Physics & Planning: ICA

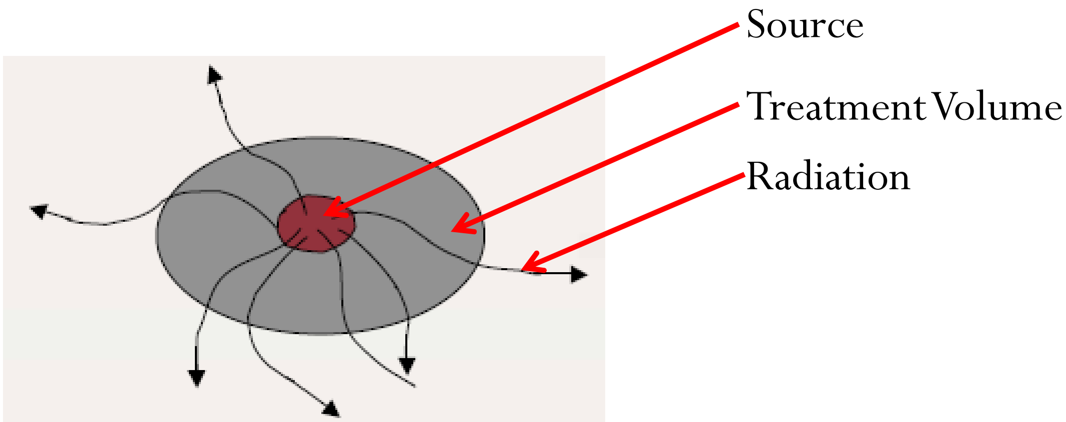
Suresh Chaudhari

Medical Physicist

Dept. of Medical Physics

Brachytherapy

- Brachytherapy (also referred to as Curietherapy) is defined as a short-distance treatment of malignant disease with radiation emanating from small sealed (encapsulated) sources.
- The sources are placed directly into the treatment volume or near the treatment volume.



Types

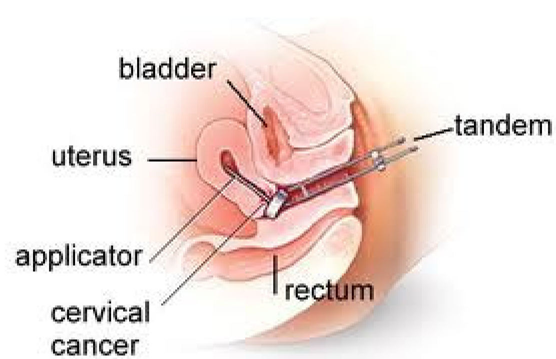
- *Intracavitary:* Sources are placed into a body cavity.
- *Interstitial:* Sources are implanted into the tumor volume.
- *Surface plaque:* Sources are loaded into a plaque which is brought into contact with a skin surface lesion.
- *Intraluminal:* Sources are inserted into a lumen.
- *Intraoperative:* Sources are brought surgically into or near the tumor volume.
- *Intravascular:* Sources are brought intravascularly into a lesion or near a lesion.

Dose Rate

- Low dose rate (LDR)
  - 0.4-2Gy/hr *(or 10Gy/day)*
- Medium dose rate (MDR)
  - 2-12 Gy/hr *(or 10Gy/hr)*
- High dose rate (HDR)
  - >12 Gy/hr *(or 10Gy/min)*

Intracavitary brachytherapy

- Intracavitary brachytherapy is mainly used for treatment of the cancer of the cervix, uterine body and vagina.
  - Various applicators are in use to hold sources in an appropriate configuration in the tumor volume.
  - A cervical applicator consists of a central tube (tandem) and lateral capsules (ovoids or colpostats).

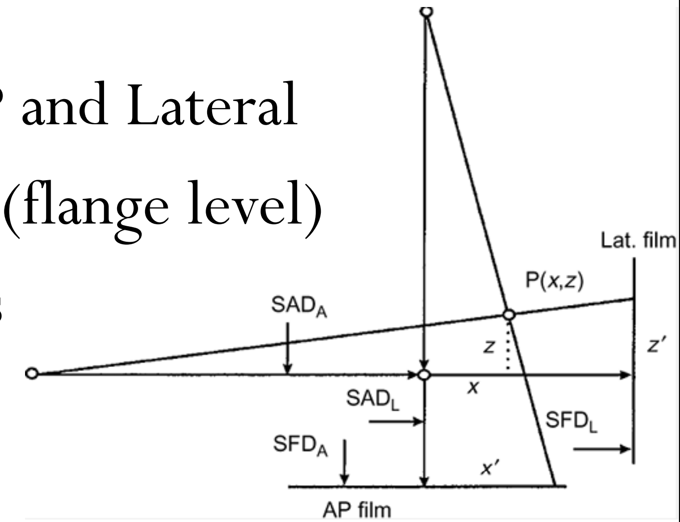


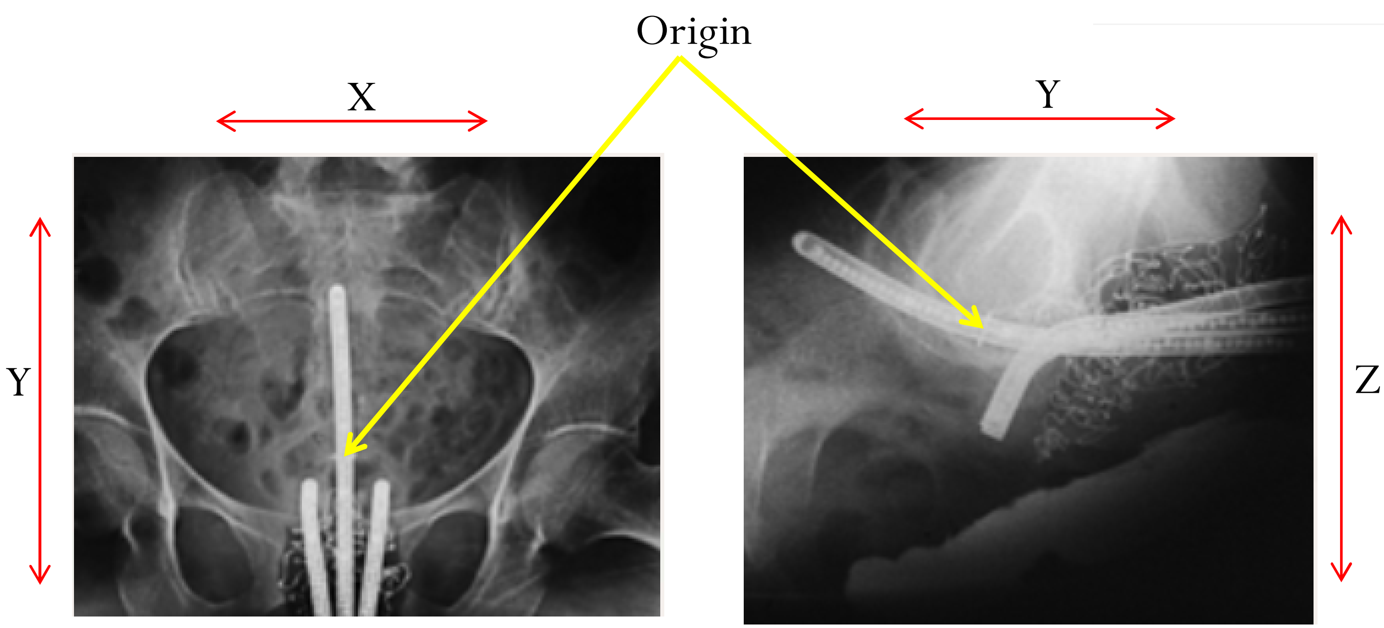
Intracavitary Planning

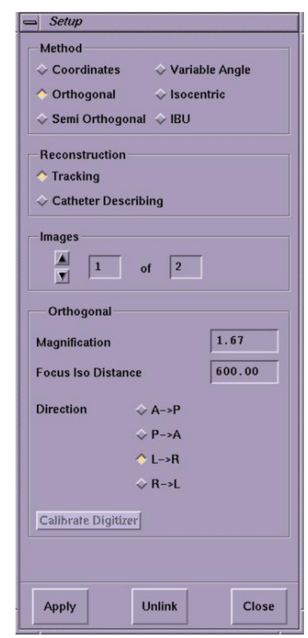
- Planning Steps
  - Radiograph
  - Applicator Reconstruction
  - Dose specification
  - Bladder and Rectum points for reporting
  - Dwell Positions
  - Dose calculation
  - Plan Evaluation
  - Treatment

Radiograph

- Isocentric Orthogonal Radiograph: AP and Lateral
- Locate origin on both the radiographs (flange level)
- Reconstruction of 3D from 2D images
  - AP: X,Y   Lat: X,Z

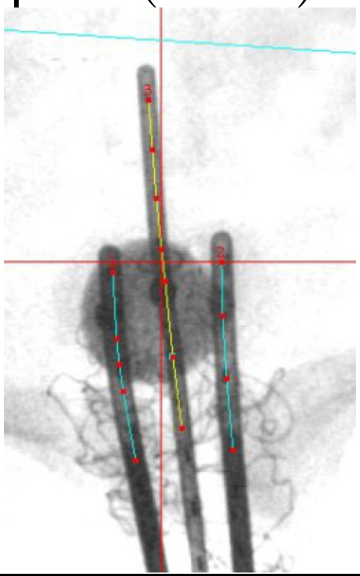


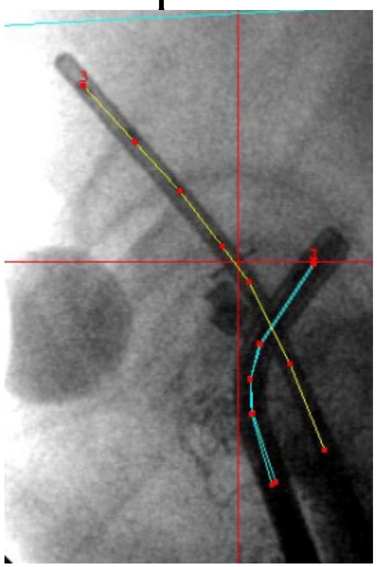


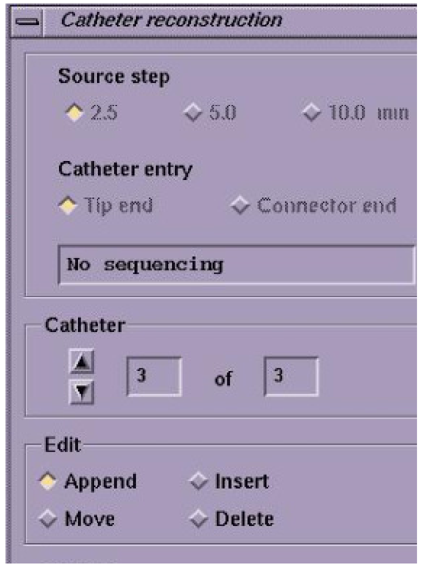


Applicator Reconstruction

- The applicators are loaded with dummy sources while radio graphing the patient.
- Step Size: 2.5mm, 5mm, 10mm
- The localization will help us in dose calculation and visual display of dose distribution on radiograph.
- Dead space (offset) due to tapered end & Source dimensions.







Dose Specification

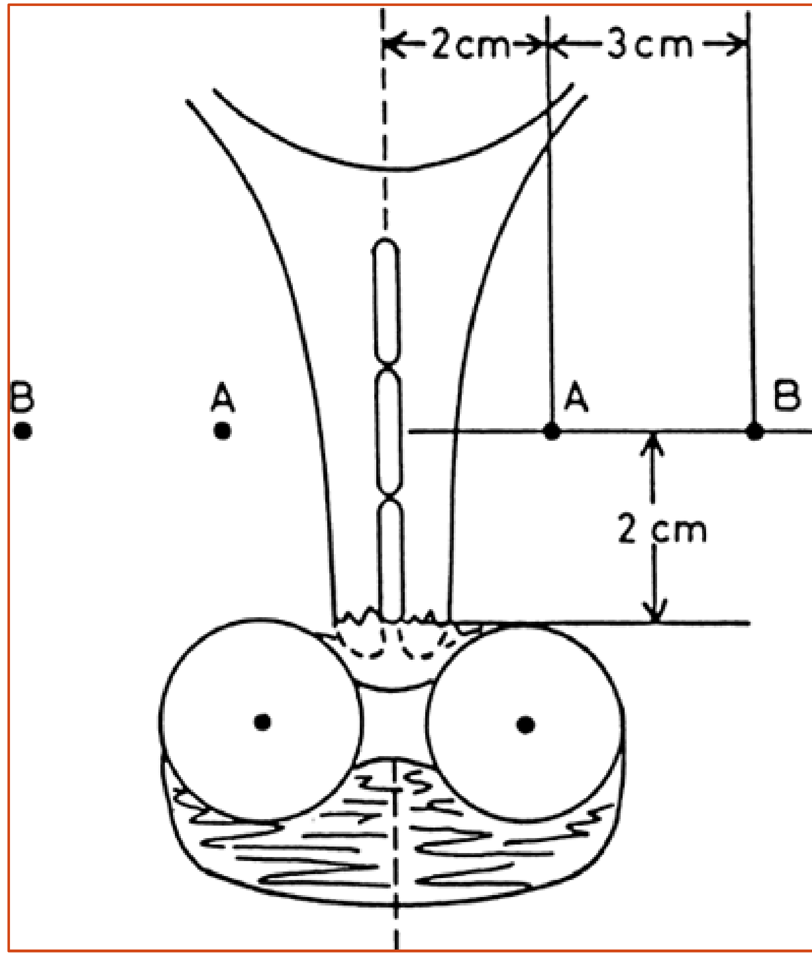
- The Manchester System
  - The Manchester system is one of the oldest and the most extensively used systems in the world.
  - It is characterized by doses to four points:
    - Point A
    - Point B
    - Bladder point
    - Rectum point.
- ICRU 38

Pont A

- Point A is defined as be 2 cm superior to the external cervical os (or cervical end of the tandem),

  and 2 cm lateral to the cervical canal.

- Point B is defined 3 cm lateral to point A.

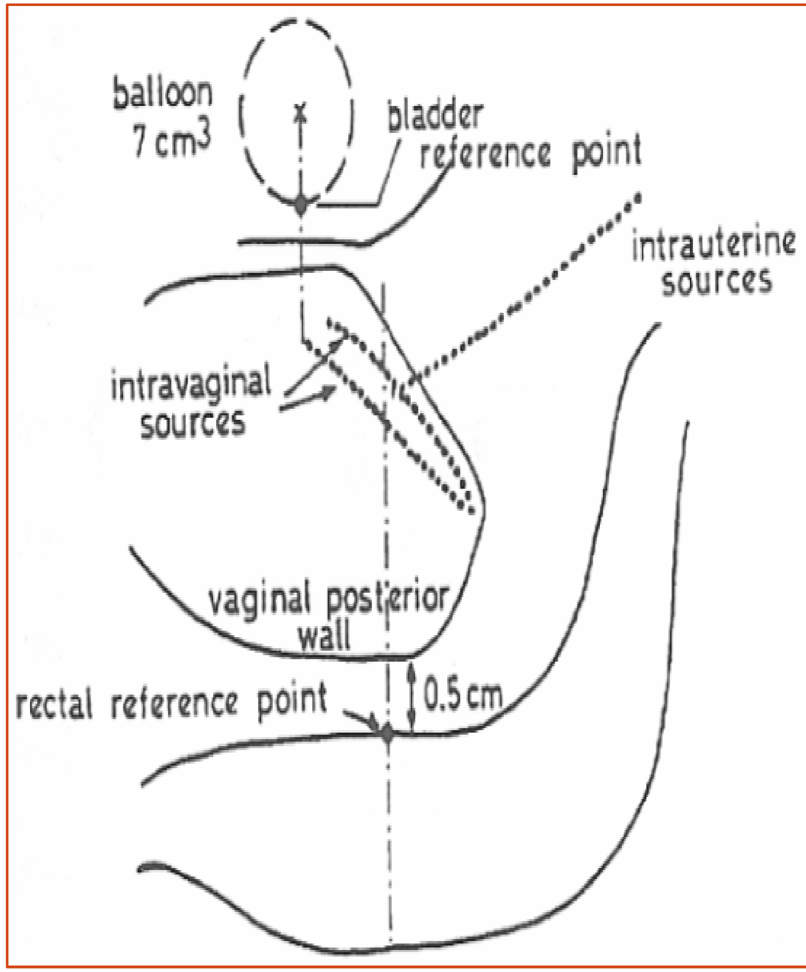


Bladder Point

- The bladder point falls on the surface of a Foley balloon filled with 7 cc of iodinated radiographic contrast snugged into the trigone of the bladder.

- Lat Radiograph
  - AP Line is drawn through the center of balloon.
  - Reference point is taken on this line at posterior surface of balloon.

- AP Radiograph
  - Point is taken at center of balloon

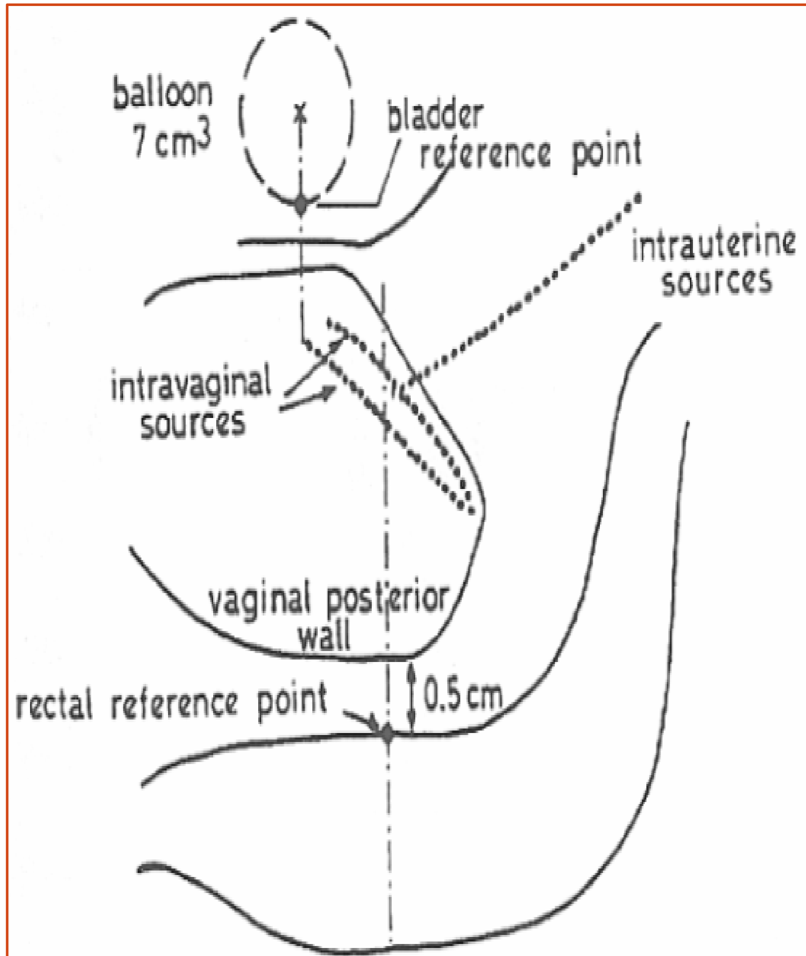


Rectum Point

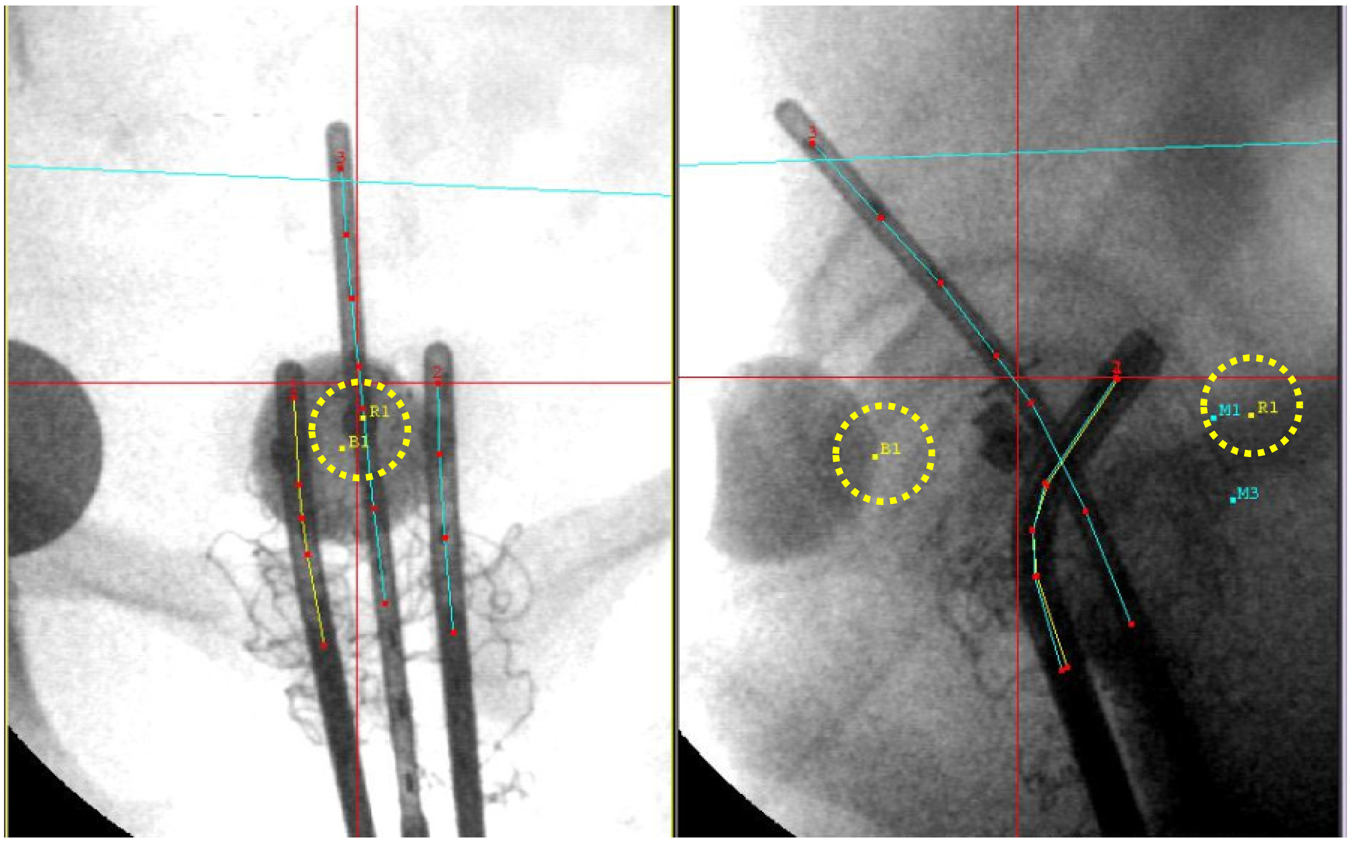
- The rectal dose point falls at the location of the maximum dose at the anterior rectal wall in the region of the vaginal applicator.

- Lat Radiograph
  - AP Line is drawn from lower end of intrauterine sources or from middle of intravaginal sources.
  - Reference Point is located on this line 0.5cm behind the posterior vaginal wall.

- AP Radiograph
  - Reference Point is at lower end of intrauterine source or at middle of intravaginal sources.



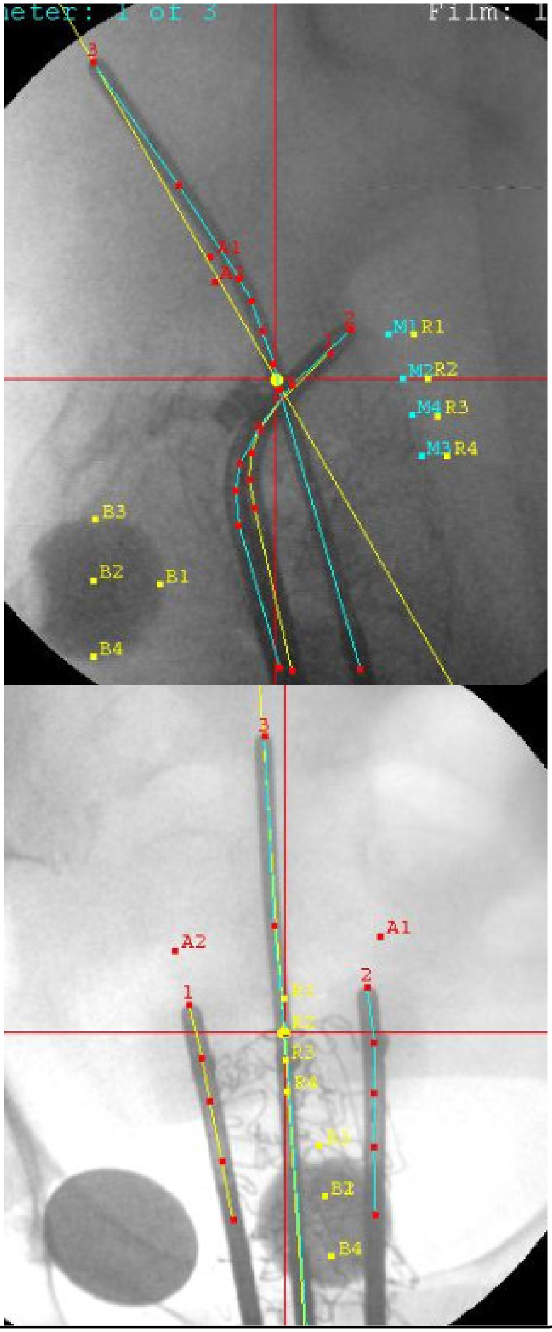
Points on Radiograph



Reference Points:TMH

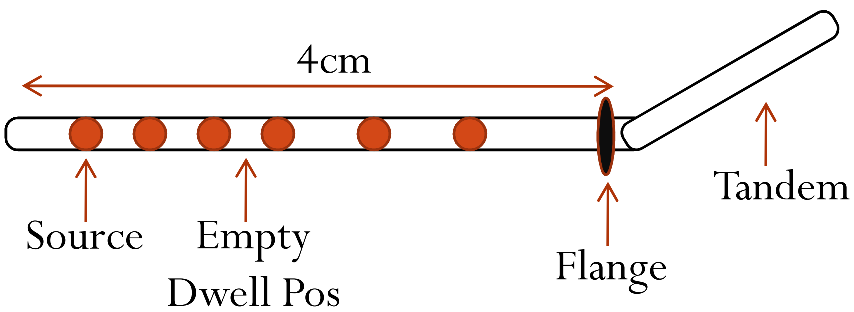
- Bladder Points
  - 4 points on balloon
  - Centre, Superior, Inferior, posterior.

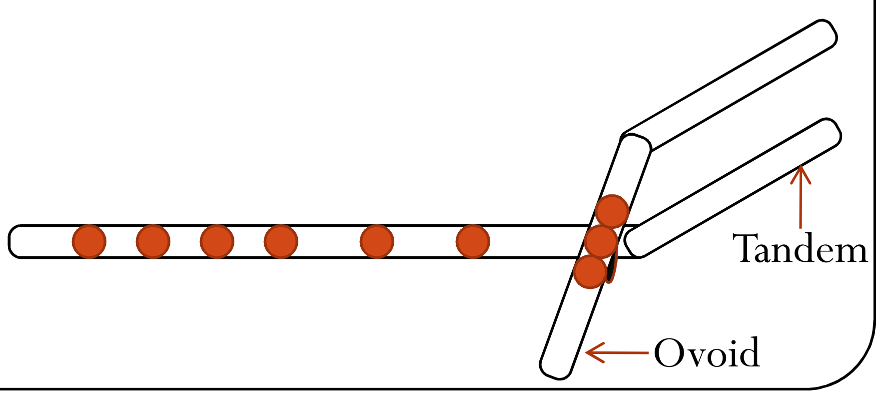
- Rectum Points
  - 3 Points
  - 1st point same as ICRU38
  - 1 cm Superior, 1cm Inferior



Dwell Positions

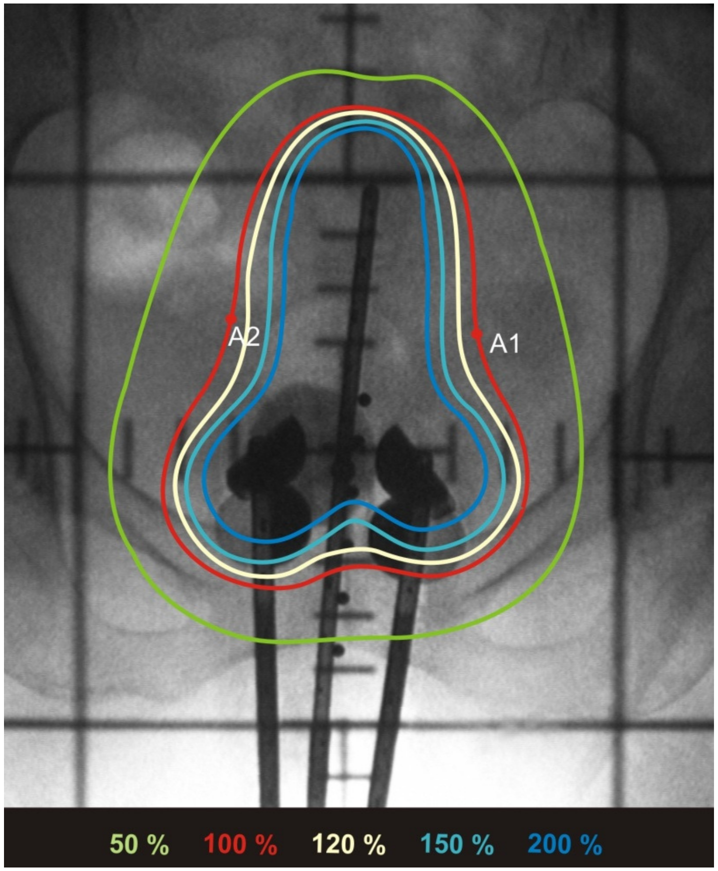
- Dwell positions should be such that to result optimum target dose and lowest possible dose to OAR.
- Predefined dwell positions depending on Tandem length and Ovoid diameter.
- Tandem (Step Size:2.5mm)
  - 4cm: 1,3,5,7,10,13
  - 5cm: 1,3,5,7,10,13,16
  - 6cm: 1,3,5,7,10,13,16,20
- Ovoid (Step Size:2.5mm)
  - 1.5cm & 2cm: 4,5,6
  - 2.5cm:4,5,6,7

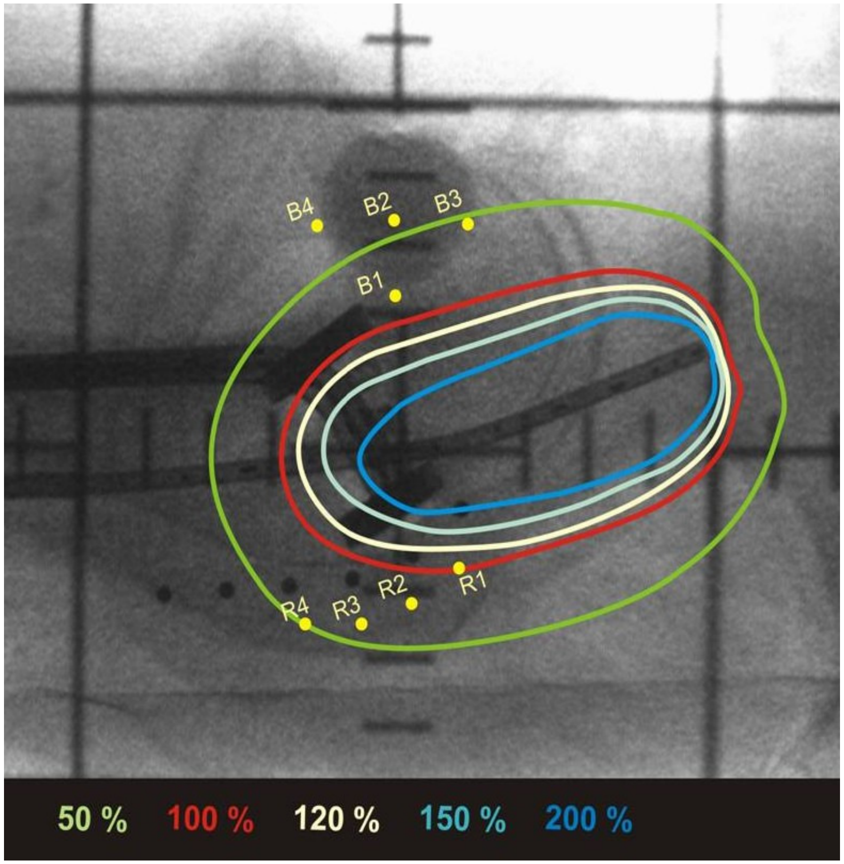




Dose Calculation

- Prescription at Pont A





Dose Rate Calculation: TG43

- The dose rate, *D(r, Θ)*, at point *(r, Θ)* can be written as

$$D(r,\theta)=S_k\Lambda[G(r,\theta)/G(r_0,\theta_0)]g(r)F(r,\theta),$$

  - S_k is air-kerma strength of the source (cGy cm^2 h^{-1} =U^{-1});
  - Λ =dose rate constant (cGy h^{-1} U^{-1})
  - *G (r, Θ)* = geometry factor (cm^{-2})
  - *g (r)* = radial dose function (unitless)
  - *F (r, Θ)* = anisotropy function (unitless)

Air kerma strength S_K

- Air kerma strength S_K, *with units given in* ,is defined in the AAPM TG 43 report as

$$S_K = (\dot{K}_{air}(d_{ref}))_{air} \times d_{ref}^2$$

  - *dref is the reference distance at which the reference air* kerma rate is defined

- A shorthand notation is used with U defined as

$$1\ \mathrm{U} = 1\ \mu\mathrm{Gy} \cdot \mathrm{m}^2 \cdot \mathrm{h}^{-1} = 1\ \mathrm{cGy} \cdot \mathrm{cm}^2 \cdot \mathrm{h}^{-1}$$

Dose rate constant Λ

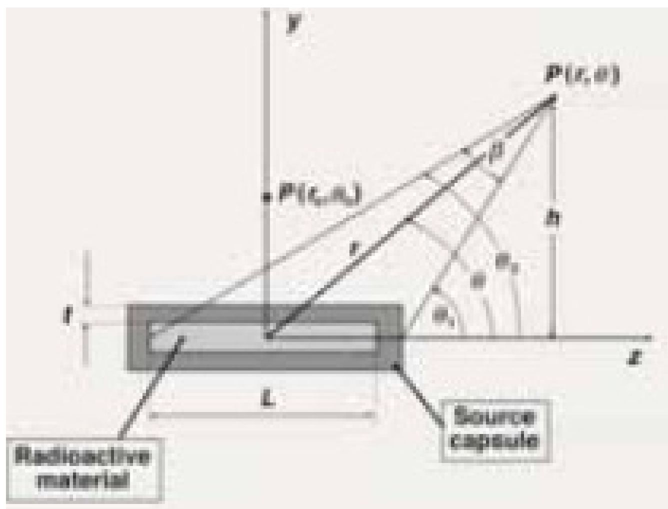
- The dose rate constant is defined as the dose rate to water at a distance of 1 cm on the transverse axis (reference point) per unit air kerma strength in water.

$$\Lambda = \frac{\dot{D}(r_o,\theta_o)}{S_K} \text{ with units of } \frac{cGy \cdot h^{-1}}{cGy \cdot cm^2 \cdot h^{-1}} = cGy \cdot h^{-1} \cdot U^{-1} = cm^{-2}$$

- The dose rate constant accounts for:
  - Effects of source geometry.
  - Spatial distribution of radioactivity within source encapsulation.
  - Self-filtration within the source.
  - Scattering in water surrounding the source.

Geometry factor

- Geometry factor accounts for the geometric falloff of the photon fluence with distance *r from the source and also* depends on the spatial distribution of activity within the source.



Radial dose function *g(r)*

- Radial dose function *g(r) accounts for the effects of* attenuation and scatter in water on the transverse plane of the source ($\theta = \pi/2$)excluding falloff which is included by the geometry function G(r, θ).
- The radial dose function *g(r) may also be influenced* by filtration of photons by the encapsulation and source materials.

r(cm)	*g*(*r*) Ir-192
0.5	0.994
1	1.000
2	1.010
3	1.020
4	1.010
5	0.996

Anisotropy function F(r, θ)

- Anisotropy function accounts for the anisotropy of dose distribution around the source, including the effects of absorption and scatter in water.
- F(r, θ) is defined as unity on the transverse plane.
- F(r, θ) decreases in directions off the transverse plane
  - As *r decreases.*
  - As approaches 0^{o} or 180^{o}.
  - As the source encapsulation thickness increases.
  - As the photon energy decreases.

Plan Evaluation

- Point A
  - 100% Dose

- Bladder Dose
  - Bladder dose to 90% of pt A. Total bladder dose below 80Gy (LDR equivalent at 50cGy/hr).
  - 65-75% of Point A for HDR

- Rectal Dose
  - Total Rectal dose below 75Gy (LDR equivalent at 50cGy/hr).
  - 55-65% of Point A for HDR

Thank You