-192 and I-125

# The Paris System

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- ◆ Designed for Ir-192 wires but later extended to Ir-192 seeds in strands
- ◆ The sources should be equidistant arranged in patterns (squares or triangles)
- ◆ The dose (called the “basal dose”) is the arithmetic mean of the minimum dose rates located half-way between the sources in the well defined patterns
- ◆ Tables provided to determine treatment times

# Most common clinical applications

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- ◆ Gynecological treatments
- ◆ Prostate implants
- ◆ Breast implants

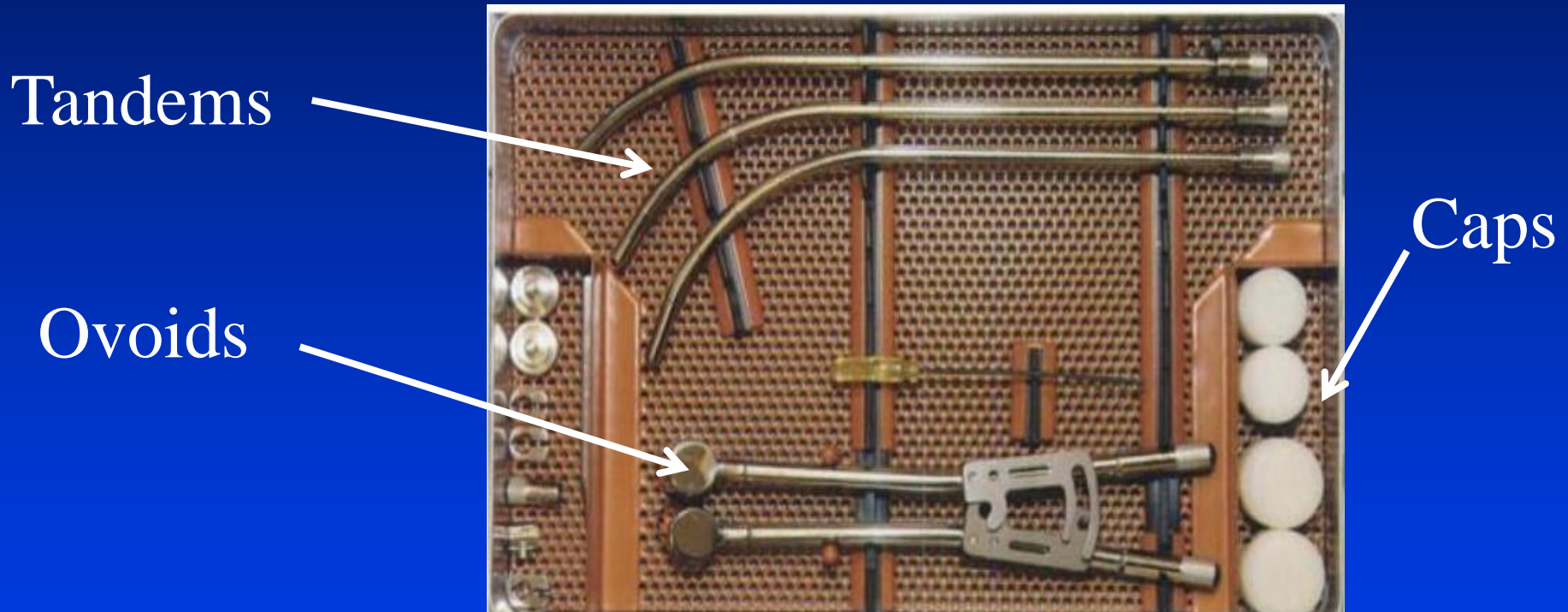
# Gynecological brachytherapy

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- ◆ Uterine cervix
- ◆ Vagina
- ◆ Endometrium

# Cervix cancer: Manchester System Fletcher-Suit tandem and ovoids

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Tandem and ovoids are inserted into the uterine canal and vagina, respectively



# Some newer cervix cancer applicators



MANCHESTER



FLETCHER-SUIT



TANDEM-RING



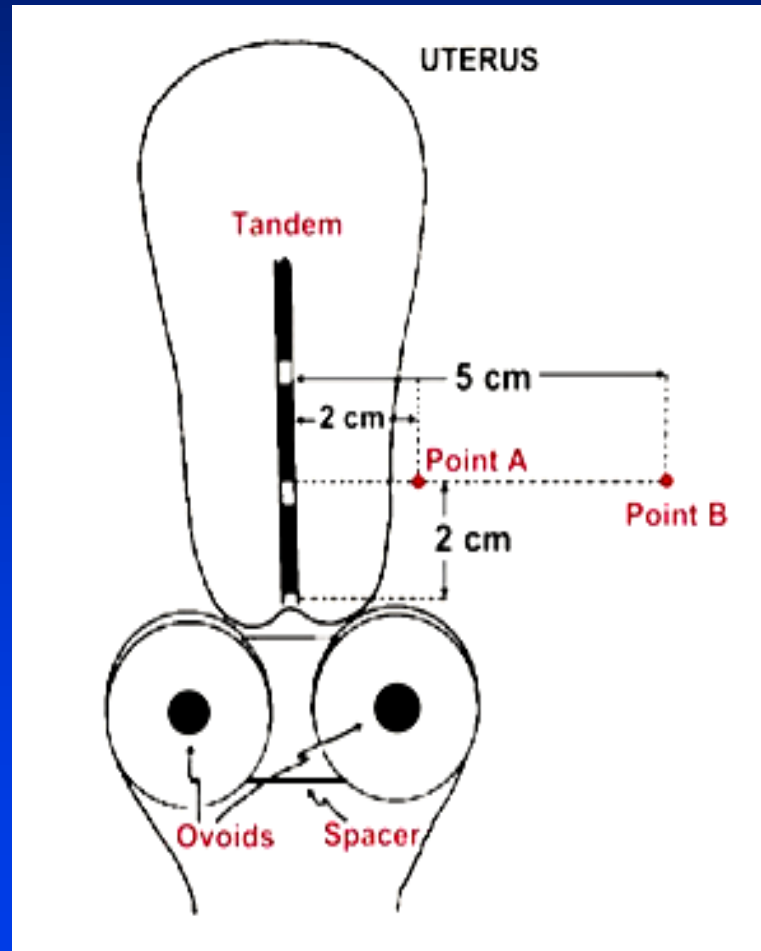
TANDEM-RING  
CT/MR  
COMPATIBLE



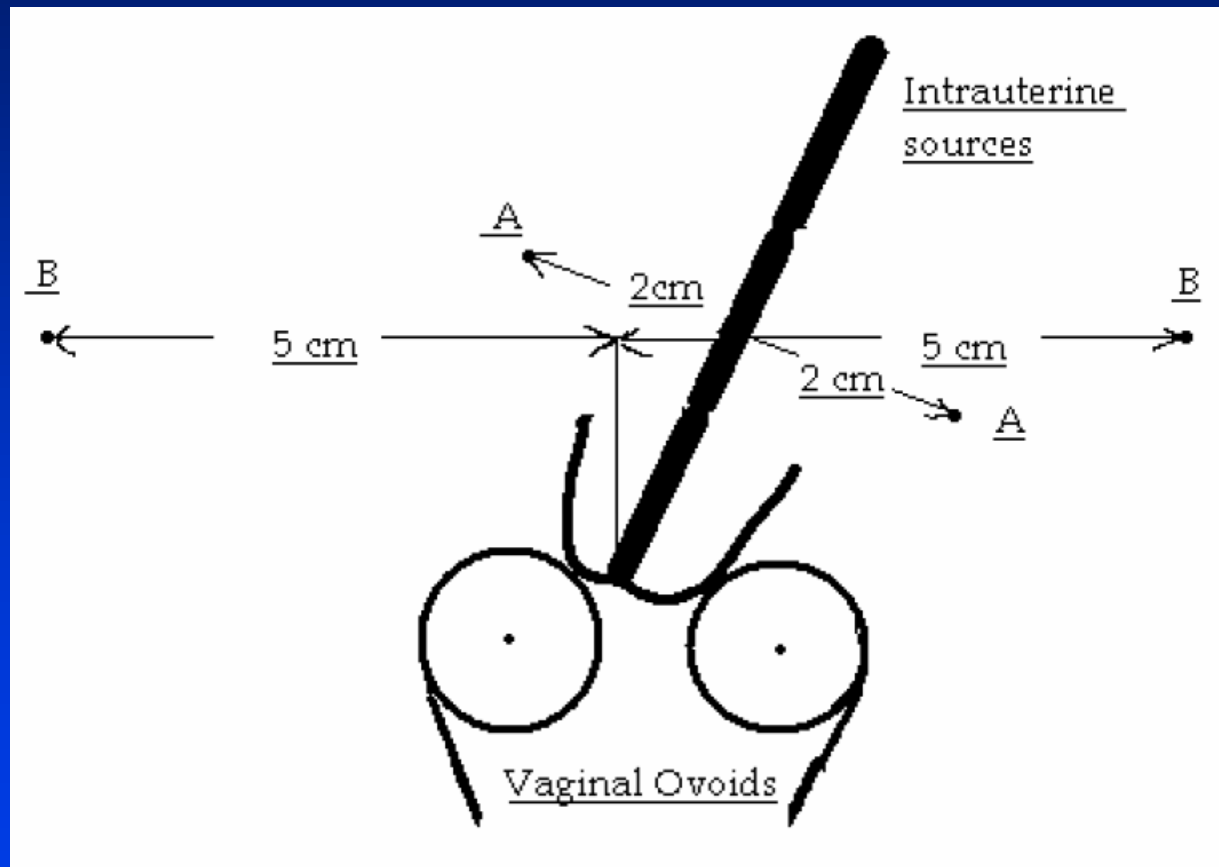
HENSCHKE

# Manchester System: doses were calculated at two points, A and B

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# Off-axis tandem



## The American Brachytherapy Society recommended Point A doses with HDR for early disease

EBRT (Gy) @ 1.8 Gy/fraction	No. of HDR fractions	HDR dose/ fraction
20	6	7.5
20	7	6.5
20	8	6.0
45	5	6.0
45	6	5.3

*Abbreviations:* EBRT = external beam radiation therapy; HDR = high-dose-rate; LDR = low-dose-rate.

## The American Brachytherapy Society recommended Point A doses with HDR for advanced disease

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EBRT (Gy) @ 1.8 Gy/fraction	No. of HDR fractions	HDR dose/ fraction
45	5	6.5
45	6	5.8
50.4	4	7.0
50.4	5	6.0
50.4	6	5.3

*Abbreviations:* EBRT = external beam radiation therapy; HDR = high-dose-rate; LDR = low-dose-rate.

# ICRU Report 89

Volume 13 No 1–2 2013

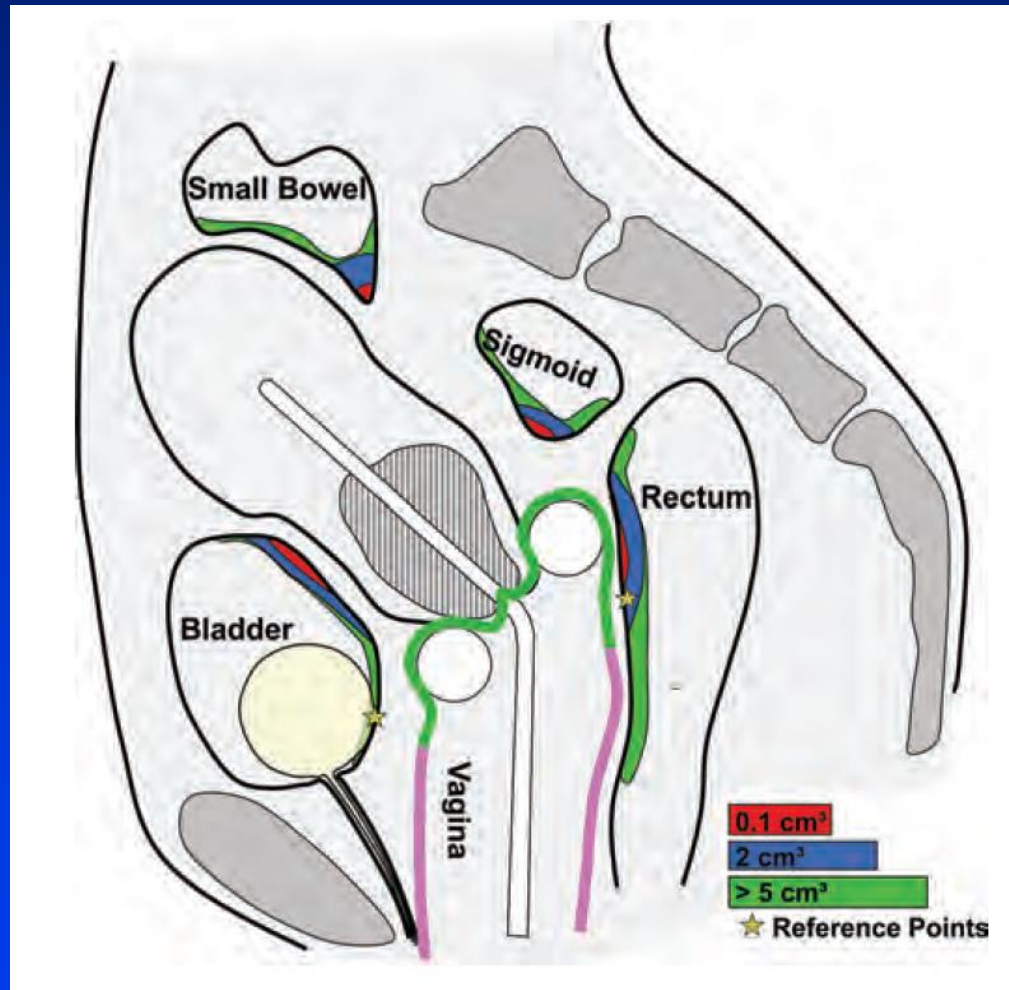
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## Journal of the ICRU

### ICRU REPORT 89

**Prescribing, Recording, and Reporting  
Brachytherapy for Cancer of the Cervix**

# Tissues imaged and planned in 3-D



# ICRU 89 recommended prescribing, recording, and reporting levels

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- ◆ Level 1: minimum requirements that should be followed by all centers, for all patients, and represents the minimum standard of treatment
- ◆ Level 2: advanced standards of dose planning and treatment that allows a more comprehensive and standardized exchange of information between centers and based on a more complete set of parameters



# Example: Level 1 dose and delivery reporting for cervix brachytherapy

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Dose reporting:

- TRAK
- Point A dose
- Recto-vaginal reference-point dose
- $D_{0.1\text{cm}^3}$  and  $D_{2\text{cm}^3}$  for the bladder and rectum

Dose delivery pattern:

- Absorbed-dose rate/dose per fraction
- Number of fractions
- Time between fractions
- (Pulse number, size, time, if PDR)
- Overall treatment time
- Total EQD2 dose

Source and dose calculation:

- Radionuclide and source model
- Source strength
- Dose-calculation algorithm

# Level 2: additional dose and delivery reporting

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Dose reporting for defined volumes:

- $D_{98\%}$ ,  $D_{90\%}$ ,  $D_{50\%}$  for the CTV<sub>HR</sub>
- ( $D_{98\%}$ ,  $D_{90\%}$  for the CTV<sub>IR</sub> if used for prescription)
- $D_{98\%}$  for GTV<sub>res</sub>
- $D_{98\%}$  for pathological lymph nodes

Dose reporting OARs:

- Bladder reference point dose
- $D_{0.1\text{cm}^3}$ ,  $D_{2\text{cm}^3}$  for sigmoid<sup>a</sup>
- $D_{2\text{cm}^3}$  bowel
- Intermediate- and low-dose parameters in bladder, rectum, sigmoid, bowel  
(e.g.,  $V_{15\text{ Gy}}$ ,  $V_{25\text{ Gy}}$ ,  $V_{35\text{ Gy}}$ ,  $V_{45\text{ Gy}}$  or  $D_{98\%}$ ,  $D_{50\%}$ ,  $D_2\%$ )
- Vaginal point doses at level of sources (lateral at 5 mm)<sup>a</sup>
- Lower- and mid-vagina doses (PIBS, PIBS  $\pm$  2 cm)<sup>a</sup>

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<sup>a</sup>Surrogate points for volumetric vaginal dose assessment.

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# Vaginal brachytherapy

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- ◆ Can be treated low dose rate although, nowadays, most commonly, high dose rate
- ◆ Usually use cylindrical applicator of appropriate diameter
- ◆ Stepping pattern designed to give uniform dose around the applicator at selected depth in tissue, typically 0.5 cm

# Intracavitary applicators used for vaginal brachytherapy

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Use the largest diameter applicator that is comfortable for the patient so as to produce the best depth dose

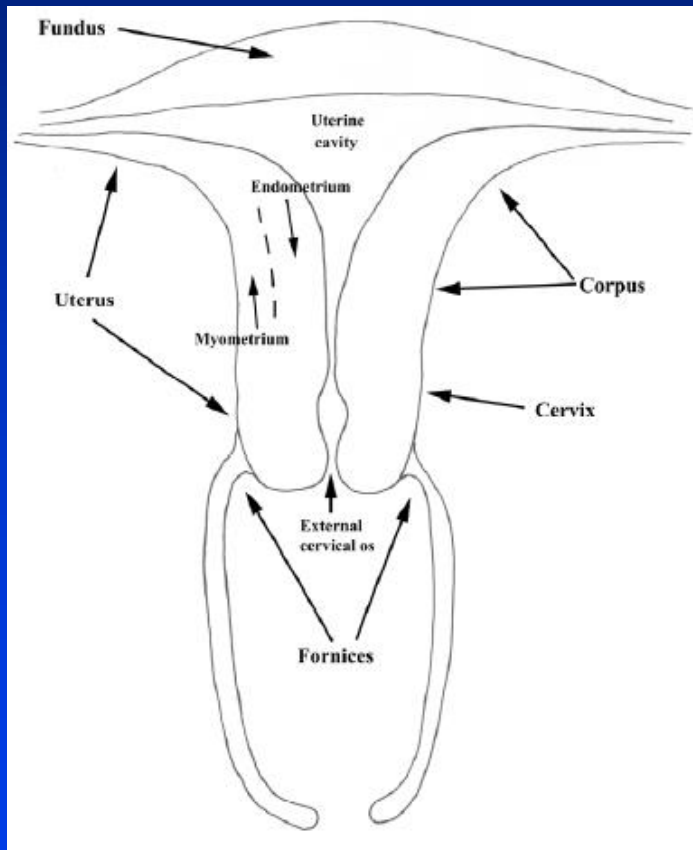
# Endometrial brachytherapy

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- ◆ Can be treated low dose rate although, nowadays, most commonly, high dose rate
- ◆ For post-hysterectomy patients
  - *treat the vagina (vaginal cuff brachytherapy)*
- ◆ For other patients
  - *treat the vagina plus the uterine cavity with special applicator*

# Endometrial brachytherapy

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# Typical dose distribution

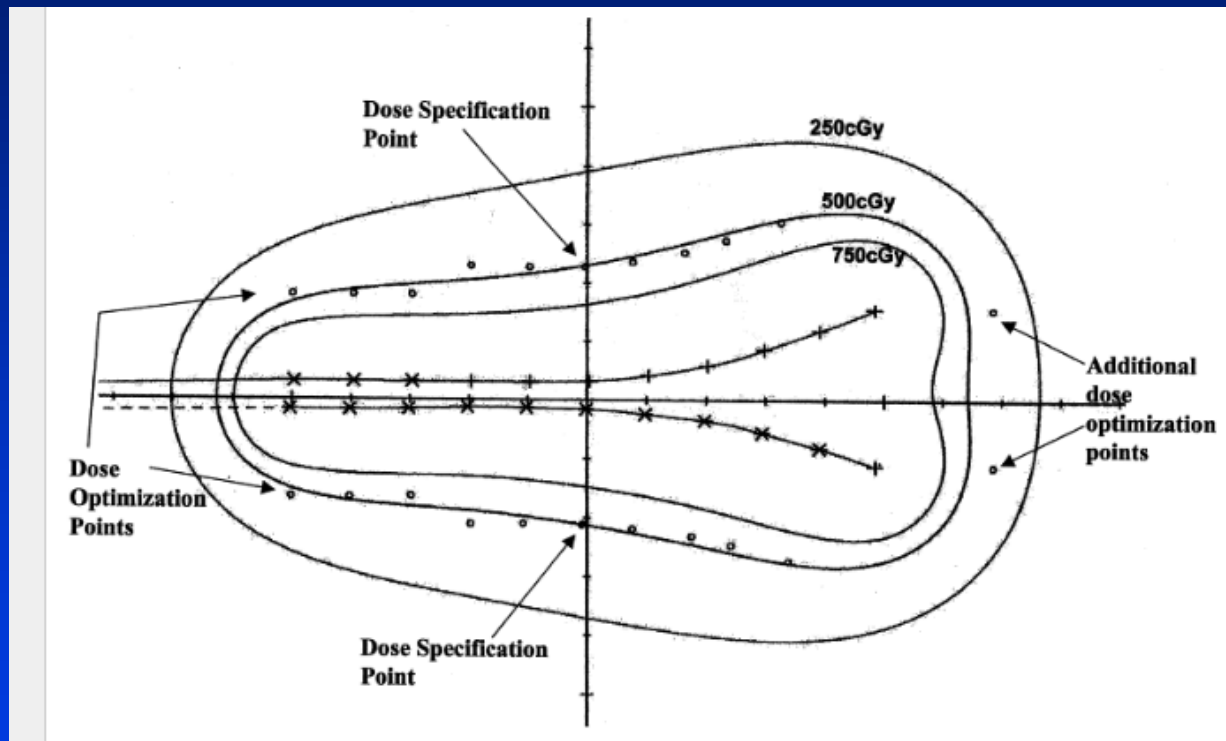


Fig. 4

Examples of isodose distribution of an optimized treatment plan for treating inoperable primary endometrial cancer with a Y-shaped applicator.

# ABS HDR dose guidelines (if no added external beam)

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No. of HDR fractions	HDR dose/fx
4	8.5 Gy at 2 cm
5	7.3 Gy at 2 cm
6	6.4 Gy at 2 cm
7	5.7 Gy at 2 cm

HDR doses are specified at 2 cm from the  
midpoint of intrauterine sources



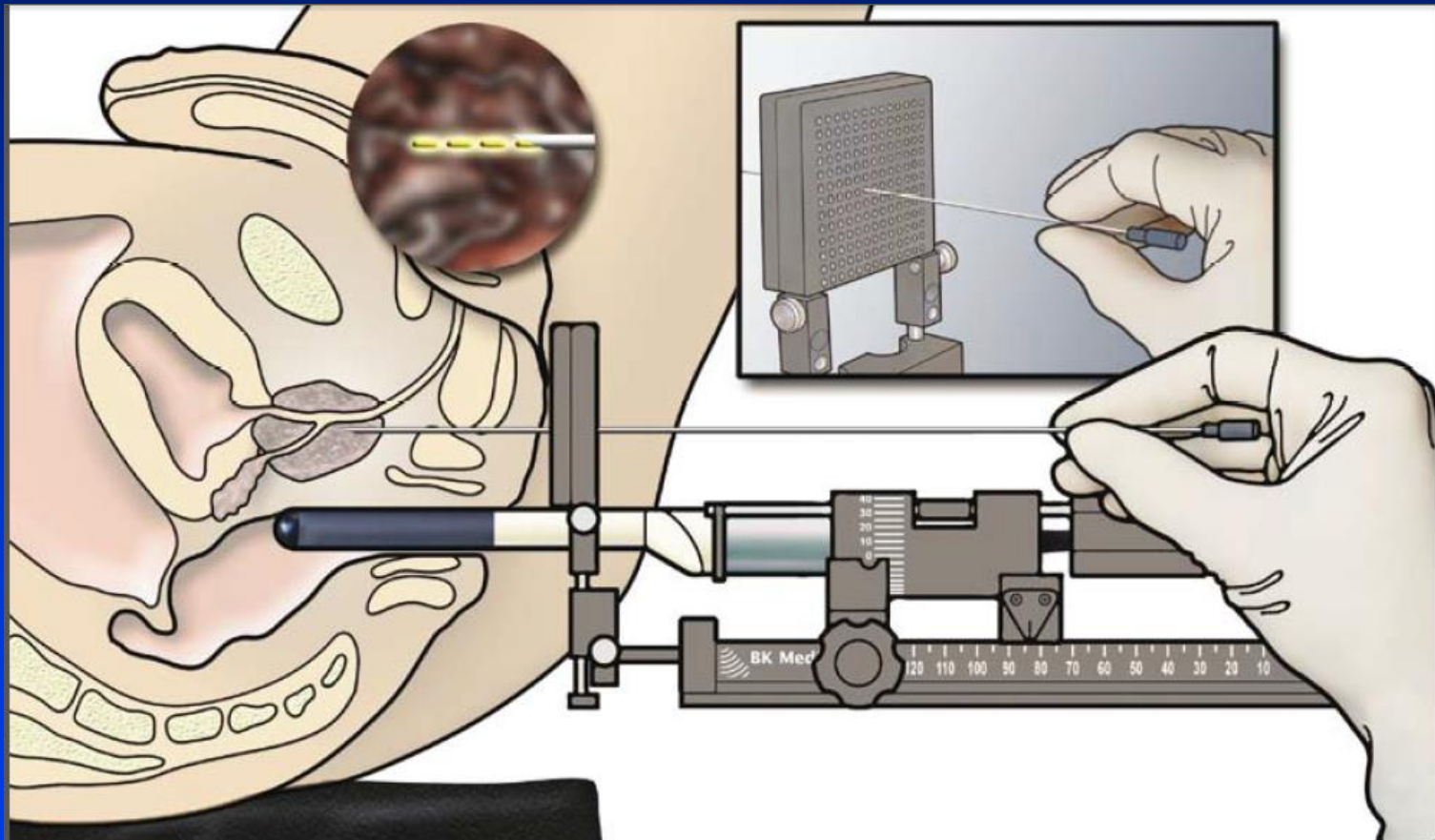
# Prostate brachytherapy

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- ◆ There are two major alternatives:
- ◆ Permanent implants with either I-125 or Pd-103 seeds
- ◆ Temporary high dose rate implants with Ir-192 or electronic brachytherapy

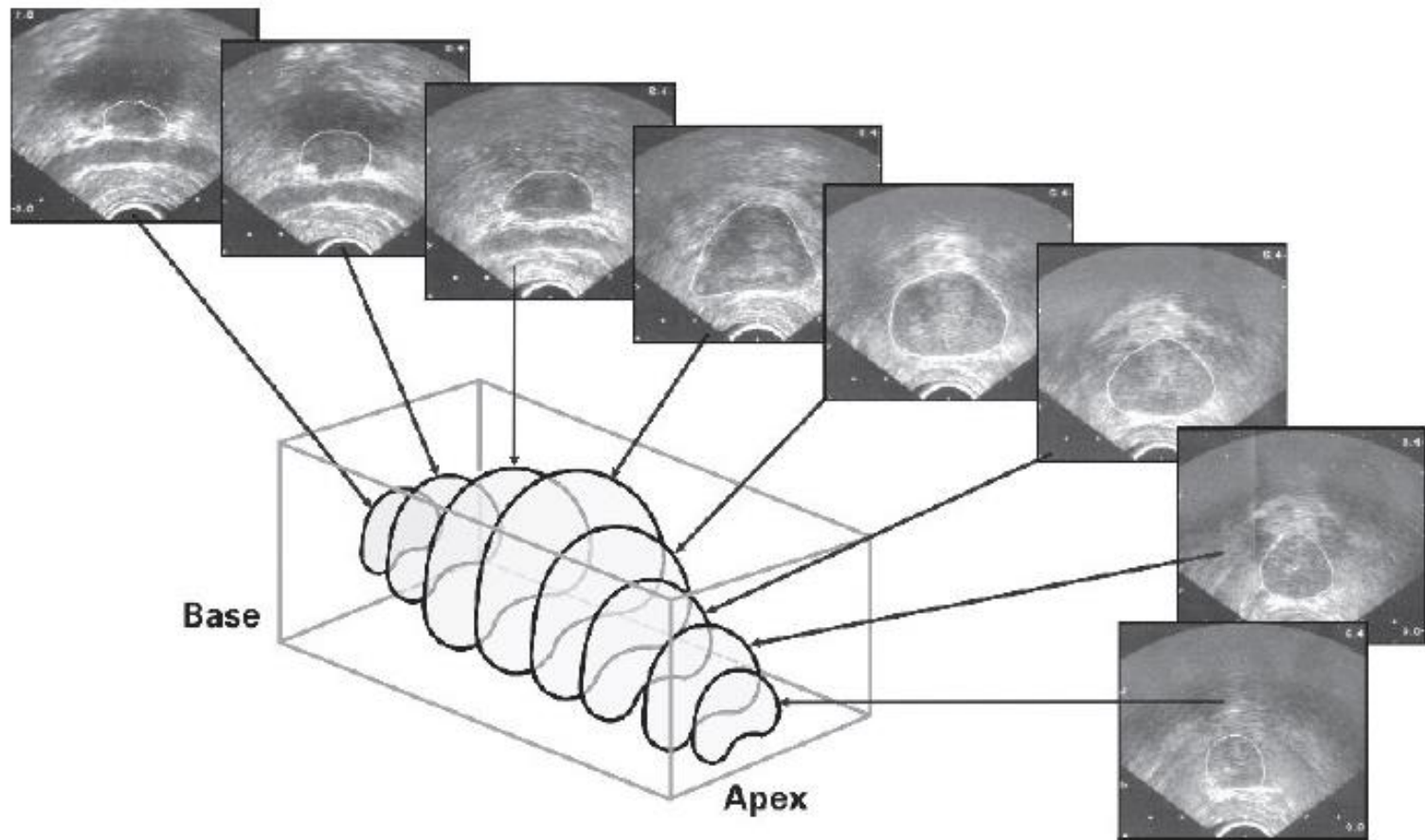
# Ultrasound-Guided Transperineal Prostate Brachytherapy

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# Series of transrectal ultrasound (TRUS) images

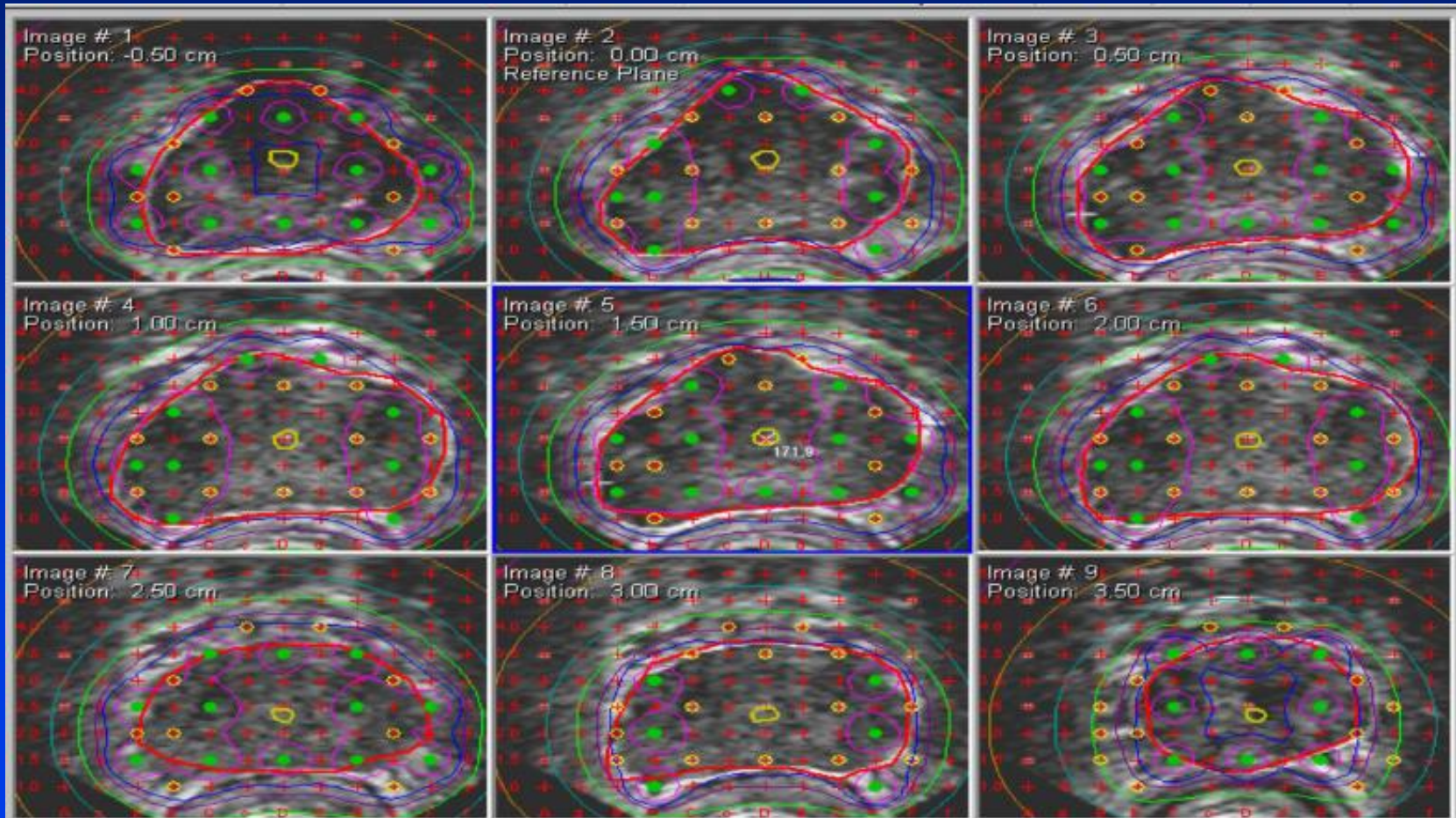
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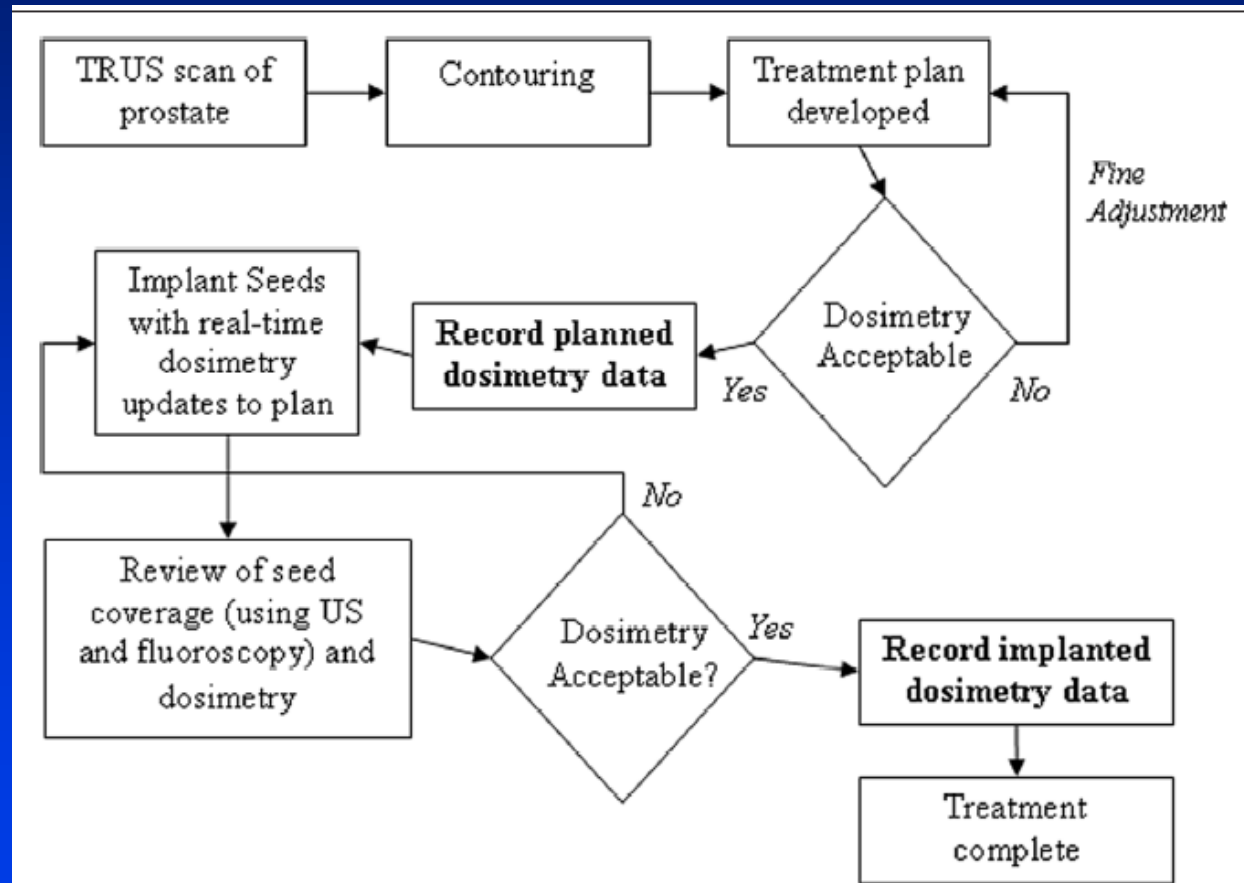
# TRUS images used for planning

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# Schematic of the planning and treatment process for permanent implants

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# Sources used for permanent prostate implants

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- ◆ With I-125 (half life 60 days) the dose is delivered over many months
- ◆ With Pd-103 (half life 17 days) the dose is delivered over many weeks
- ◆ The total dose delivered to infinity is calculated by the formula:

$$\text{Total dose} = (\text{initial dose rate}) \times (\text{mean life})$$

# Examples

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1. If the initial dose rate for an I-125 implant is 7 cGy/h, then the total dose to complete decay is:

$$7 \times 1.44 \times 60 \times 24 = 14,515 \text{ cGy}$$

i.e. about **145 Gy**

2. If the initial dose rate for a Pd-103 implant is 21 cGy/h, then the total dose to complete decay is:

$$21 \times 1.44 \times 17 \times 24 = 12,338 \text{ cGy}$$

i.e. about **123 Gy**

# American Brachytherapy Society recommended total doses for prostate treatments

## Prescription doses to the planning target volume

$^{125}\text{I}$

Monotherapy	140–160 Gy
Combination	
EBRT	41.4–50.4 Gy (1.8 Gy/d <sup>a</sup> )
PPB dose	108–110 Gy

$^{103}\text{Pd}$

Monotherapy	110–125 Gy
Combination	
EBRT	41.4–50.4 Gy (1.8 Gy/d <sup>a</sup> )
PPB dose	90–100 Gy

PPB = permanent prostate brachytherapy; EBRT = external beam radiation therapy.

<sup>a</sup> 2 Gy/d also acceptable.



# ABS Prostate TG suggested doses for HDR prostate treatments

For monotherapy either

10.5 Gy x 3 fractions

or 8.5-9.5 Gy x 4 fractions

or 6.0-7.5 Gy x 6 fractions

# ABS Prostate TG suggested doses for HDR prostate treatments

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As a boost in combination with 36-40 Gy EBRT  
15 Gy x 1 fraction

or, with 40-50 Gy EBRT either  
9.5-10.5 Gy x 2 fractions  
or 5.5-7.5 Gy x 3 fractions  
or 4.0-6.0 Gy x 4 fractions

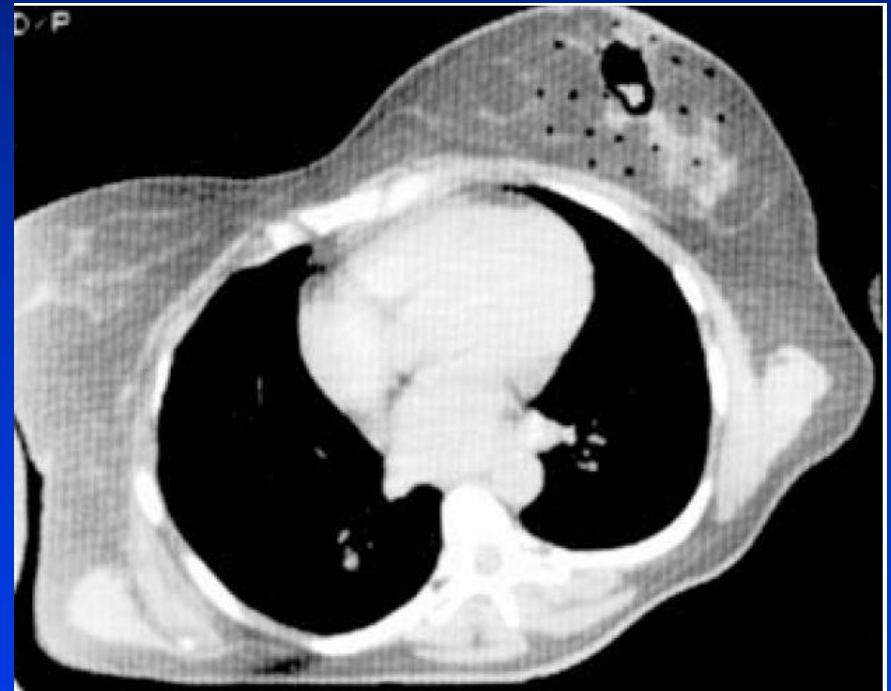
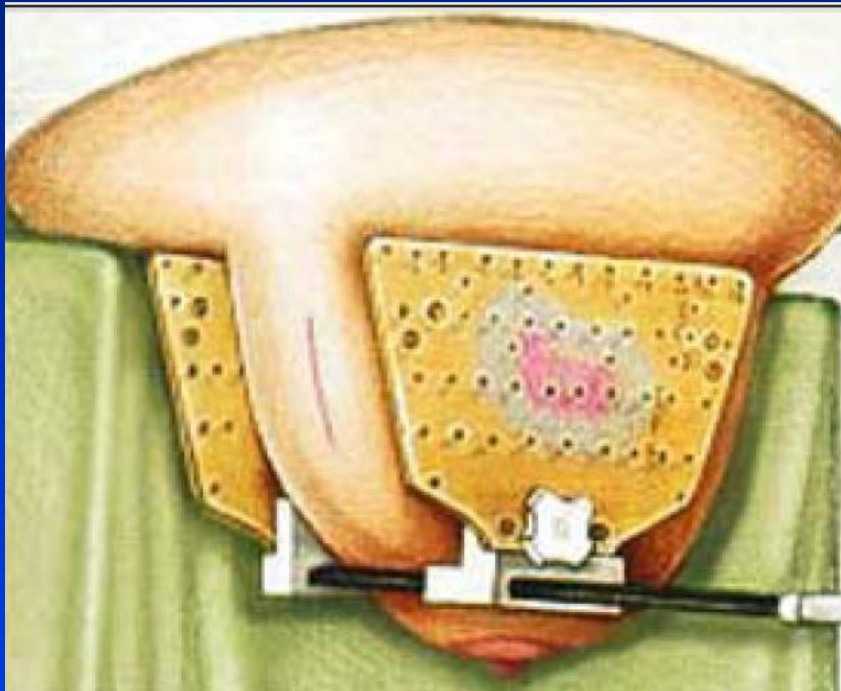
# Accelerated Partial Breast Irradiation (APBI)

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- ◆ Brachytherapy for breast cancer can be used after lumpectomy either as a boost to external beam therapy or as monotherapy
- ◆ Two major techniques are applied
  1. needles are inserted interstitially into the breast using a template with either LDR or HDR, or
  2. an applicator is inserted at the time of surgery into the cavity and expanded so as to make the cavity roughly spherical and an HDR source is stepped through the applicator

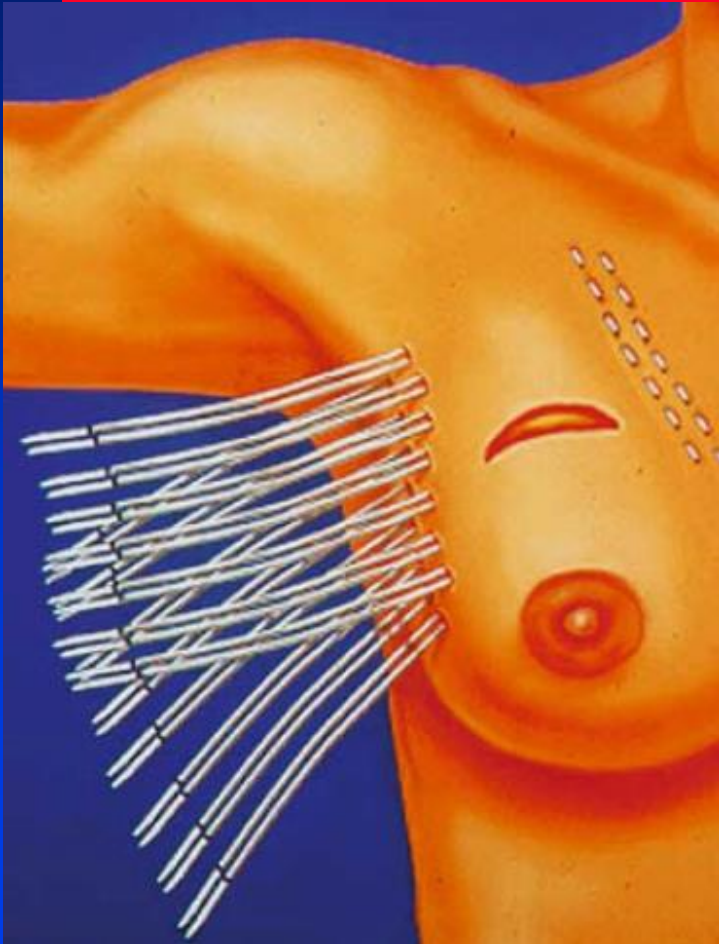
# Template for interstitial needle technique

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# Interstitial needle technique

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# APBI applicators available

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- ◆ MammoSite: Hologic
- ◆ Contura: SenoRX
- ◆ Savi: Cianna Medical
- ◆ ClearPath: North America Scientific
- ◆ Double Balloon: Best
- ◆ Axxent Balloon: iCAD (electronic brachytherapy)

# Example: the MammoSite

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There are two types: a single lumen (shown) and multiple lumens

# Typical APBI brachytherapy doses when used as monotherapy

- ◆ LDR: 45-50 Gy at about 0.5 Gy/h
- ◆ HDR: 34 Gy at 1.0 cm outside the cavity wall in 10 fractions



# Imaging for brachytherapy

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IMAGE ASSISTED PROVISIONAL TREATMENT PLANNING  
(treatment simulation and provisional dose calculation)  
conventional radiography, sectional imaging: MR, CT, US, PET

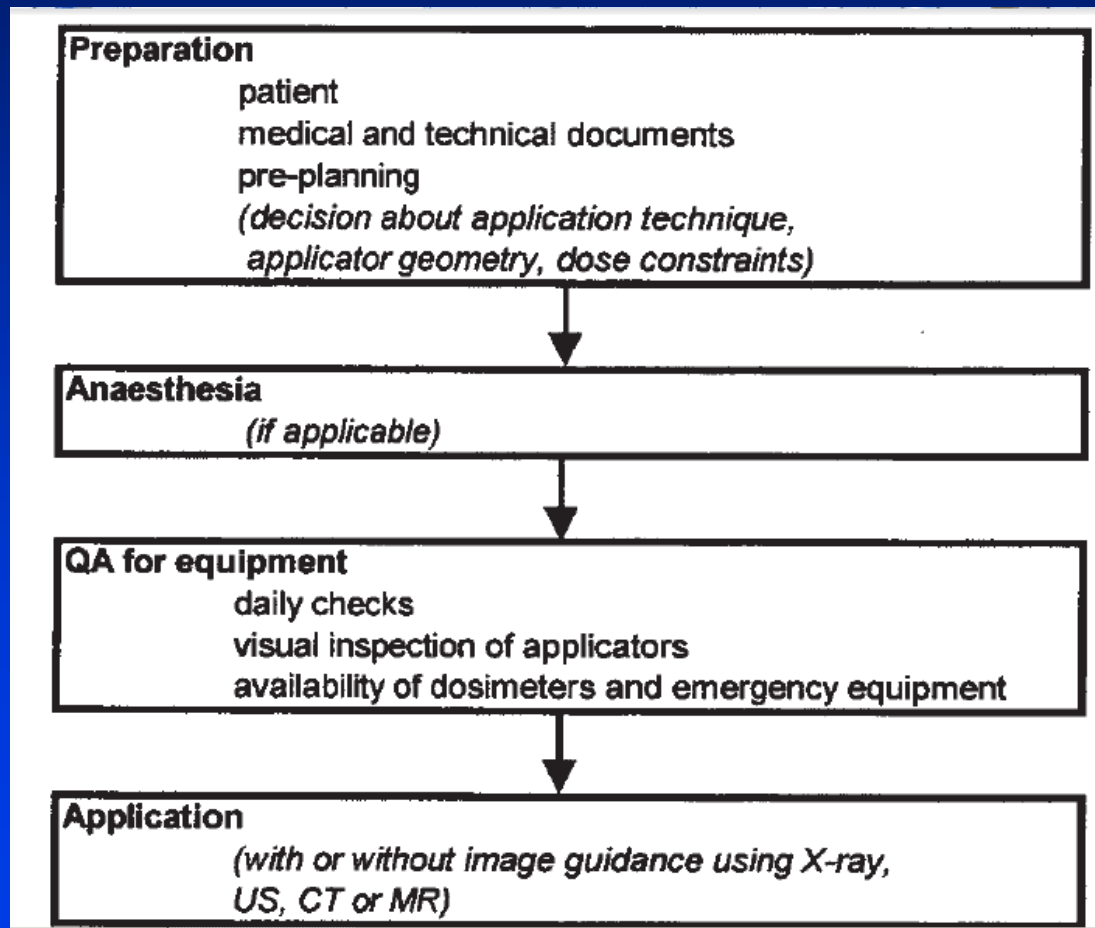
IMAGE GUIDED APPLICATION  
Radiography, MR, CT, US, endoscopy  
with or without on-line treatment planning

IMAGE ASSISTED DEFINITIVE TREATMENT PLANNING  
Imaging after application for definitive treatment planning  
(Radiography, US, CT, MR)

IMAGE ASSISTED QUALITY CONTROL OF DOSE DELIVERY  
Imaging for quality control during or after brachytherapy  
Radiography, CT, MR

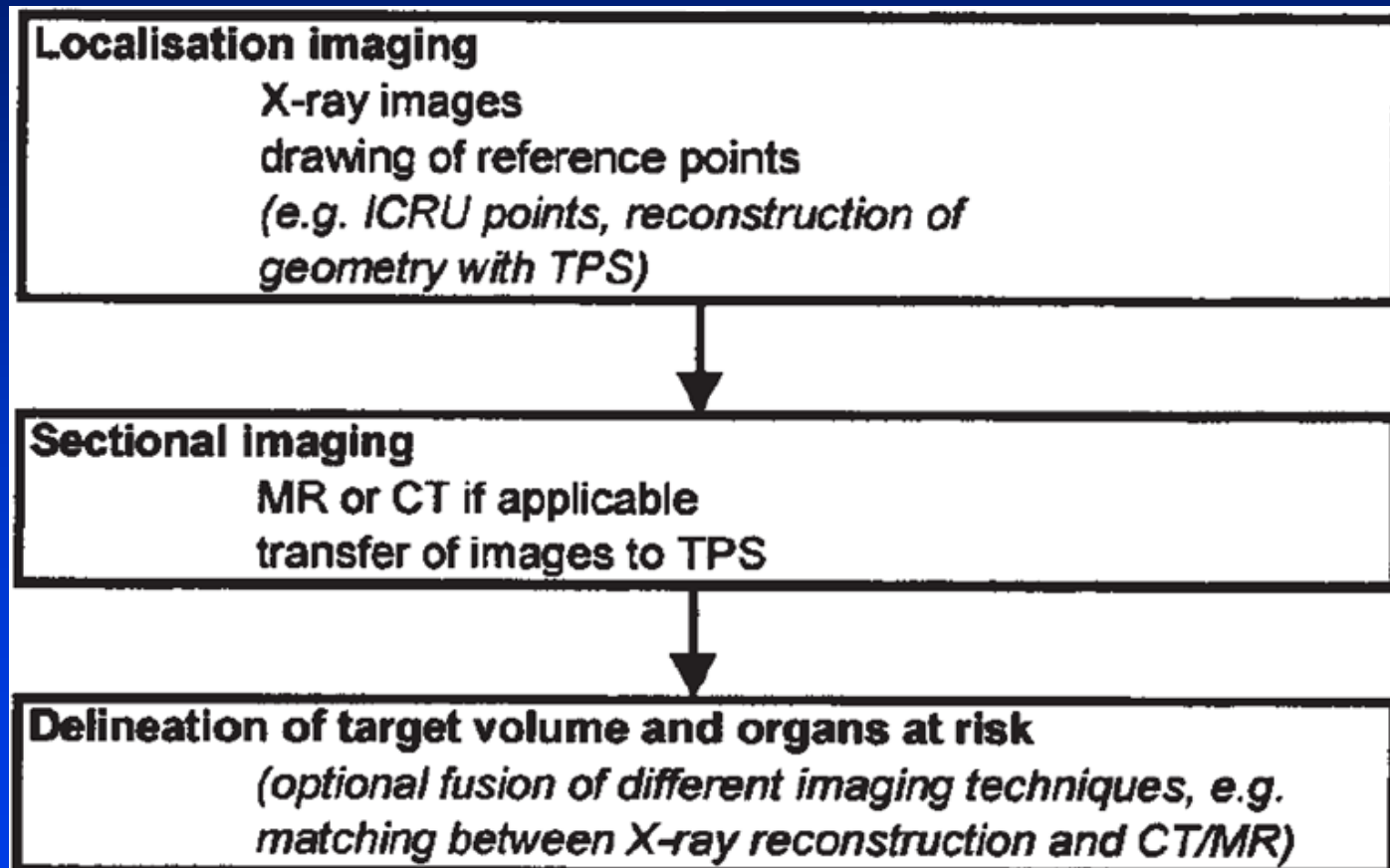
# General flow scheme for a brachytherapy procedure: preparation and application

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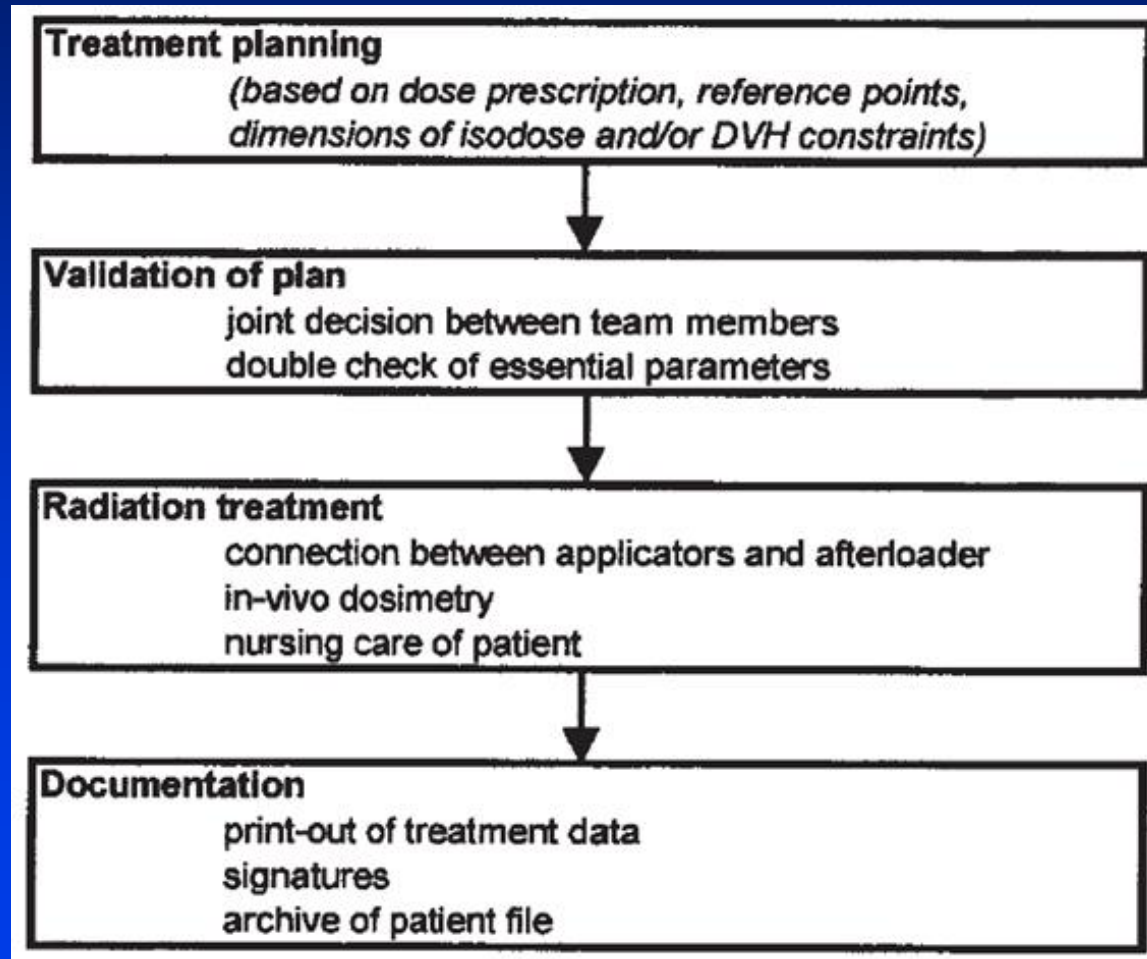
# Flow scheme for brachytherapy imaging for treatment planning

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# General flow scheme for a brachytherapy procedure: planning and treatment

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# Brachytherapy quality assurance

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- ◆ Quality assurance program is needed to assure:
  - *safety of the patient, the public, and the staff*
  - *positional accuracy*
  - *temporal accuracy*
  - *dose delivery accuracy*

# ESTRO Brachytherapy QA Guidelines

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## **A PRACTICAL GUIDE TO QUALITY CONTROL OF BRACHYTHERAPY EQUIPMENT**

**EUROPEAN GUIDELINES FOR QUALITY ASSURANCE IN RADIOTHERAPY**

**BOOKLET No. 8**

# AAPM Report No. 59:

## Code of practice for brachytherapy physics

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### RECOMMENDED QUALITY ASSURANCE PROGRAM FOR BRACHYTHERAPY EQUIPMENT

- A. Manual afterloading brachytherapy
- B. Remote afterloading brachytherapy devices
  - 1. Daily remote afterloader QA protocol
  - 2. Quarterly remote afterloader QA protocol
  - 3. Acceptance testing and annual remote afterloader QA
- C. Quality assurance for treatment planning and evaluation systems

# Safety of the patient, the public, and the staff

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- ◆ Error avoidance
  - *clear prescriptions, equipment testing, patient identification, etc.*
- ◆ Emergency procedures
  - *training staff, availability of equipment, etc.*
- ◆ Radiation safety
  - *room shielding, control of sources, monitoring devices, interlocks, etc.*



# Positional accuracy

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- ◆ Machine programming parameters
  - *accurate transfer of positional data from treatment planning system to treatment machine*
  - *correct lengths, positions, channel numbers*
- ◆ Correct location of applicators, catheters, etc.
  - *for each patient treatment*
- ◆ Correct location of sources
  - *for each patient treatment*

# Typical source positioning accuracy QA phantom

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FOR MONTHLY / DAILY CONSTANCY CHECKS OF  
HDR SOURCE POSITIONING AND STEPPING ACCURACY  
UTILIZING GAFCHROMIC® RTQA FILM.

# Temporal accuracy

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- ◆ LDR

- *need to assure that treatment is terminated once the prescribed dose is delivered*

- ◆ Remote afterloading (LDR, PDR and HDR)

- ◆ *timer and dwell time accuracy*
  - ◆ *magnitude of transit dose*
  - ◆ *accurate transfer of temporal data from treatment planning system to treatment machine*

# Dose delivery accuracy

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## ◆ Physical aspects

- *source strength calibration, accurate data in treatment planning computer, accurate decay correction, account for effect of applicator attenuation, etc.*

## ◆ Clinical aspects

- *accuracy of anatomical data and transfer of that data to the treatment planning system*
- *accuracy of planning system, optimization, etc.*

# Source strength calibration

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- ◆ Primary standards laboratories have developed advanced methods to calibrate different sources
- ◆ These are typically well beyond the scope of most users who need to check source strengths in-house

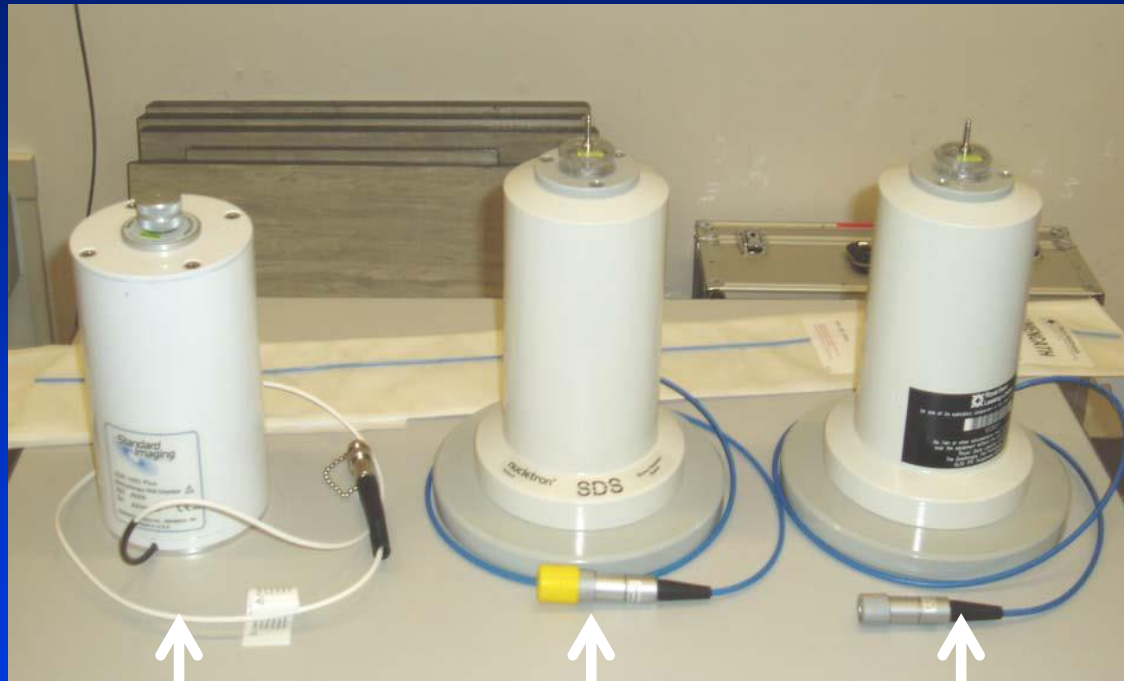
# Source strength verification by the user

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This is typically done using a well-type ionization chamber that has been calibrated by the primary standards laboratory or at a secondary standards lab using a method traceable to that at the primary lab

# Typical well-type ionization chambers

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Standard Imaging

Nucletron

PTW

# Data supplied by the calibration lab

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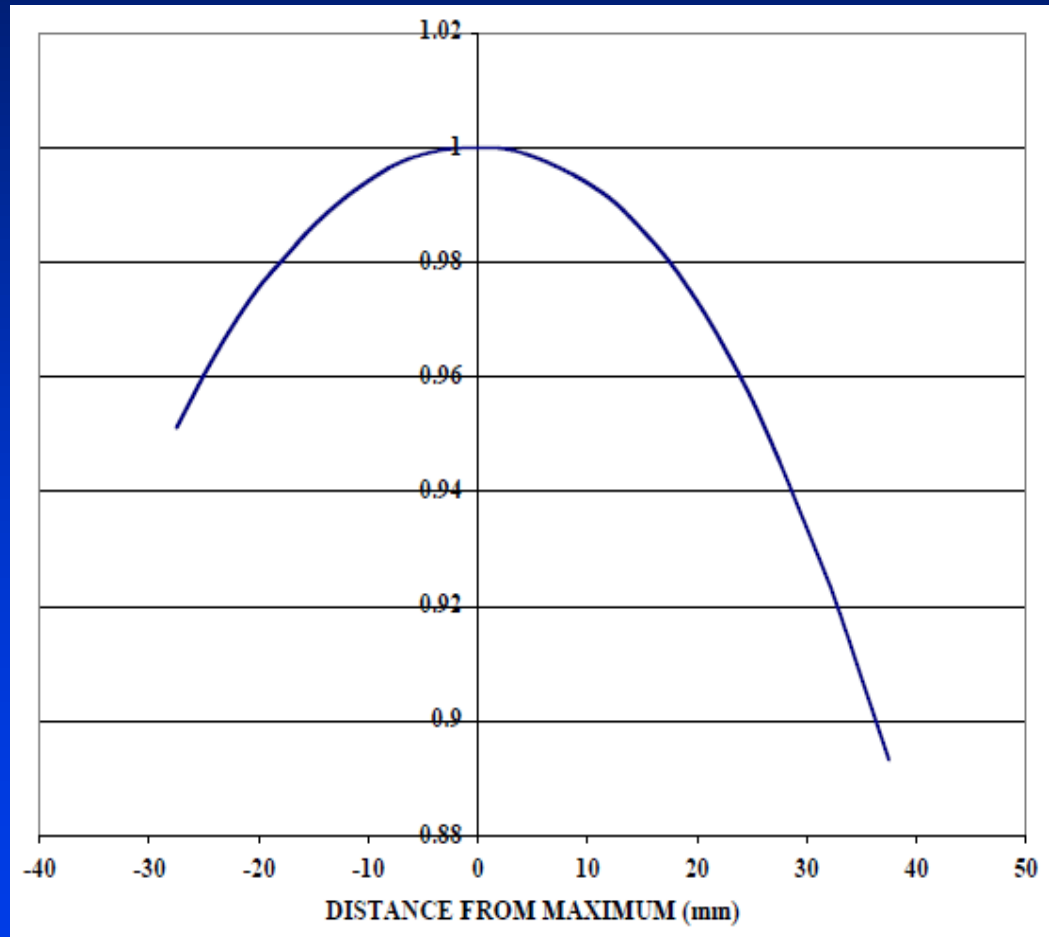
- ◆ Sweet spot location
- ◆ Air kerma strength calibration factor for the chamber
- ◆ Source used for the calibration
- ◆ Irradiation conditions
- ◆ Traceability to national calibration lab



# Sweet spot location

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The location of the sweet spot on the central axis of the chamber is determined by moving a single source and taking multiple readings



# Pre-treatment brachytherapy QA for each patient

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- ◆ Check for completeness of printed information
- ◆ Check for consistency of plan with treatment prescription
- ◆ Double check of data by independent second person
- ◆ If possible perform (simple) manual calculation of treatment time
- ◆ Signing of document before treatment starts by physician and physicist

# Summary

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- ◆ Classical systems little used today except for the Manchester System for cervix cancer
- ◆ Computerized planning now used with advanced imaging
- ◆ QA program for delivery and planning equipment, input and output data, essential to assure safety and accuracy