Basic Principles of ICA

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Basic Principles of ICA

- **The basic principles of brachytherpy have not changed much during the past 100 years of radiotherapy**

- **Recent advances has made brachytherapy**
  - **Much more efficient for the patient**
  - **Much safer for the staff from radiation protection point of view**

Basic Principles of ICA

- **Brachytherapy Definitions**
  - **Interstitial Brachytherapy –**
    - **sources are implanted in the tumor**
  - **Contact Brachytherapy – Plesiobrachytherapy**
    - **Sources are close to the tumor**
    - **Intracavitary**
    - **Intraluminal**
    - **Endovascular**
    - **Surface brachytherapy**

Basic Principles of ICA

- **In intracavitary application, radioactive sources are placed in the uterine cavity and vagina, usually inside a predefined applicator with special geometry.**

- **It is the oldest form of "*conformal treatment*" without heavy technological involvement & cost**

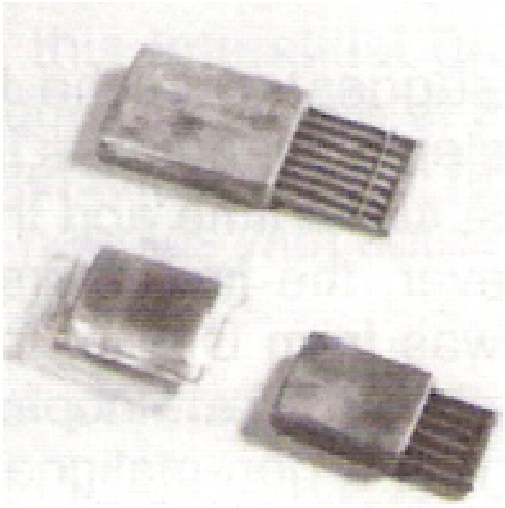
Radiotherapy for Carcinoma Cervix

- **Of vital importance to the development of brachytherapy was the establishment of the early specialist radiation centres**
  - **1908 : Radiumforschung in Vienna**
  - **1910 : Radiumhemmet in Stockholm**
  - **1912 : Curie Foundation in Paris**
  - **1930's : Holt Radium Inst. In Manchester**
  - **1950's :Fletcher System**

Radiotherapy for Carcinoma Cervix

- **Stockholm Technique**

- **Based on clinical experience**
- **2 to 3 applications of 20 hrs given over total time of 3 weeks**
- **Intra-vaginal boxes - silver or gold**
- **Intrauterine tube -flexible rubber**
- **Total prescribed dose 6500-7100 mgh Ra**
- **Dose rate-110R/hr or 2500mghr/#**



Radiotherapy for Carcinoma Cervix

Paris System

Radiobiological work of Regaud

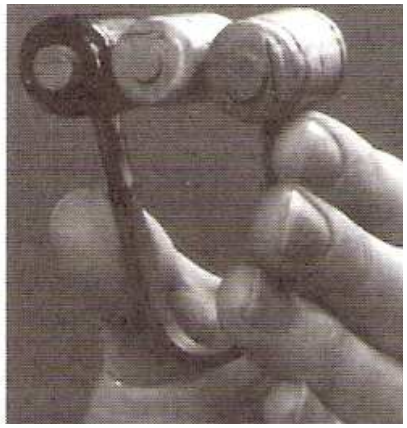
Single application of radium for 120 hours.

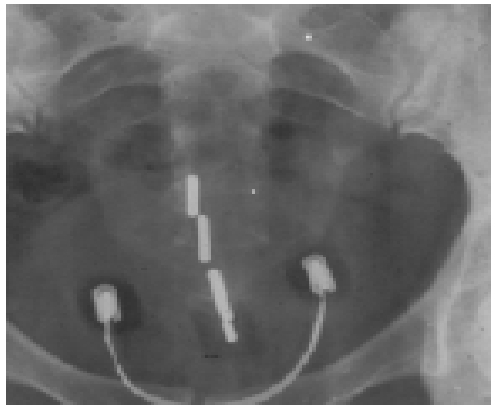
Semiflexible silk intrauterine tube

Vaginalcolpostst – cork cylinders joined by a spring

Dose of 5500 mgh Ra over a period of five days

Dose rate of 45R/h.





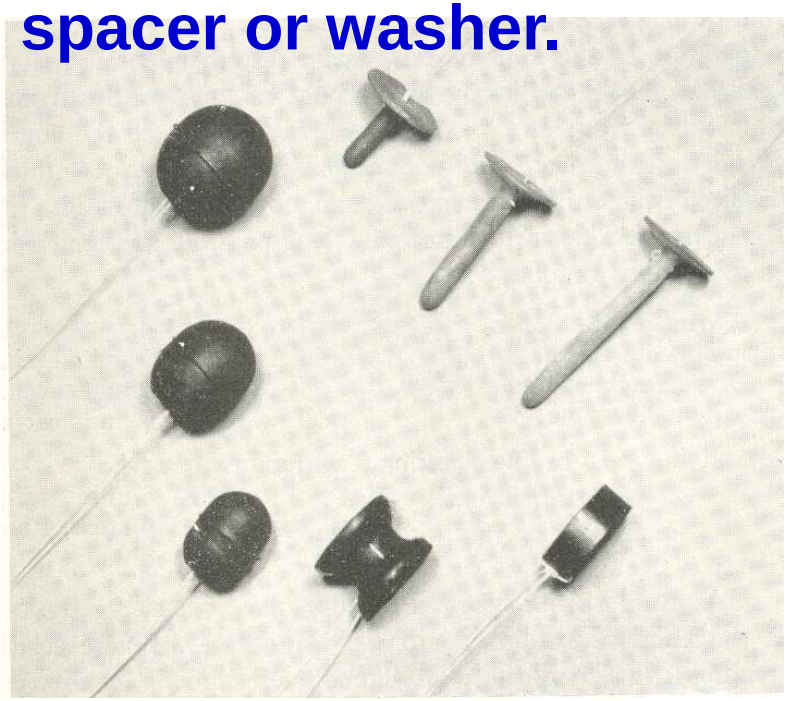
Radiotherapy for Carcinoma Cervix

Manchester System

Based on Paris technique.

Designed a set of applicators and their loading which would give the same dose rate irrespective of the combination of applicators used

•It replaced vaginal colpostats with vaginal ovoids separated by spacer or washer.



Radiotherapy for Carcinoma Cervix

Manchester System

Standard dose rate at point A --53 cGy/h

Two applications of 72 hours each are given with 7-10 days period between two applications.

Dose of 8000 R is delivered at point A

Present day brachytherapy practice is based on Manchester System

Basic Principles of ICA

- **The uterine cervix is ideally suited for Intracavitary application because**

1. **The endocervical canal and vaginal vault form a suitable vehicle to carry radioactive sources**

2. **The normal cervical tissues and vaginal vault epithelium are relatively radioresistant and tolerate high doses of irradiation**

3. **The intensity of irradiation rapidly falls off with distance from the intracavitary sources. This restricts the amount of irradiation received by normal tissues beyond the cervix region.**

Basic Principles of ICA

Advantages:

1. High dose in short time.
   - Cervix : 20,000-25,000 cGys.
   - Uterus : 20,000-30,000 cGys.
   - Vagina : 10,000 – cGys.
2. Control rate higher.
3. Sharp fall of dose, less normal tissue damage.
4. Less late radiation morbidity.
5. Preservation of normal anatomy.
6. Better sexual functional life.

Basic Principles of ICA

- **Effect of ICBT on survival**

Treatment		%age Survival at 5 years
1.	Ext.RT alone	36%
2.	Ext.RT+ICBT	67%
3.	Single ICBT	60%
4.	2 or more ICBT	73%

•In the management of carcinoma cervix intracavitary application plays a sheet anchor role and is responsible for most of the cures.

Basic Principles of ICA

- **Radiotherapy treatment**

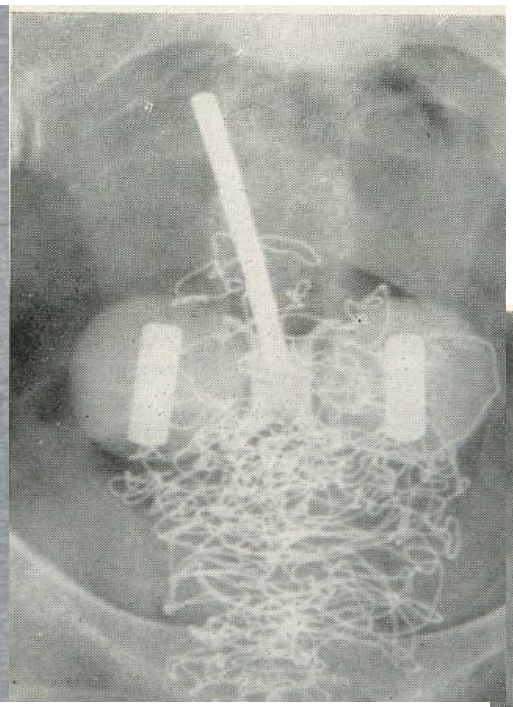
- **Proportion of Ext RT increases with tumour bulk and stage.**
- **Except for small tumours, Ext RT precedes ICRT.**

- **All treatment should be completed in 50 days**

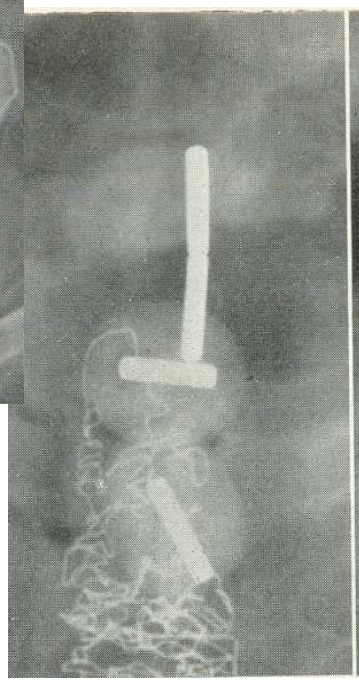
- **Para-central dose should be 80-90 Gy.**
- **Pelvic sidewall dose should be 45-60 Gy.**

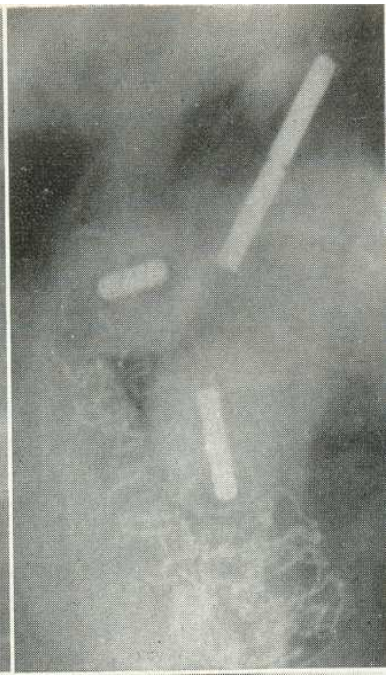
Applicators

Radiotherapy for Carcinoma Cervix



Loose pre-laoded Manchester System





Loose system and therefore, chances of slipping of ovoids and hence disturbed geometry and creation of cold and hot spots leading to high failure or increased morbidity.

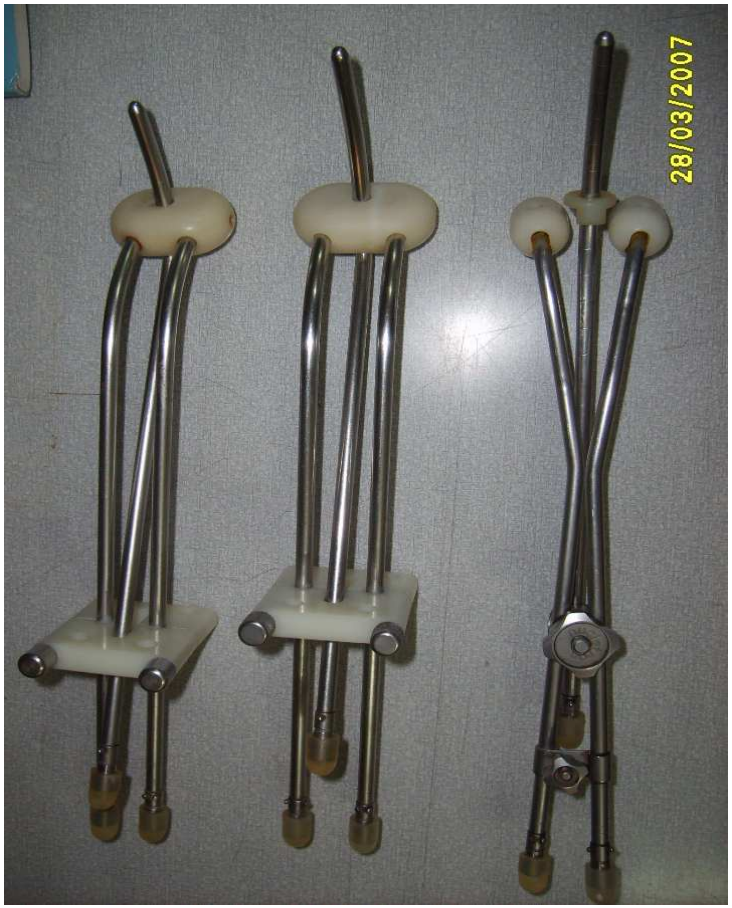
Radiotherapy for Carcinoma Cervix

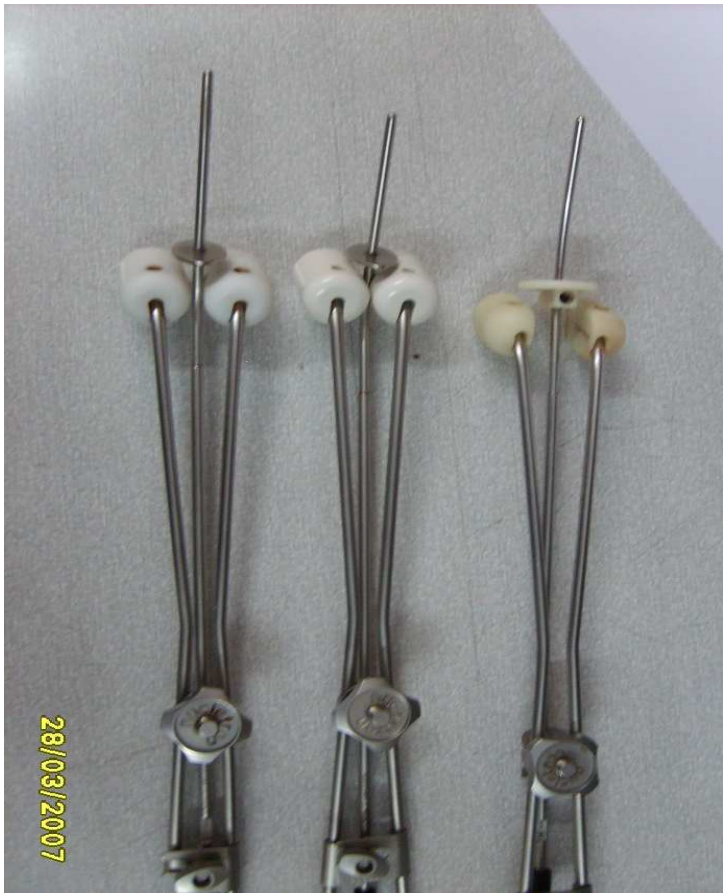
Loose pre-laoder-Manchester Fixed PGI pre-loader

Radiation hazard : being a preloaded system.

Radiotherapy for Carcinoma Cervix

After loaders





Radiotherapy for Carcinoma Cervix

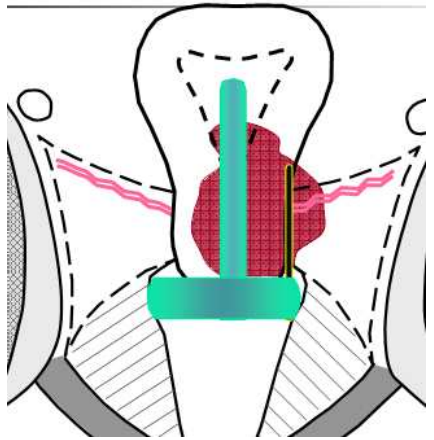
Drawback:

Unilateral tumor extension exceeding:

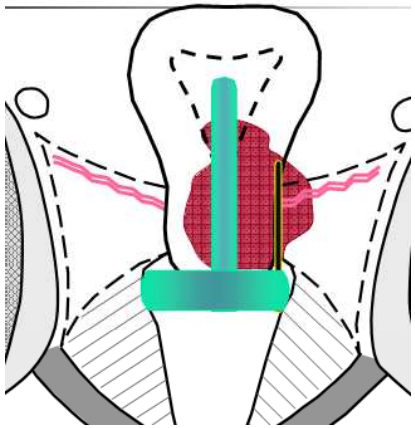
- **3.5 cm at the level of the ring**
- **2.5 cm at the level of point A**
- **2.2 cm at a distance 3-4 cm cranial to the ring surface**

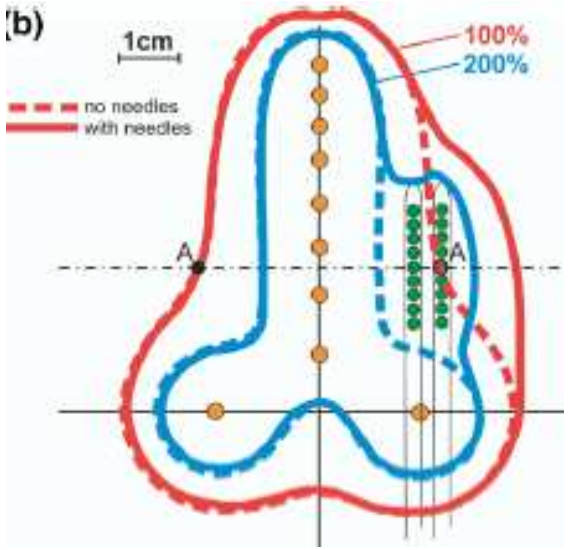
tumor extension can not be covered by the symmetrical dose distribution of the tandem alone without exceeding dose limits for OAR

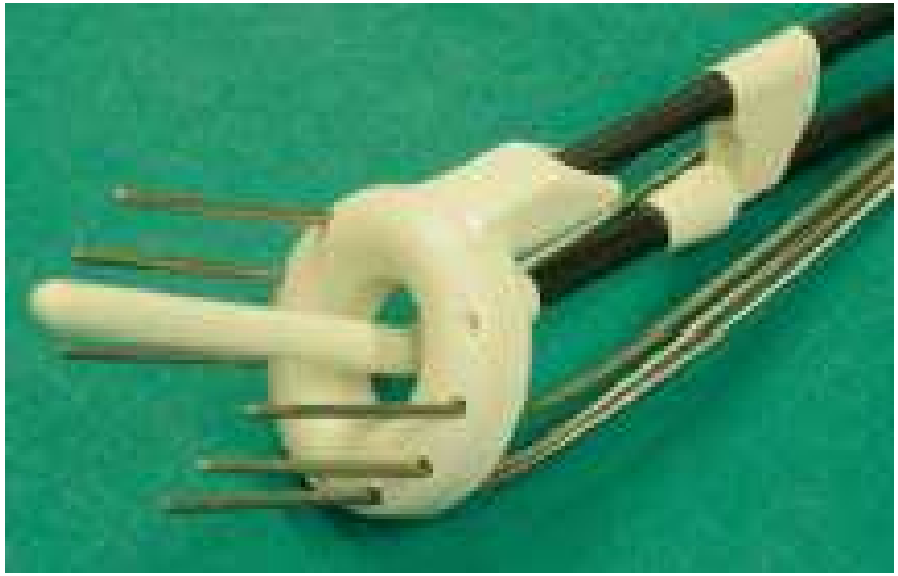
CT/MR Compatible Ring & Tandem Applicator



Radiotherapy for Carcinoma Cervix





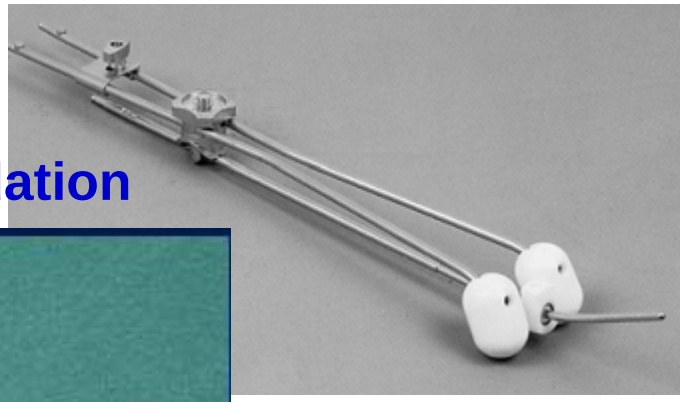


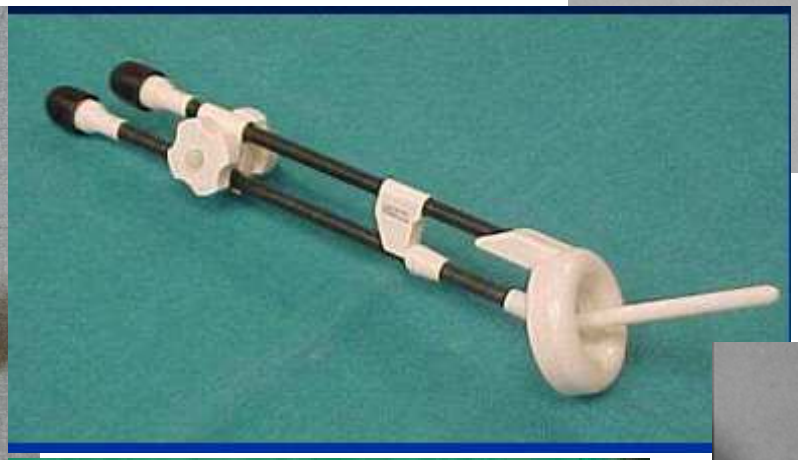
Clinical situations requiring a combined intracavitary/interstitial technique

Intracavitary + interstitial Brachytherapy, if D90 < 85 Gy

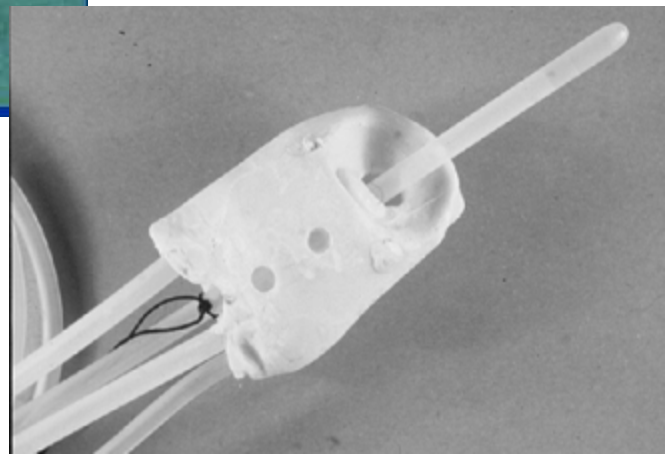
Basic Principles of ICA

- **Applicators**
- **All applications must be done under sedation**





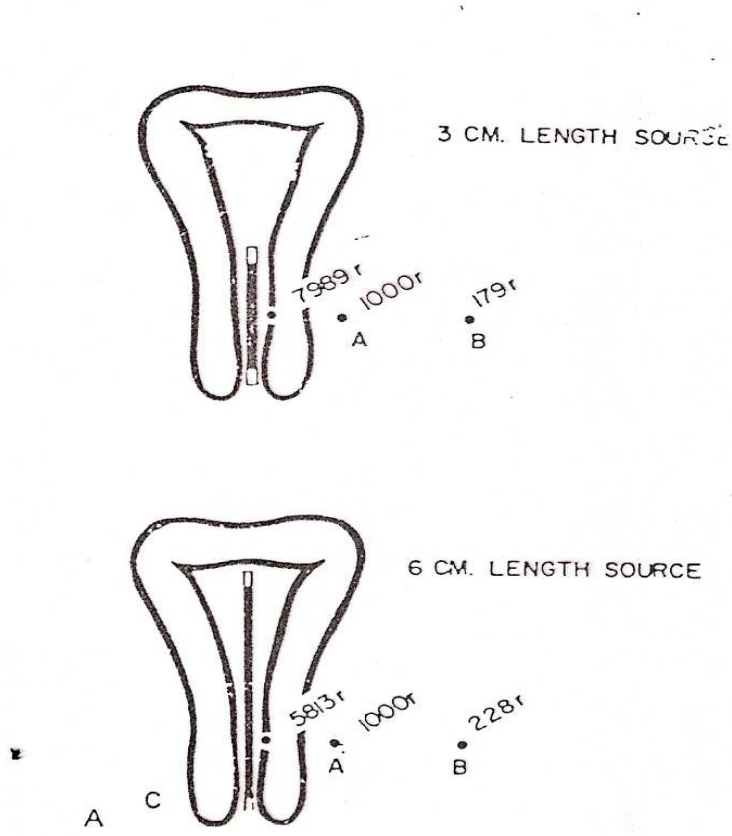
Standardised



Personaliseed

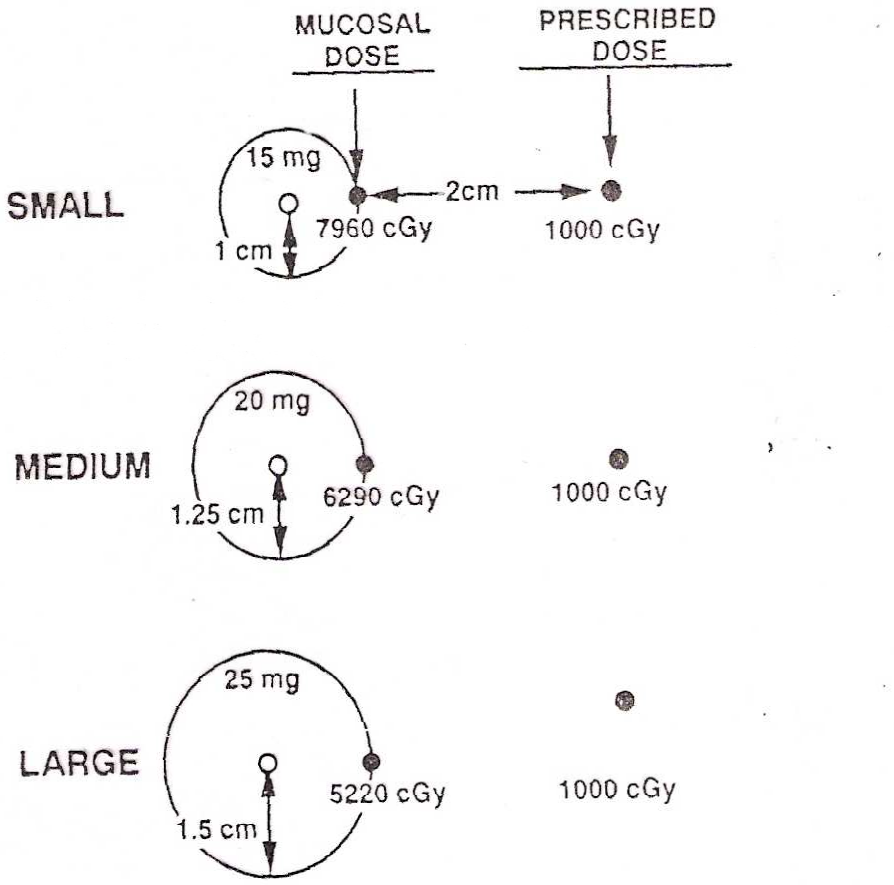
Basic Principles of ICA

- **Tandem Loading**
- **To optimize the lateral dose to parametrium, the tandem should be as long as anatomy permits but not more than 6 cm.**
- **As the tandem size increases the penetration or "lateral throw-off" of the dose distribution increases**
- **Increase in tandem length increases the point "B" contribution relative to the uterine cavity surface dose**



Basic Principles of ICA

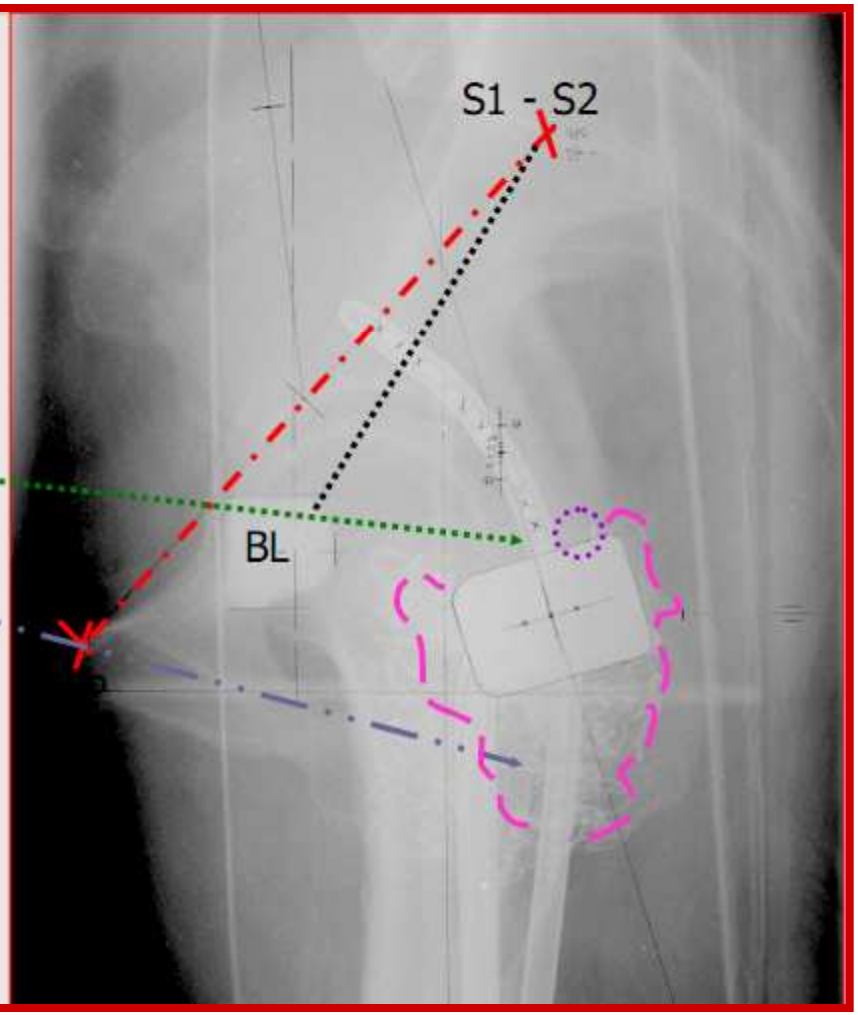
- **Ovoid Loading**
- **The largest ovoids that permits adequate separation to admit the flange on the tandem between them without causing downward displacement of the ovoids should be used.**
- **In order to optimize the ratio between the dose at depth and the vaginal mucosal dose.**
- **As colpostat diameter increases from 2cm to 3cm the vaginal surface dose decreases by 35% relative to the point "A" dose.**



Basic Principles of ICA

Lateral View of Applicator Placement

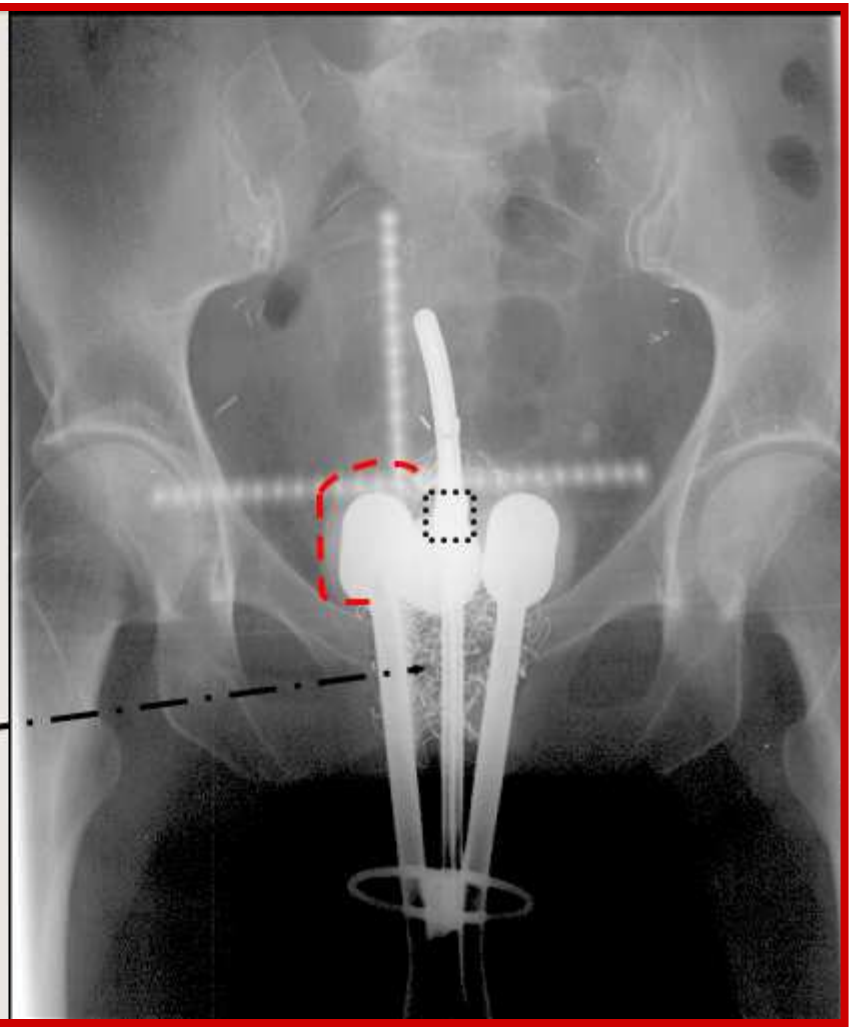
- Tandem - 1/3 of the way between S1 – S2 and the symphysis pubis
- The tandem - midway between the bladder and S1 - S2
- Marker seeds should be placed in the cervix
- Ovoids should be against the cervix (marker seeds)
- Tandem should bisect the ovoids
- The bladder and rectum should be packed away from the implant



Basic Principles of ICA

Anterior – Posterior View of Applicator Placement

- The ovoids should fill the vaginal fornices, add caps to increase the size of the ovoids if necessary.
- The ovoids should be separated by 0.5 – 1.0 cm, admitting the flange on the tandem.
- The axis of the tandem should be central between the ovoids



Basic Principles of ICA

- **Conditions to be met for successful ICBT**

- **An adequate dose has to be delivered to the para-cervical areas.**
- **Geometry of the radioactive sources must prevent under dosed regions on and around the cervix.**
- **Mucosal tolerance has to be respected.**
- **Optimal placement "Pear-Shaped" distribution delivering a high dose to the cervix and para-cervical tissues and a reduced dose to rectum and bladder "Banana-Shaped"**

Basic Principles of ICA

- **Mucosal Tolerance**
- **Local dose to cervix should be $2^{1/2}$ – 3 times the paracervical dose**
- **Surface dose to vaginal mucosa should be <150 Gy to proximal & < 90 Gy to distal vagina**
- **Rectal dose should be <75 Gy**
- **Bladder dose should be <80 Gy**

Basic Principles of ICA

- **Manchester System**
- **Developed by Todd & Meredith in 1930**

- **Defined the treatment in terms of dose to a point.**
- **Defined two points – A & B**
- **Abandoned previous dosage system of mg./hrs. in favour of roentgen unit.**
- **Designed a set of applicators and their loading which would give the same dose rate irrespective of the combination of applicators used**

Basic Principles of ICA

- **Loading of applicators**

- **In order that point A receives same dose rate, no matter which ovoid combination is used ,it is necessary to have different radium loadings for each applicator size**
- **Dose rate 57.5 R/hr to point A**
- **Not more than 1/3 dose to point A must be delivered from vaginal radium**

Basic Principles of ICA

Manchester Loading

Table 4.12 *Dose rates at point A for standard Manchester loadings*

Applicator	Loading	Configuration	Dose rate at point A (cGy h^{-1})
6-cm uterine tube	6, 4, 4 units		34.4
4-cm uterine tube	6, 4 units		34.2
2-cm uterine tube	8 units		27.3
Large ovoids	9 units	1-cm spacer	18.3
Medium ovoids	8 units	1-cm spacer	18.8
Small ovoids	7 units	1-cm spacer	18.9
Large ovoids	9 units	Washer	18.9
Medium ovoids	8 units	Washer	19.0
Small ovoids	7 units	Washer	19.0
Large ovoids	9 units	In tandem	14.6
Medium ovoids	8 units	In tandem	14.9
Small ovoids	7 units	In tandem	14.8

The unit of source activity is 18 μGy h^{-1} (2.5 mg radium equivalent).

Basic Principles of ICA

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Basic Principles of ICA

- **Rectal dose is mainly affected by vaginal source weightings**
- **To lower the rectal doses the dwell times for the vaginal sources must be decreased**
- **Width of the reference volume will also decrease**
- **Hence attention must be paid to the inclusion of the tumor volume into the reference volume.**

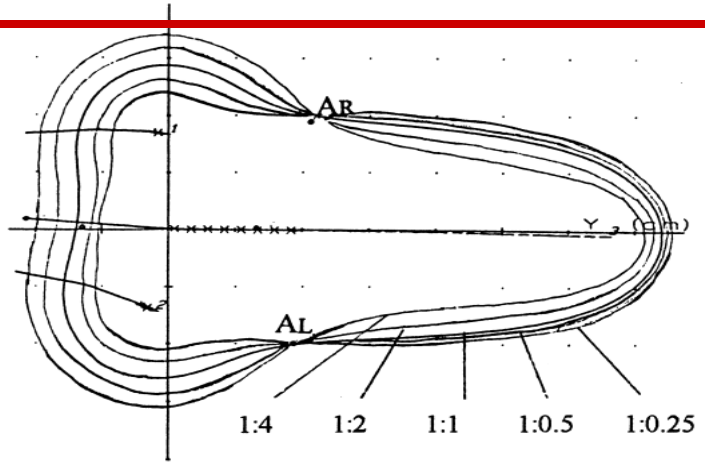


Fig. 4. Oblique coronal views of the reference dose distribution of uterine and vaginal sources with 2.5 mm steps for (T_u/T_v): 1:1; 1:2; 1:4; 1:0.5; and 1:0.25 ratios.

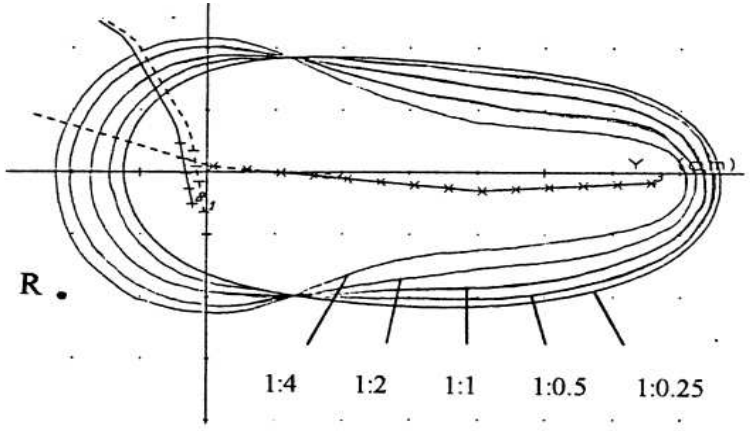


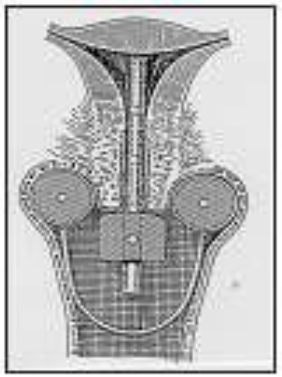
Fig. 7. Oblique sagittal views of the reference dose distribution of uterine sources with 5 mm steps and vaginal sources with 2.5 mm steps for (T_u/T_v): 1:1; 1:2; 1:4; 1:0.5; and 1:0.25 ratios.

Dose Reporting

Basic Principles of ICA

Historical Systems / Techniques

Paris



Manchester

Fletcher

Stockholm

Sets of rules

- certain *activity* (mg of 226Ra)
- for a certain *time* (hours)

} mgh

- in certain *spatial* relations

→ FOR A GIVEN TUMOUR VOLUME

Manchester system: point A introduction

Radiotherapy for Carcinoma Cervix

- **Treatment prescription**

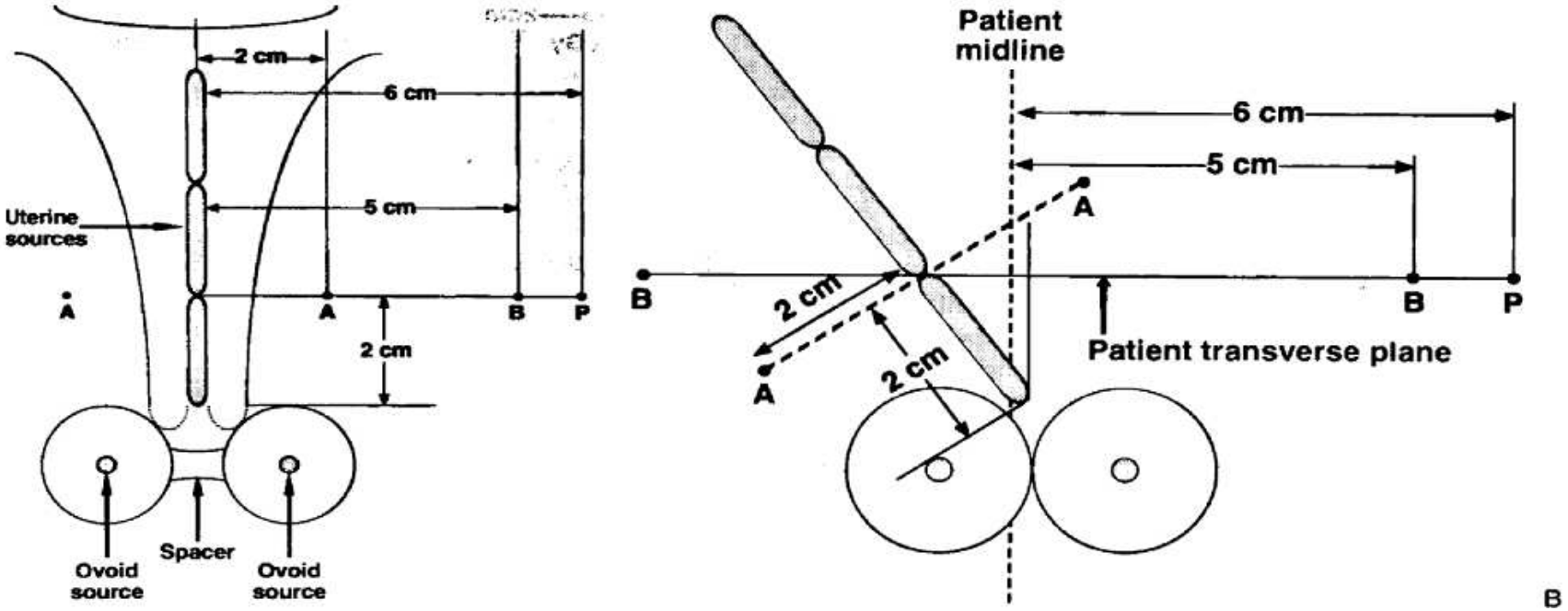
- **Milligram- hours (today equivalent is TRAK)**
- **Dose to point ‘A’ part of reporting even today**
- **ICRU - 60 Gy Reference Volume**

- **Dose to organs at risk**

Basic Principles of ICA

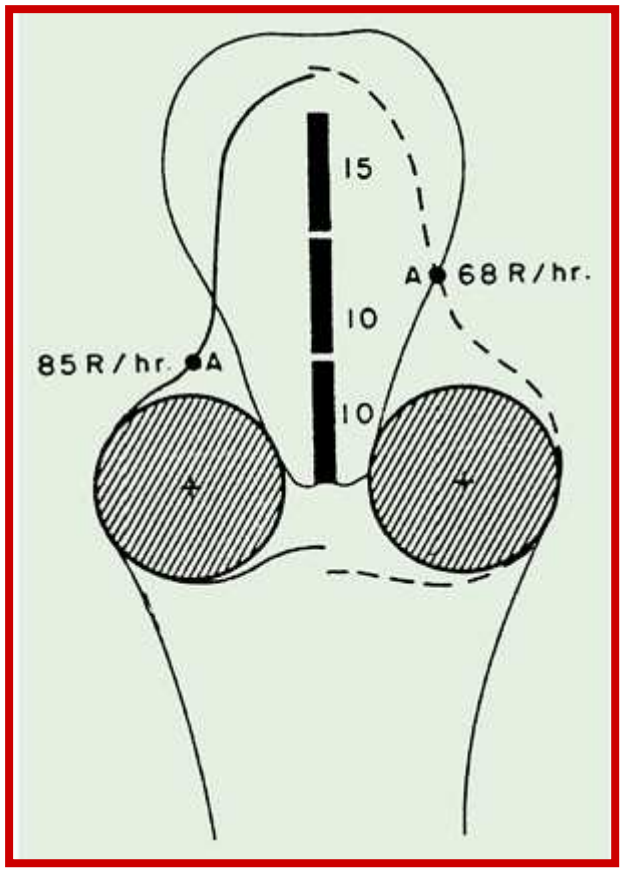
Definition of Point A

Pt A was originally defined as 2cm superior to the vaginal fornix & 2cm lateral to the cervical canal



Later it was redefined to be 2cm superior to the external cervical os (or lower end of tandem) & 2 cm lateral to the cervical canal

Basic Principles of ICA



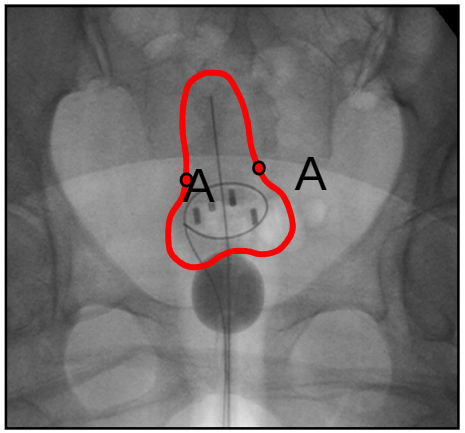
- In the revised definition Point A is now fixed to the tandem
- Since the distance from the caudal most intrauterine source tip to the colpostat centre

  (tandem to colpostat displacement)

  varies from patient to patient the vaginal contribution to revised Pt A is highly variable
- Hence dose delivered to the tumor will be incorrect

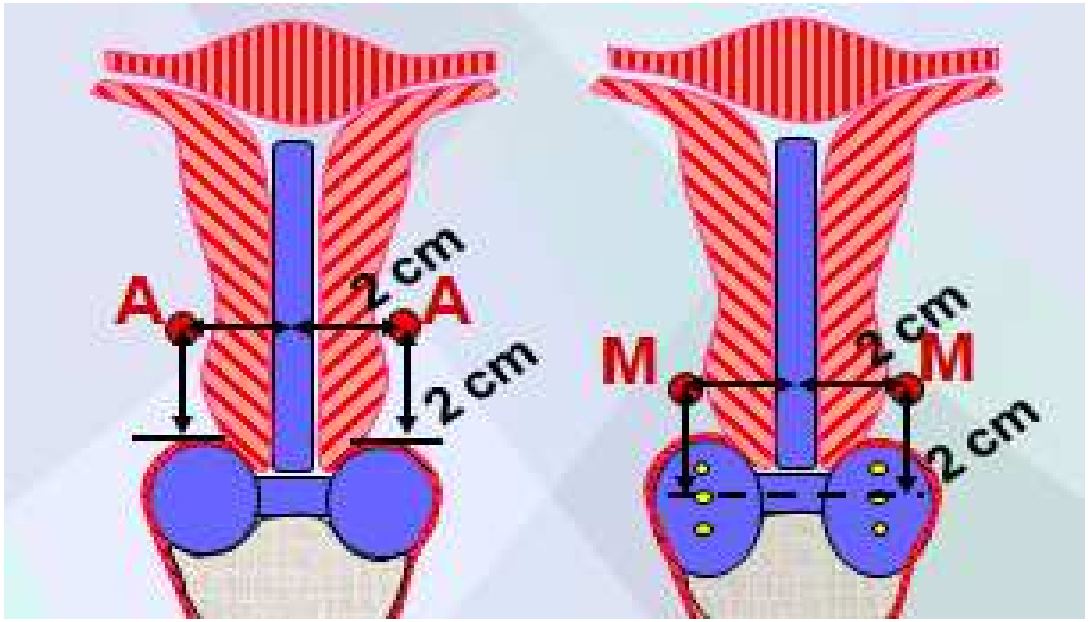
Target Dose: 2D

- **Point A:**
- **Current practice is to prescribe dose to Point A**
- **Empiric point, does not reflect dose to tumor**
- **Reference is with applicator**
- **It is located where dose gradiant is high i.e.about 10% per mm.**



Target Dose: 2D

- Inter & intra institutional inconsistencies in definition



Small inaccuracies in determination of distance

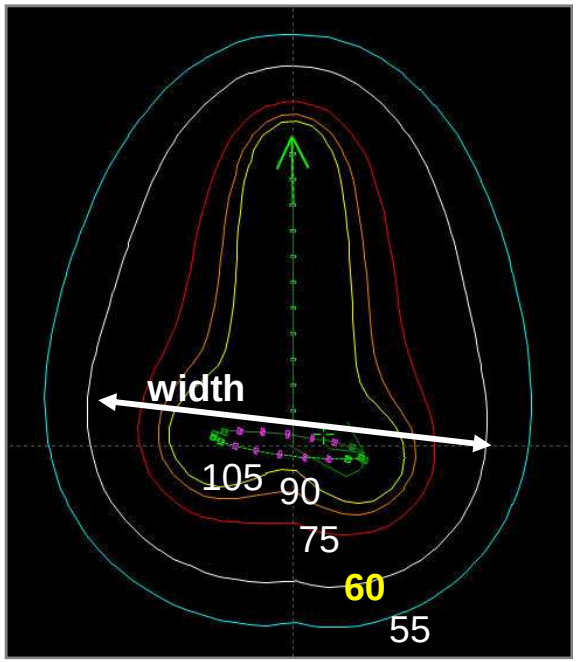
large difference in reported dose

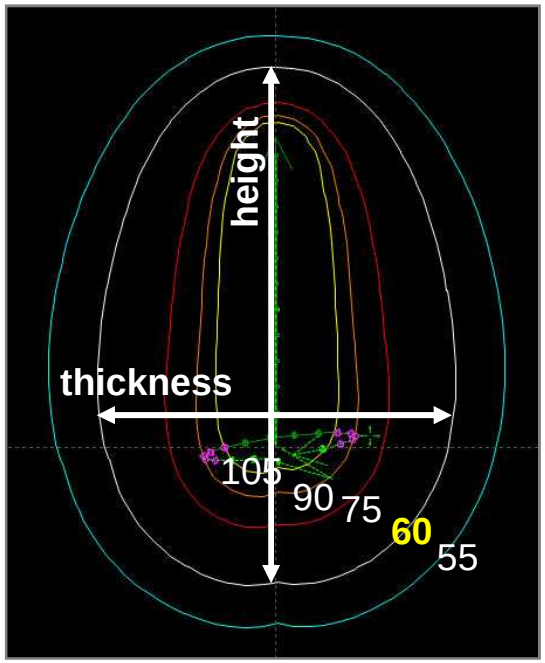
Target Dose: 2D

Reference volume

ICRU 38 recommended:
"...description of volume encompassed by *reference isodose* when reporting intracavitary BT..."

"...*60 Gy* accepted as *reference* level for LDR brachytherapy (equivalent dose in HDR, PDR)."





Reporting dimensions:

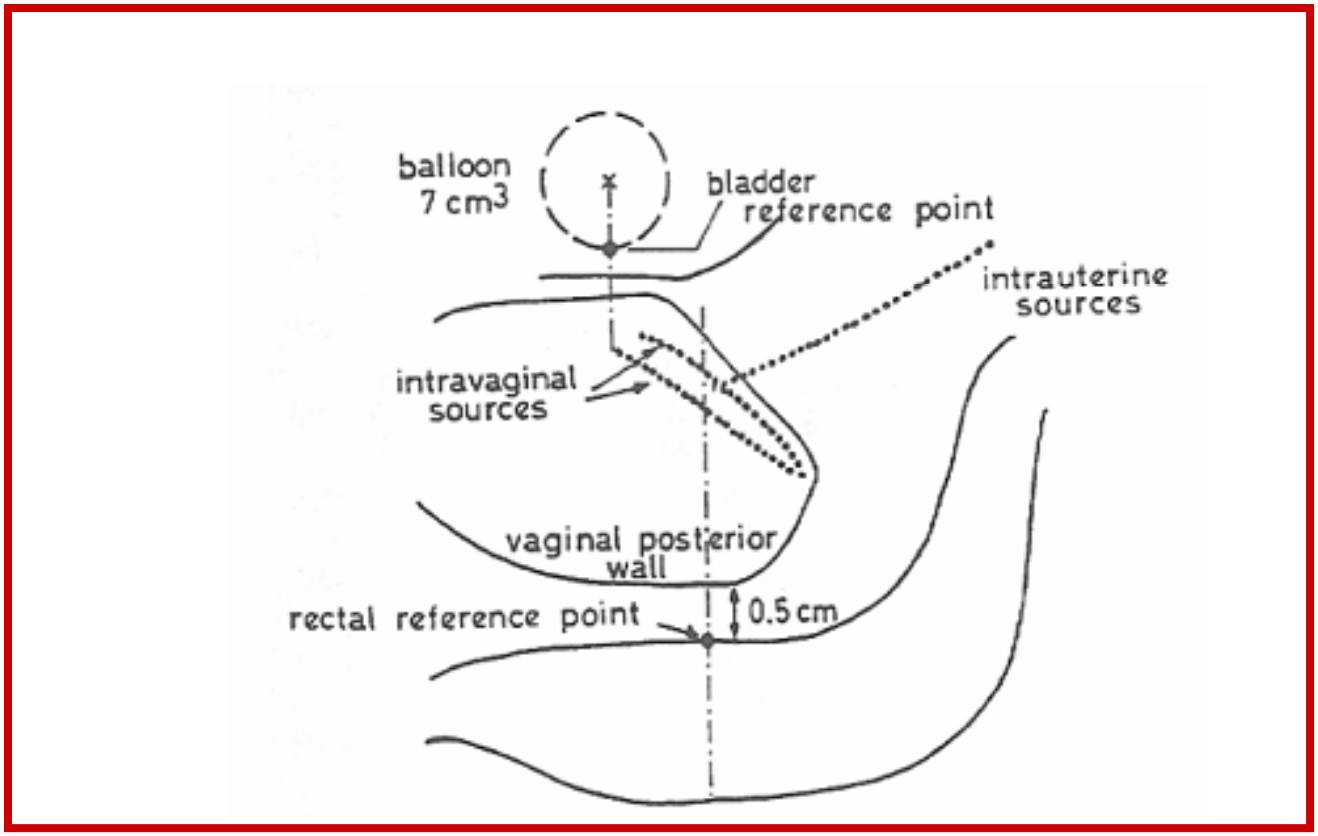
- **Width**
- **Thickness**
- **Height**

of the reference V

ICRU report 38, Bethesda, 1985.

Dose to Organs at risk: 2D

Dose to bladder and rectum: ICRU Points



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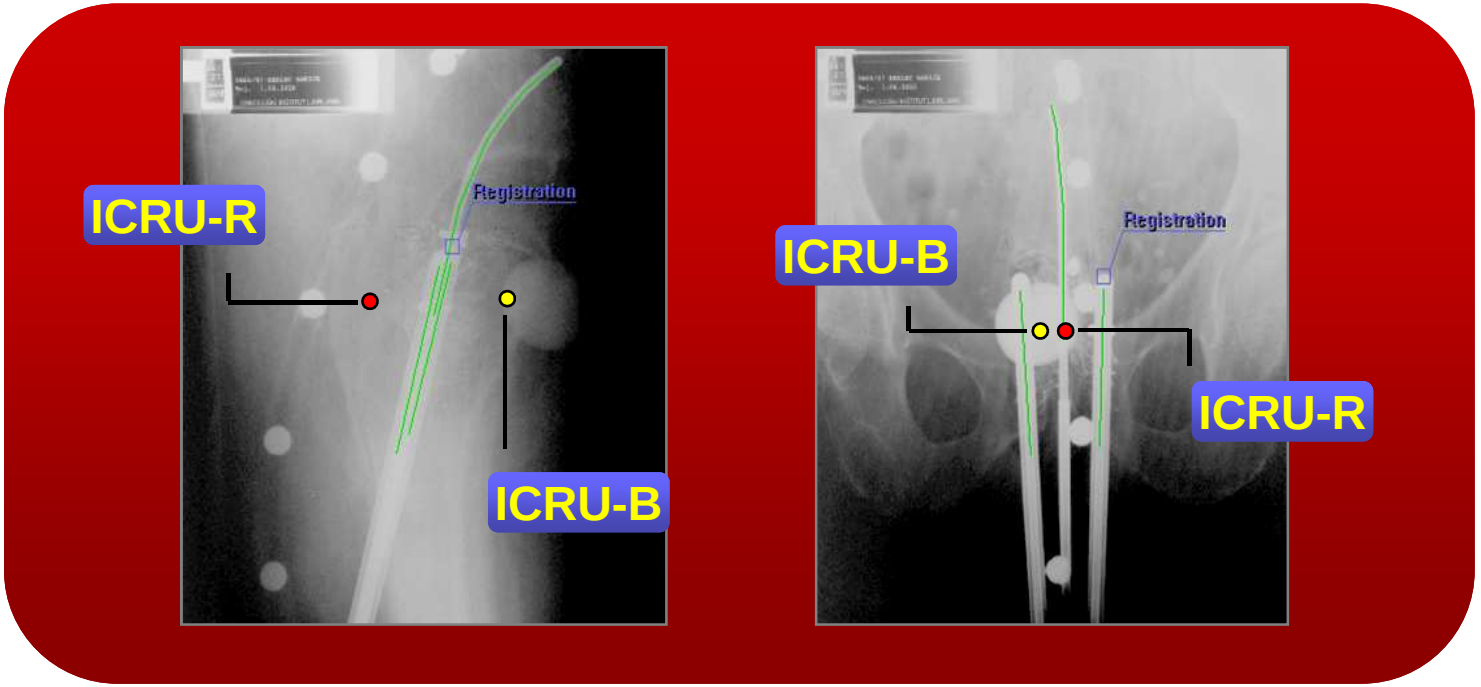
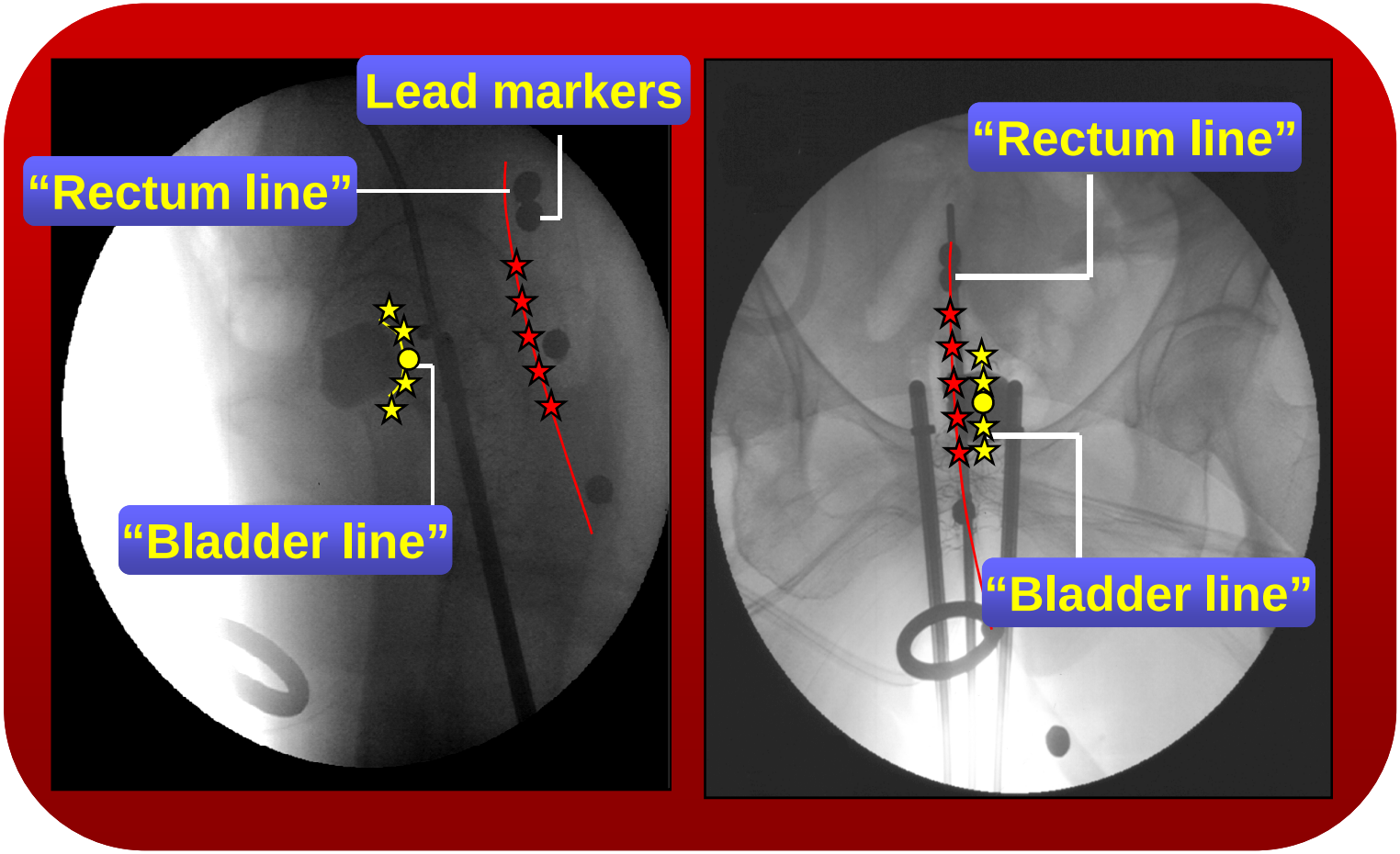


ICRU report 38, Bethesda, 1985.

Dose to Organs at risk: 2D

Do ICRU point-doses represent true D-max?

Looking for D-max: orthogonal radiographs



Deshpande DD, et al. 1997;42:163-6

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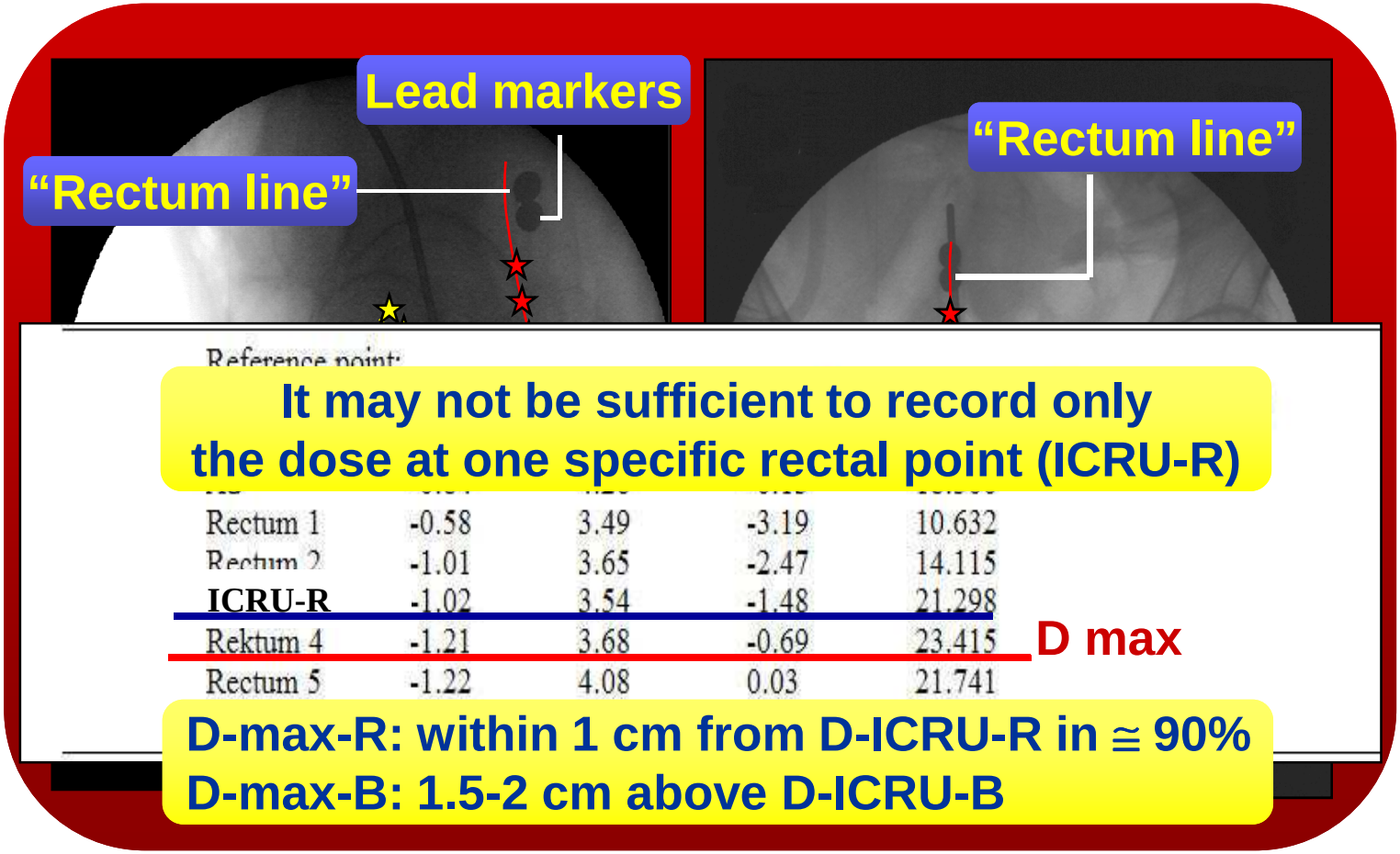
Do ICRU point-doses represent true D-max?

Looking for D-max: orthogonal radiographs



Deshpande DD, et al. 1997;42:163-6

Image Based Brachytherapy

Image Based Brachytherapy

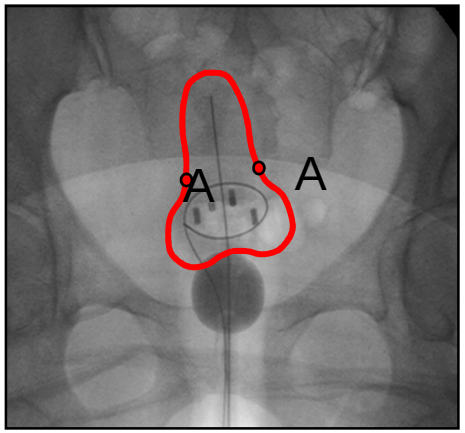
Image based brachytherapy:

- Technique where advanced imaging modalities are used to gain information regarding the volumetric dose distribution.

- The primary advantage of 3D Image Based brachytherapy is the possibility to *adapt* and *conform* the dose given by BT to the anatomy of each *individual patient* taking into account both tumor regression and the position of OARs

Target Dose: 2D

- **Point A:**



- **Current practice is to prescribe dose to Point A**
- **Empiric point, does not reflect dose to tumor**
- **Reference is with applicator**
- **It is located where dose gradiant is high i.e.about 10% per mm.**

Target Dose: 2D

- **Main limitation of 2D approaches:**

- **Absence of visual information on spatial relations between tumour and applicator**
  - **Where is the target volume (GTV? CTV?)**
  - **Where are the organs at risk?**

- **Clinical findings +Sectional imaging (MRI) help in visualising**
  - **Target, organs & applicator**
  - **Assess inter-relations**

Image Based Brachytherapy

- **Recently**
- **3D & 4D image–based brachytherapy treatment planning & dosimetry has been used for Cancer Cervix.**
- **Prescribed dose is always related to the target while the actual coverage can be evaluated with the use of DVH parameters**
- **Shape the spatial dose to conform to the target volume**
  - **Escalate dose to the tumor to produce greater rates of local control**
  - **Reduce dose to normal tissues & hence reduce the normal tissue toxicity.**

Image Based Brachytherapy

- **Tumor volume assessment**
  - **First based on Clinical Examination**
  - **Appropriate documentation in three dimensions**
  - **Sectional imaging gives information on tumor extension & configuration & its topography**

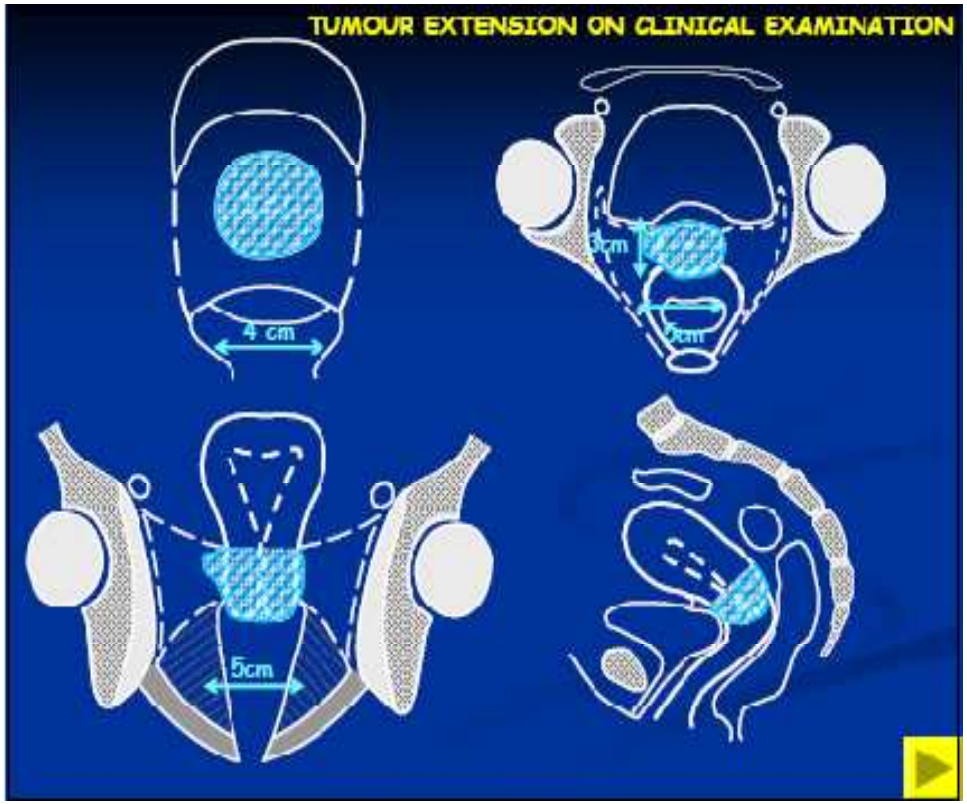
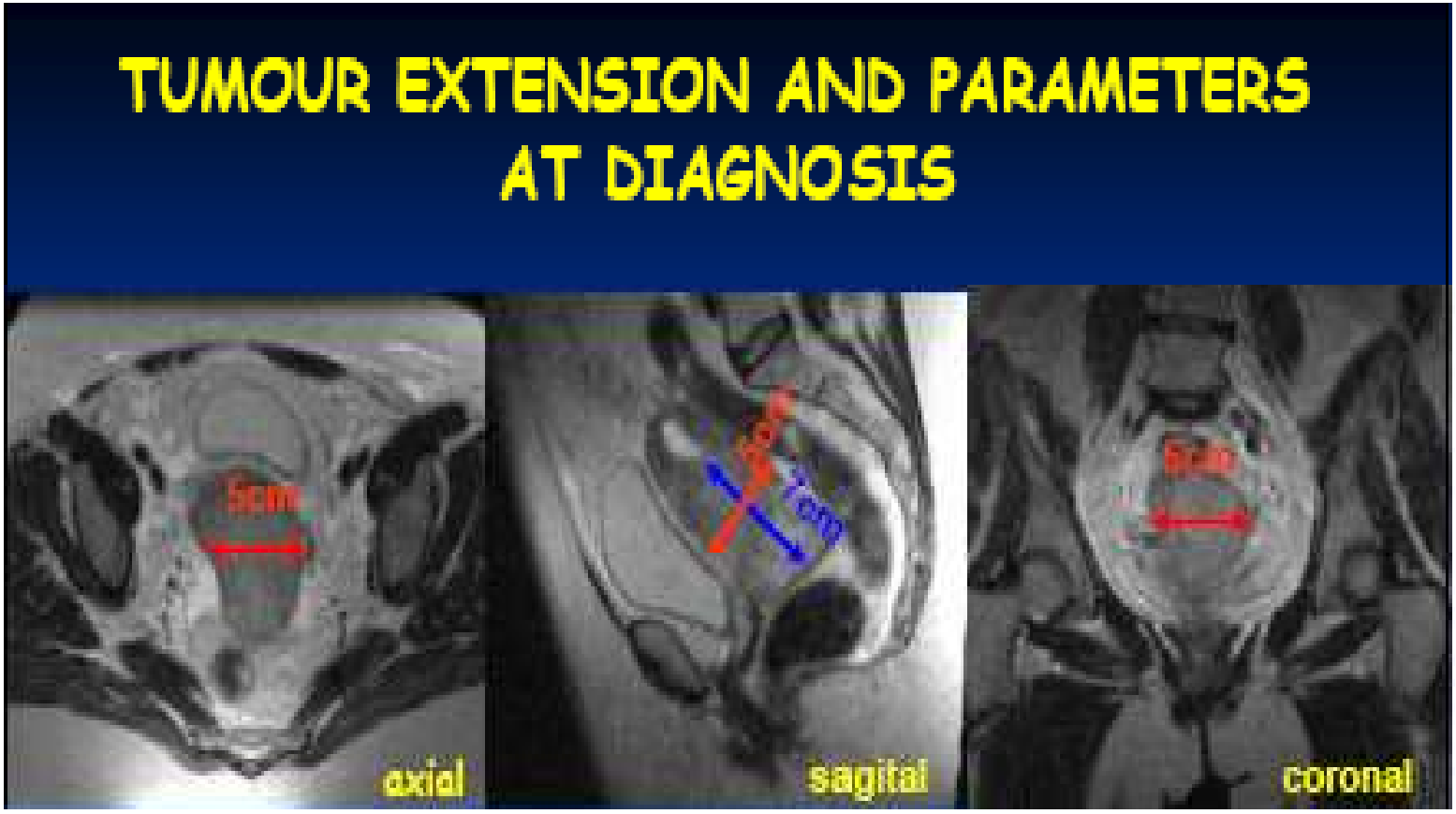
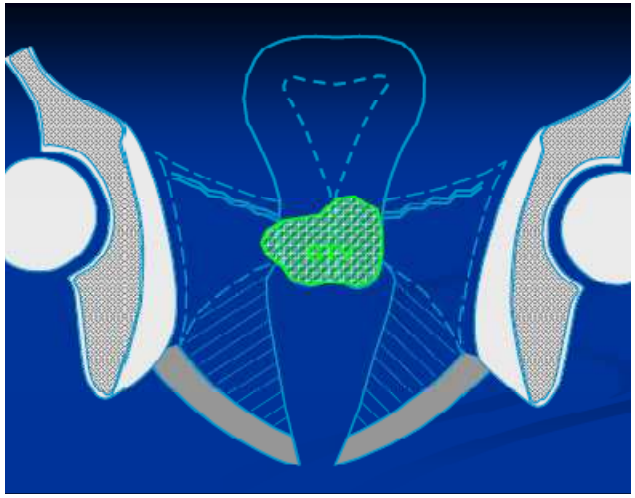


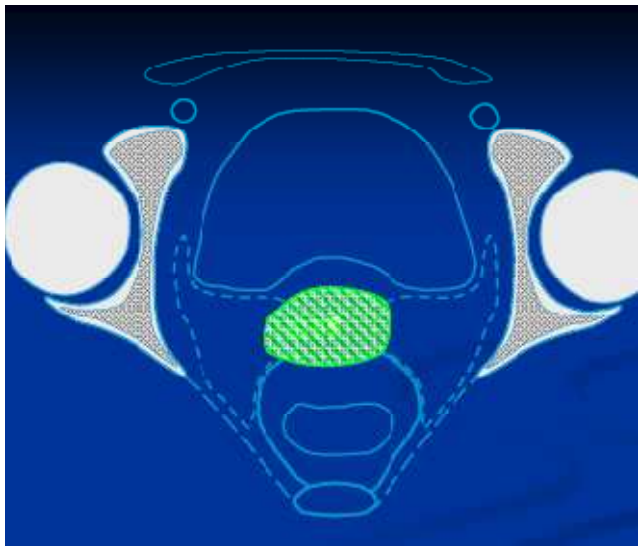
Image Based Brachytherapy



Target volume definitions

- **GTV**
  - Includes macroscopic tumor extension as detected by clinical examination (visualisation & palpation) & as visualised on MRI
  - Change of GTVs during treatment –
    - At diagnosis GTV_D
    - At brachytherapy GTV_B





Target volume definitions

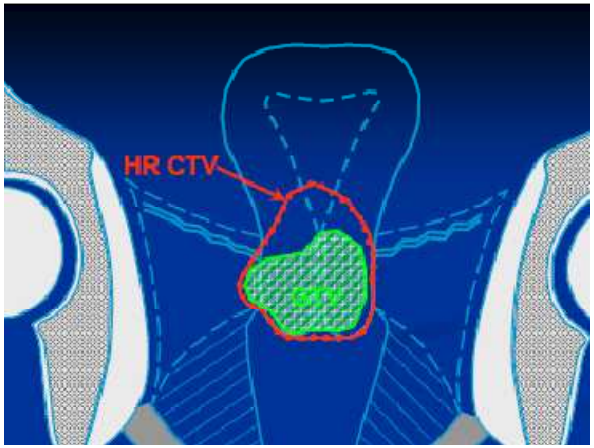
2 CTVs

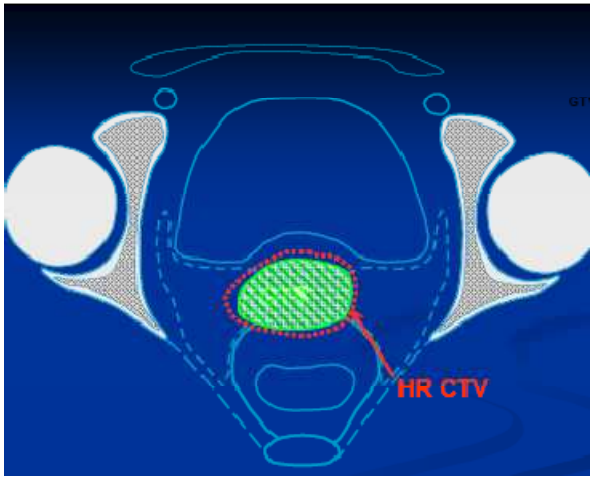
A first target related to the extent of GTV at time of BT: taking into account tumour extent at diagnosis.

- **High risk CTV**
- **Major risk of recurrence because of residual macroscopic tumor**
- **Intent is to deliver a total dose as high as possible to eradicate all residual macroscopic tumor**
- **High dose prescribed to this target (80-90+Gy)=dose to point A**

Target volume definitions

- **HR CTV includes**
- **GTV, whole of the cervix, & presumed extracervical tumor extension.**
- **Pathologic residual tissue(s) as defined by palpable indurations &/or grey zones in parametria, uterine corpus, vagina, bladder or rectum are included in HR CTV**
- **No safety margins are added**





Target volume definitions

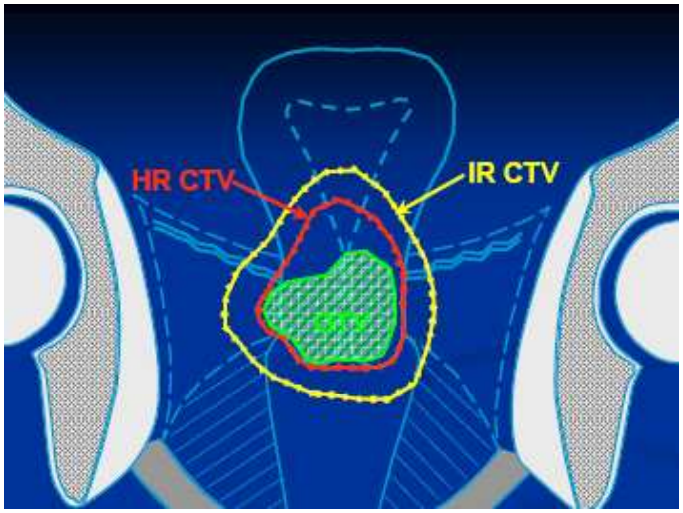
2 CTVs

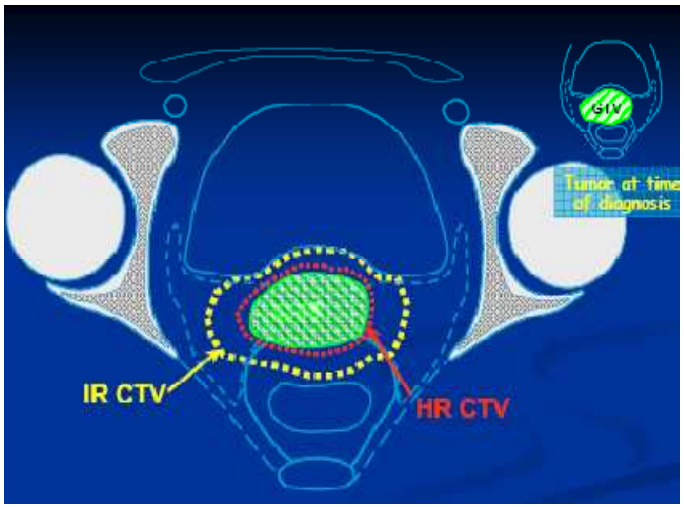
A second target related to the extent of GTV at diagnosis :

- **Intermediate risk CTV**
- **Major risk of recurrence in areas that initially had macroscopic extent of disease with residual microscopic disease at time of BT**
- **Intent is to deliver dose appropriate to cure microscopic disease in cervix cancer, which corresponds to a dose of 60Gy**
- **It includes the HR CTV plus the initial tumor extension at diagnosis**

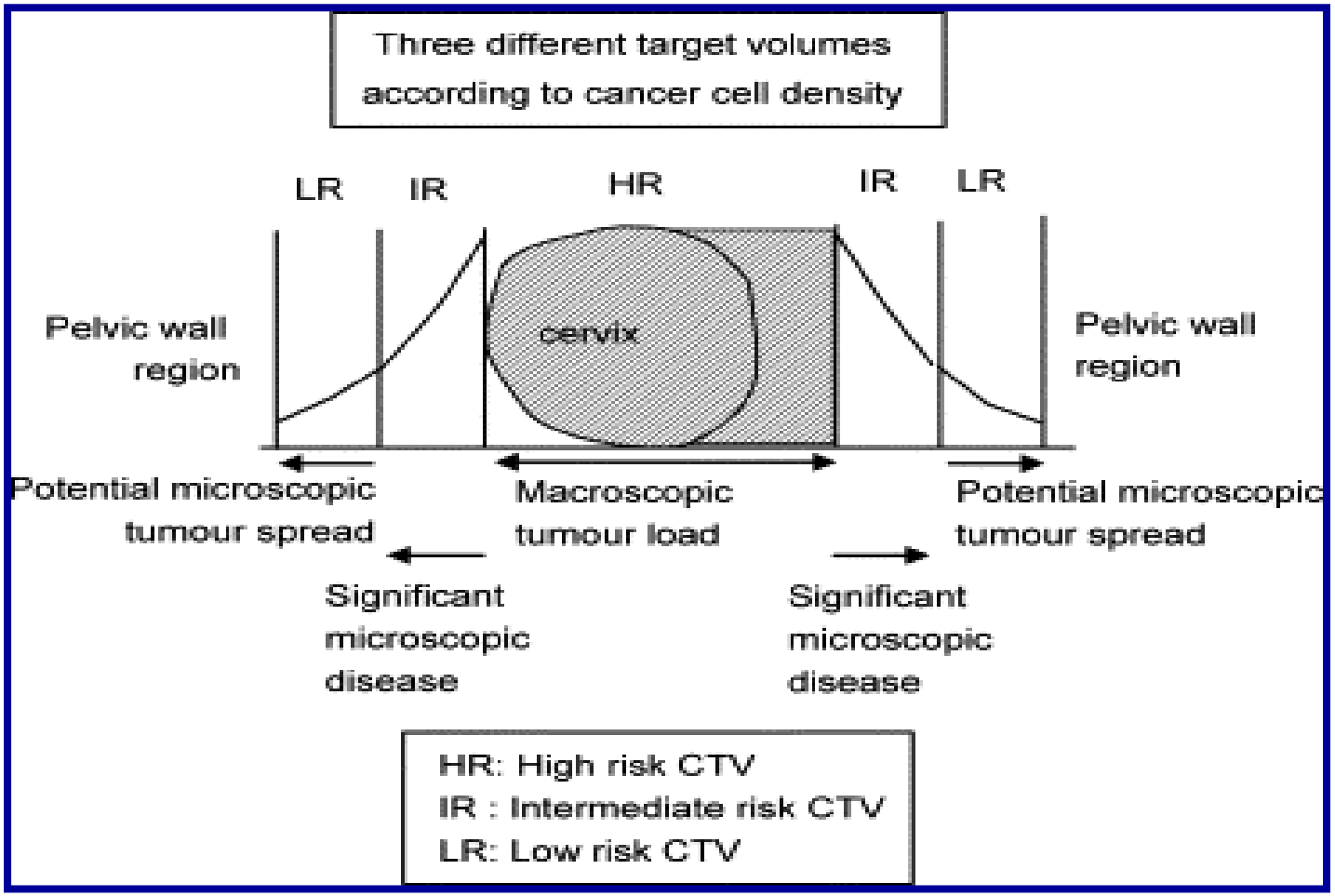
Target volume definitions

- **IR CTV includes**
- **HR CTV plus the initial tumor extension at diagnosis**
- **IR CTV encompases the HR CTV with a safety margin of 5-15 mm margin**
- **Safety margin is chosen according to the tumor site & location, & the amount of tumor regression**





Target volume definitions



Haie-Meder, Radiot & Oncol, 74, 2005

Image Based Brachytherapy

❑ Dose prescription

- ❑ The prescribed dose is always related to the target.
- ❑ The prescription dose is the planned dose to cover this target as completely as possible.
- ❑ The actual coverage can be evaluated with the use of DVH parameters
- ❑ Coverage of the target can be improved starting from the standard dose prescription & careful adaptation of the loading pattern & dwell times
- ❑ Finally dose can be prescribed to an image-based target
- ❑ For comparison, dose reporting should refer to the prescribed dose to the image-based target & to the traditional system

Image Based Brachytherapy

❑ Dose volume parameters

- ❑ **D100 & D90** – minimum dose delivered to 100 & 90% of the volume of interest respectively
- ❑ D100 is extremely dependent on target delineation.Due to steep dose gradiants, small spikes in the contour cause large deviations in D100
- ❑ **D90** is less sensitive to these influences & is therefore considered a more **'stable'** parameter

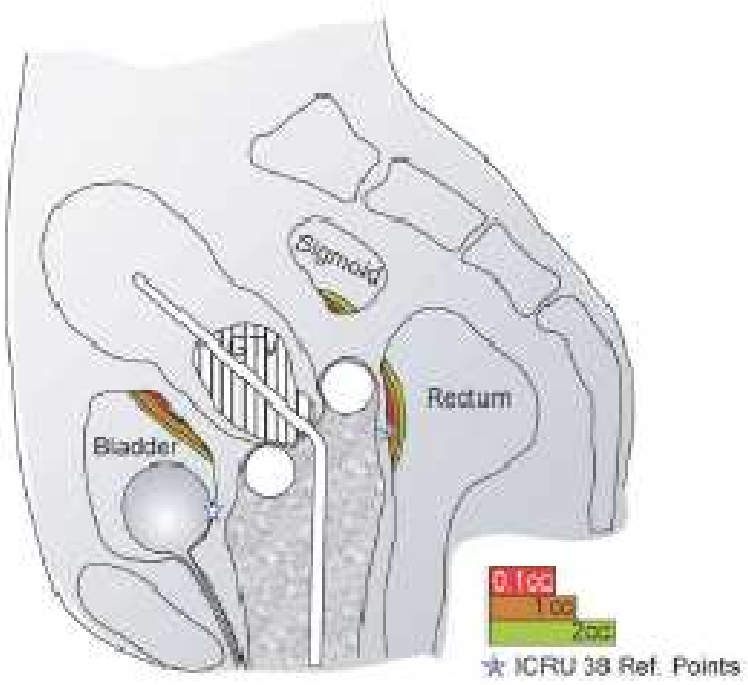
- ❑ **V(60 Gy_{EQD2})** plays a role for evaluating the **IR CTV**
- ❑ **V(85 Gy_{EQD2})** represents more closely the prescription dose to the **HR CTV**

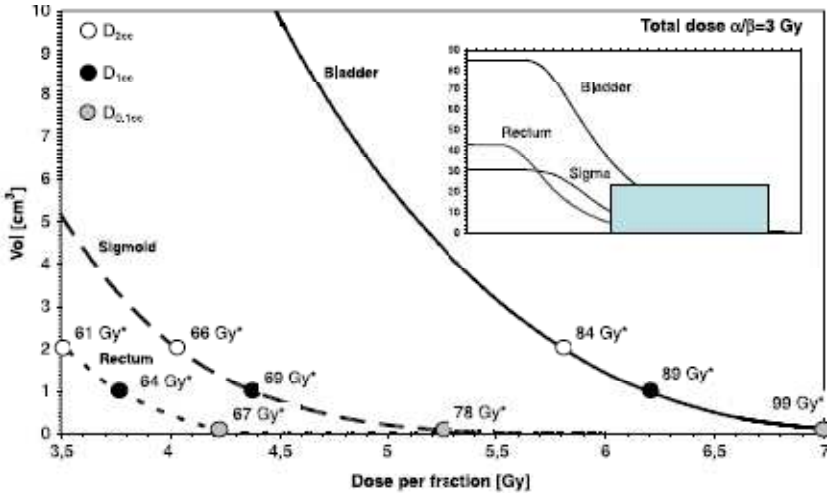
Image Based Brachytherapy

❑ OARs

- ❑ As there is a rapid dose fall-off near the sources, in particular in adjacent small organ (wall) volumes, dose assessment has to refer to one (or more) defined dose points in these limited volumes
- ❑ The minimum dose in the most irradiated tissue volume adjacent to the applicator (0.1,1,2,5cm^3)is recommended for recording & reporting
- ❑ It is assumed that these volumes are contiguous
- ❑ This is wrongly called as the ‘maximum dose’ to a 2cm^3 tissue

Image Based Brachytherapy





Potter, Radiot & Oncol, 78,2006

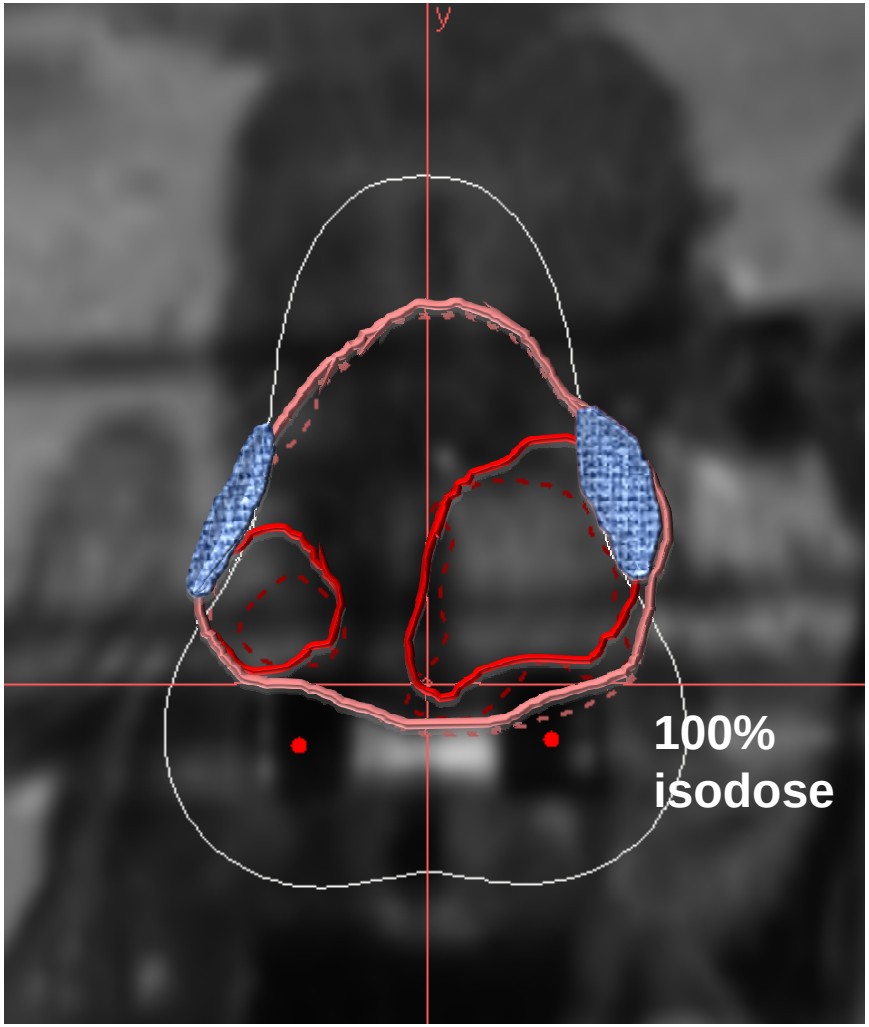
Image Based Brachytherapy

❑Dose volume constraints

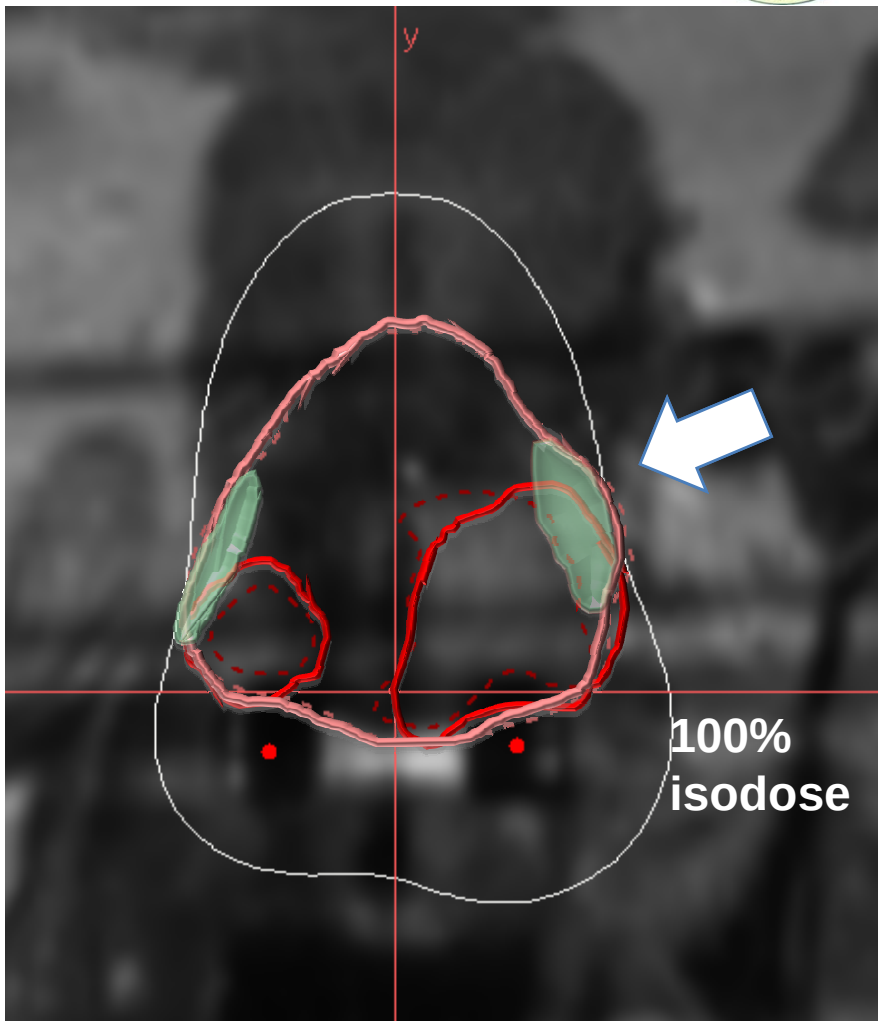
- ❑ 2 cm^3 of rectum & sigmoid — <75 Gy_3
- ❑ 2 cm^3 of bladder — < 90 Gy_3
- ❑ High risk CTV & D_{90} — greater than the PD

  V_{100} > 90%

Optimisation of treatment plans



PRESCRIPTION TO POINT A



OPTIMIZATION FOR TARGET COVERAGE

Conclusions

- Image based brachytherapy is feasible in our setup.
- Patients who present with bulky disease are the ones who benefit the most and this is relevant to the Indian scenario.
- The mean D90 of the GTV_{BT} was 120.9 Gy EQD2 – which no form of IMRT or any conformal EBRT technique can achieve.
- It is very labour intensive & needs a good team work
- During optimisation, basic principles must be remembered & followed.

Basic Principles of ICA

Thank you