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

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.**

Dose escalation

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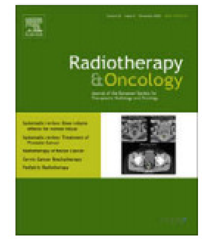


Cervix cancer brachytherapy

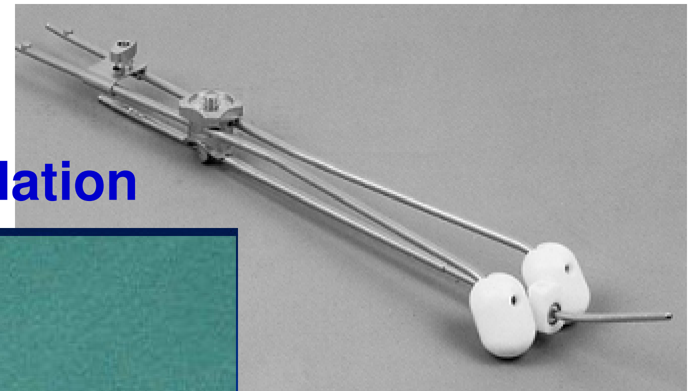
Dose–effect relationship for local control of cervical cancer by magnetic resonance image-guided brachytherapy

Johannes C.A. Dimopoulos [a,*], Richard Pötter [a], Stefan Lang [a], Elena Fidarova [a], Petra Georg [a], Wolfgang Dörr [b], Christian Kirisits [a]

D90 of HRCTV	Local reccurrence
<87 Gy	20%
>87Gy	4%

Basic Principles of ICA

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



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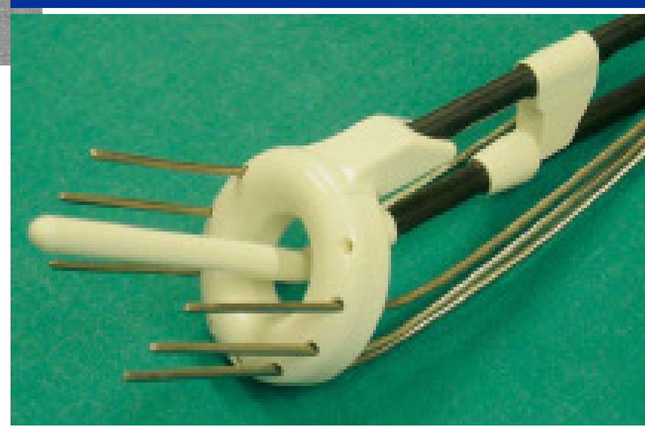
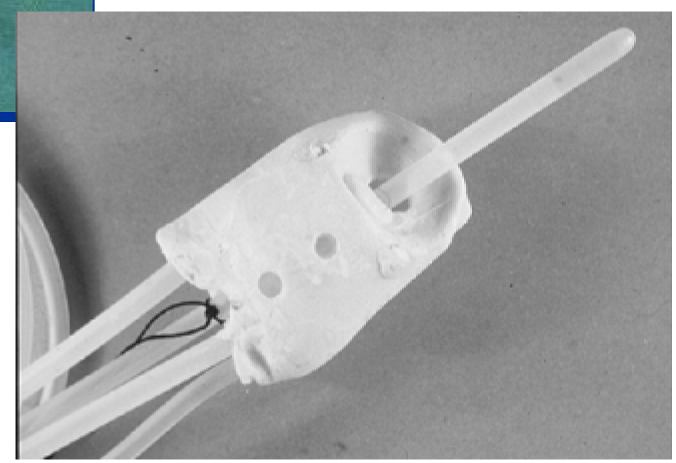




Personaliseed

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**

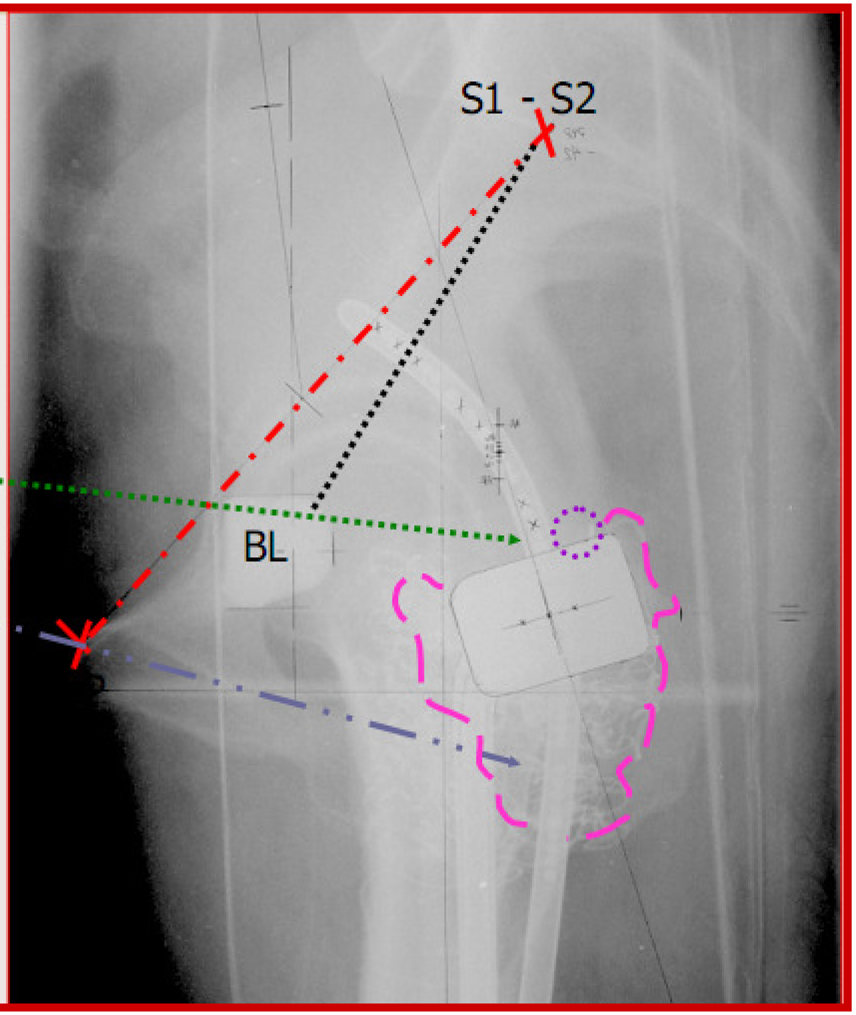
- **Rectal dose should be <75 Gy**

- **Bladder dose should be <80 Gy**

Basic Principles of ICA

Lateral View of Applicator Placement

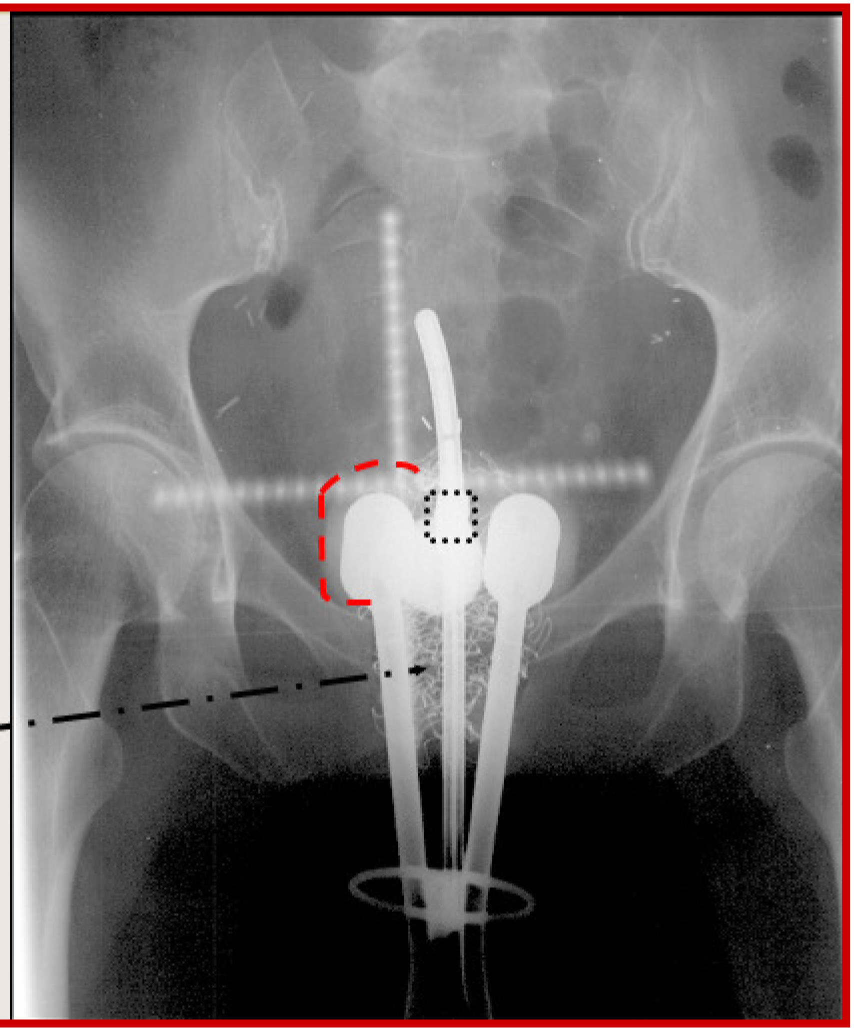
- Tandem - 1/3 of the way between S1 – S2 and the symphysis pubis
- The tandem - midway between the bladder and S1 - S2
- Marker seeds should be placed in the cervix
- Ovoids should be against the cervix (marker seeds)
- Tandem should bisect the ovoids
- The bladder and rectum should be packed away from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



Basic Principles of ICA

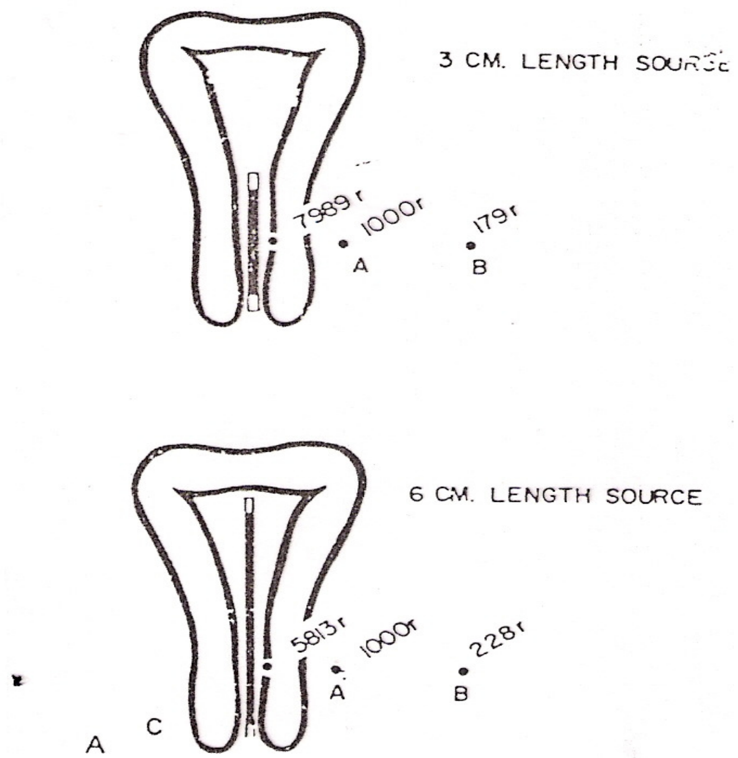
Anterior – Posterior View of Applicator Placement

- 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



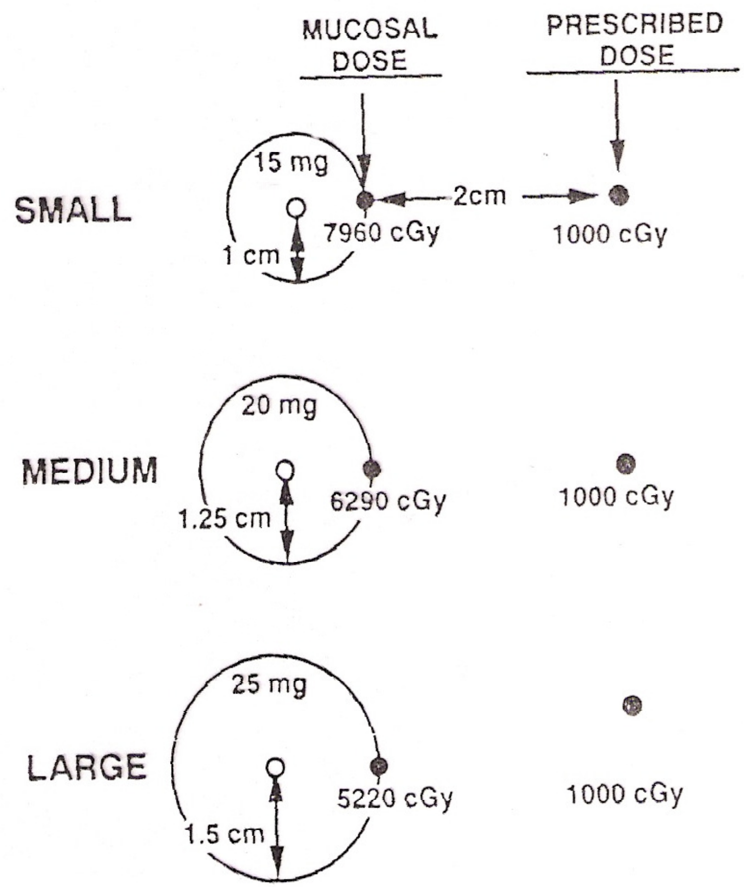
Basic Principles of ICA

- **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

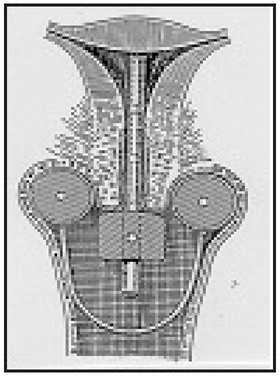
- **Ovoid Loading**
- **The largest ovoids that permits adequate separation to admit the flange on the tandem between them without causing downward displacement of the ovoids should be used.**
- **In order to optimize the ratio between the dose at depth and the vaginal mucosal dose.**
- **As colpostat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



Basic Principles of ICA

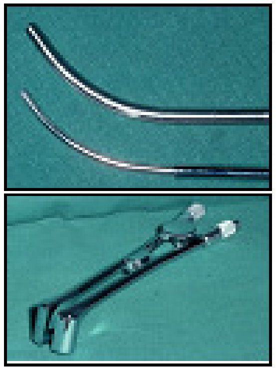
Historical Systems / Techniques

Paris

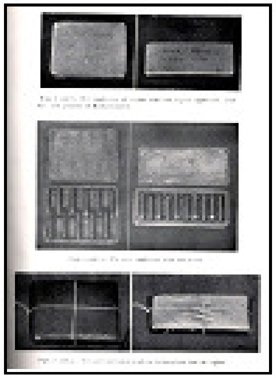


Manchester

Fletcher



Stockholm



Sets of rules

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

mgh

FOR A GIVEN TUMOUR VOLUME

Manchester system: point A introduction

Basic Principles of ICA

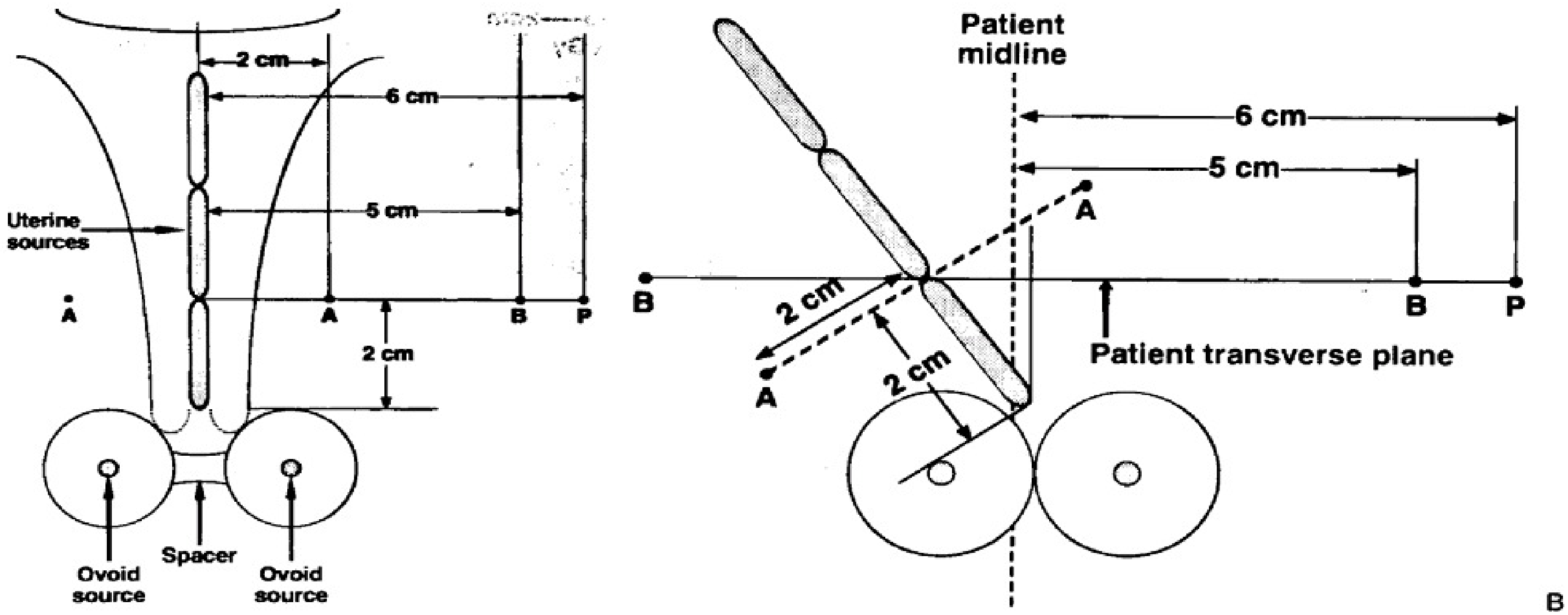
- **Manchester System**
- **Developed by Todd & Meredith in 1930**

- **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

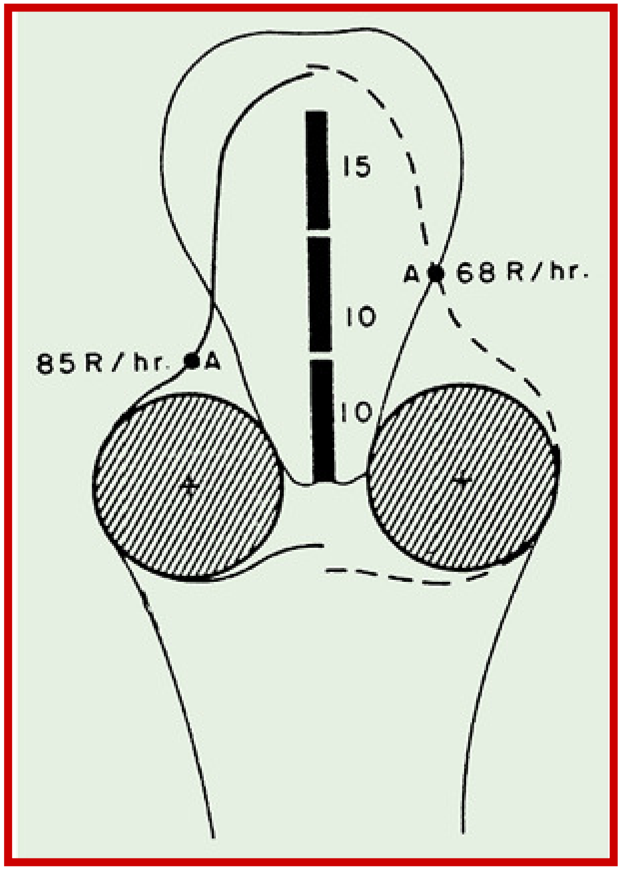
Definition of Point A

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

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 $\mu Gy\ h^{-1}$ (2.5 mg radium equivalent).

Basic Principles of ICA

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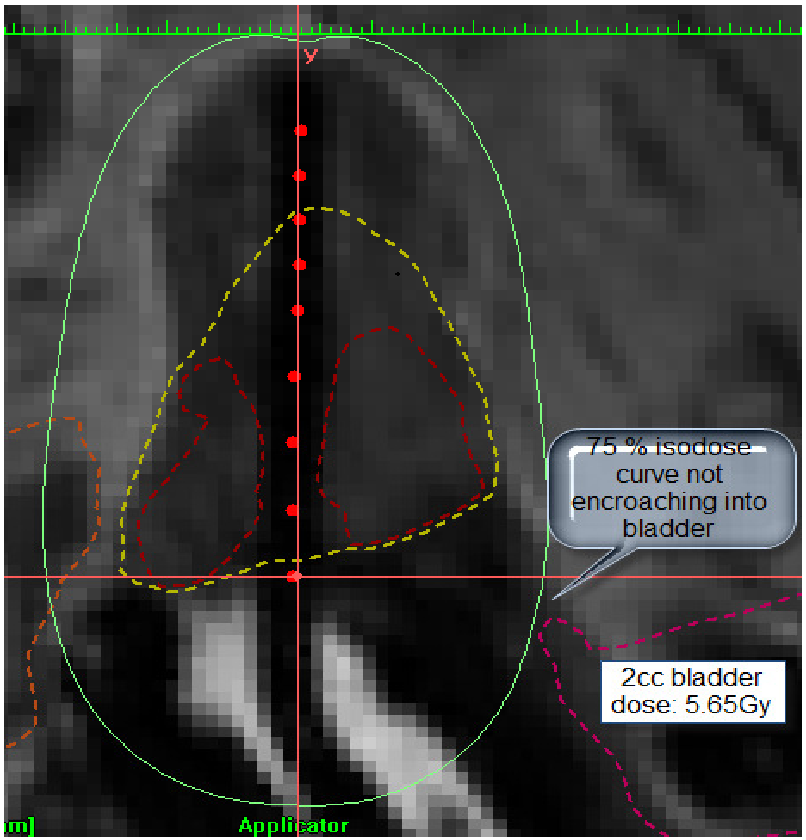
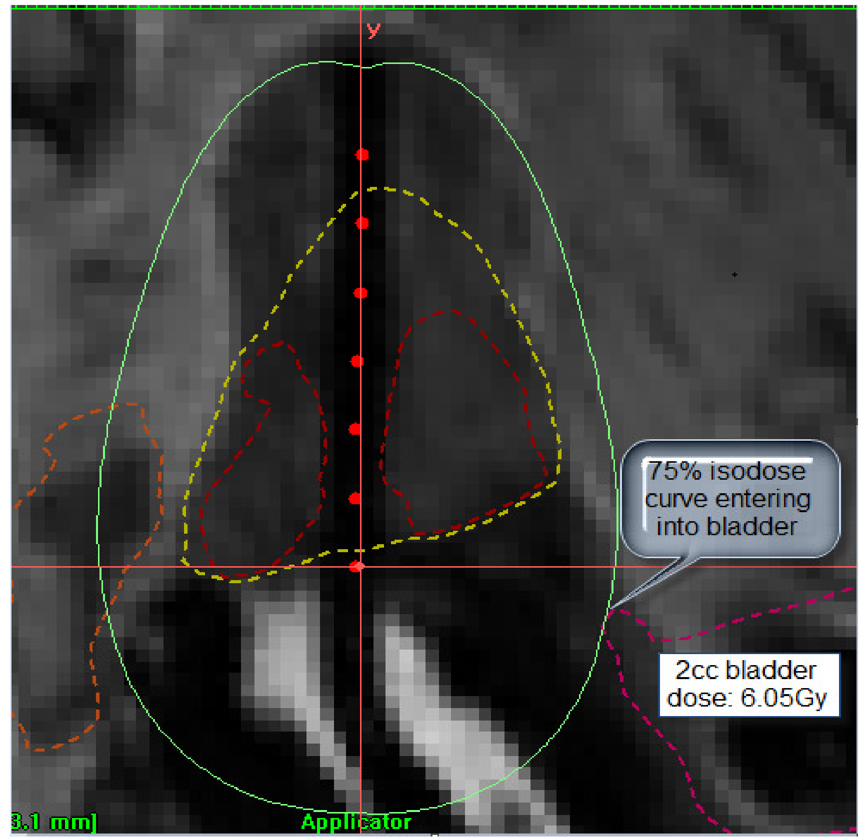
Basic Principles of ICA

Tandem Loading





1, 3, 5, 7, 9,12,15,18,21 Pt A – 700 cGy

Bladder – 266 cGy

Rectum – 390 cGy

3, 6, 9,12,15,18,21 Pt A – 700 cGy

Bladder – 281 cGy

Rectum – 416 cGy

Basic Principles of ICA

Optimisation

Analyzed parameters using 2.5 mm step positions for uterine tandem

	T_u/T_v						
	1:4	1:3	1:2	1:1[a]	1:0.5	1:0.33	1:0.25
D_A (%)	100	100	100	100	100	100	100
D_R (%)	58.3	55	48.9	40.6	34.9	32.6	31.3
D_B (%)	55	54.5	53.4	52.1	51.1	50.8	50.5
$D_{B\ mean}$ (%)	28.4	28	26.9	25.6	24.7	24.4	24.1
h (cm)	9.1	9.1	9.0	8.8	8.7	8.6	8.6
w (cm)	6.5	6.3	6.1	5.5	5.0	4.7	4.6
t (cm)	4.0	3.9	4.0	3.9	3.9	4.0	4.1
hwt (cm^3)	236.2	224.7	218.4	186	170.3	162.8	160.3
T_{tot} (s)	656.5	653.9	637.9	621.6	609.1	607	602

[a] In the 1:1 (T_u/T_v) ratio, the treatment time for each step was 16.8 s when delivering 100 cGy to point A.

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.

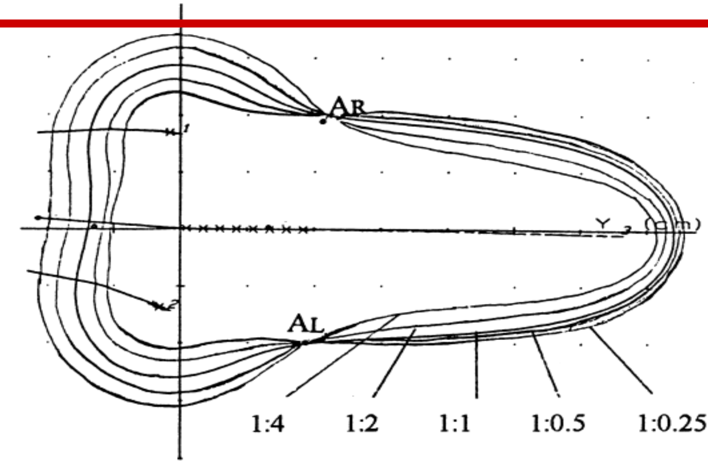


Fig. 4. Oblique coronal views of the reference dose distribution of uterine and vaginal sources with 2.5 mm steps for (T_u/T_v): 1:1; 1:2; 1:4; 1:0.5; and 1:0.25 ratios.

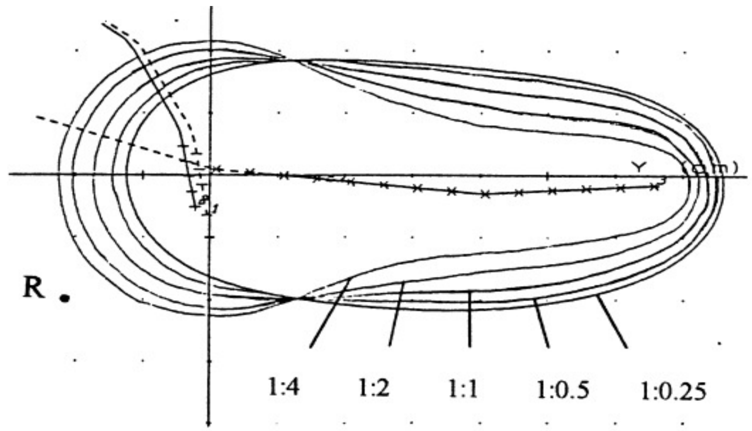


Fig. 7. Oblique sagittal views of the reference dose distribution of uterine sources with 5 mm steps and vaginal sources with 2.5 mm steps for (T_u/T_v): 1:1; 1:2; 1:4; 1:0.5; and 1:0.25 ratios.

Target Dose: 2D

Historical (1D)

Target

2D

3D/4D

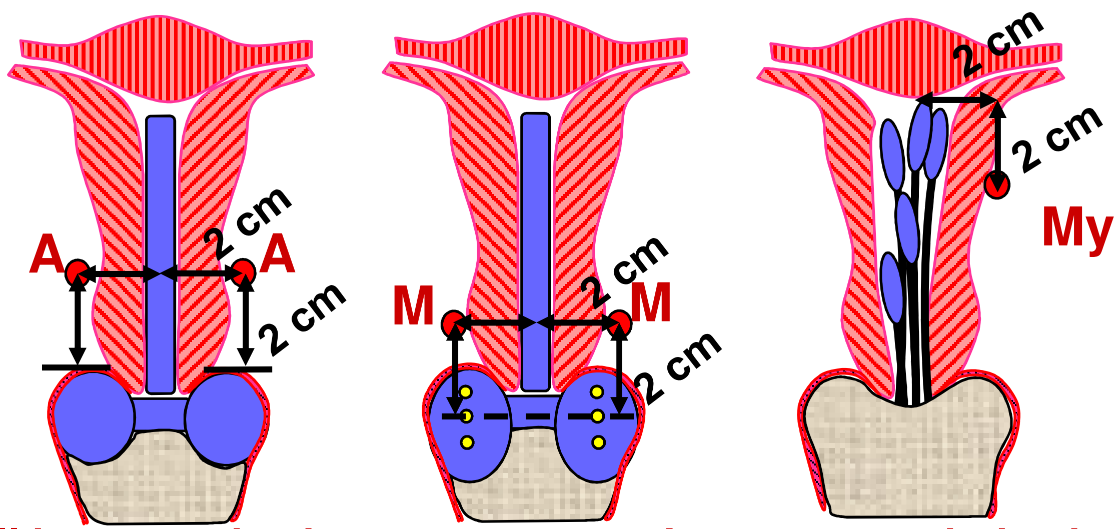
OAR

2D

3D/4D

Points

- Related to and close to sources
- Within steep dose gradient
- Depend on applicator geometry (may differ left vs. right)
- Inter- and intra-institutional inconsistencies in definition



Small inaccuracies in determination of distances → Large uncertainties in reported dose

ICRU 38:
"...points: not appropriate for specification of dose to the target..."

SIGNIFICNAT CLINICAL EXPERIENCE ACCUMULATED → POINTS STILL WIDELY USED IN CLINICAL PRACTICE

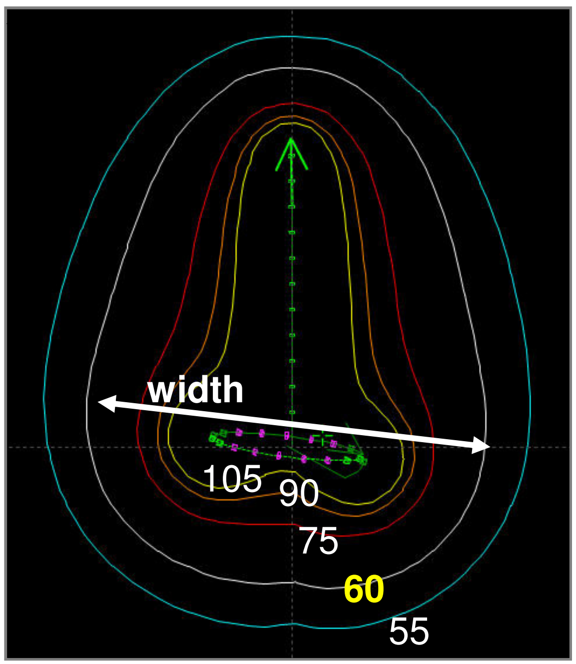
ICRU report 38, Bethesda, 1985.

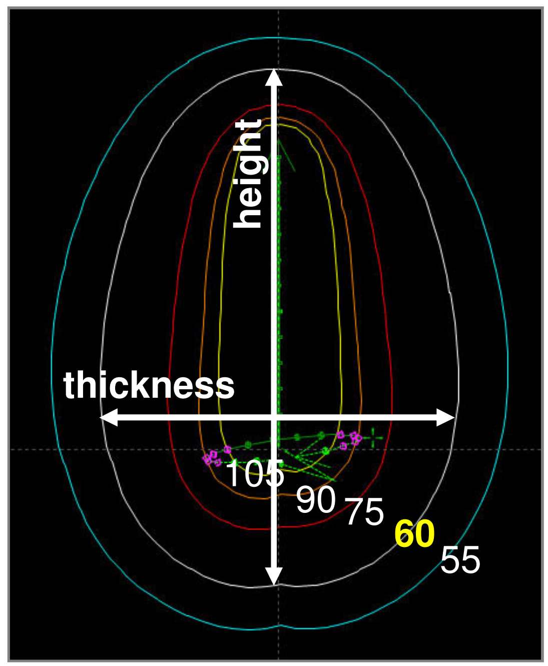
Target Dose: 2D

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)."





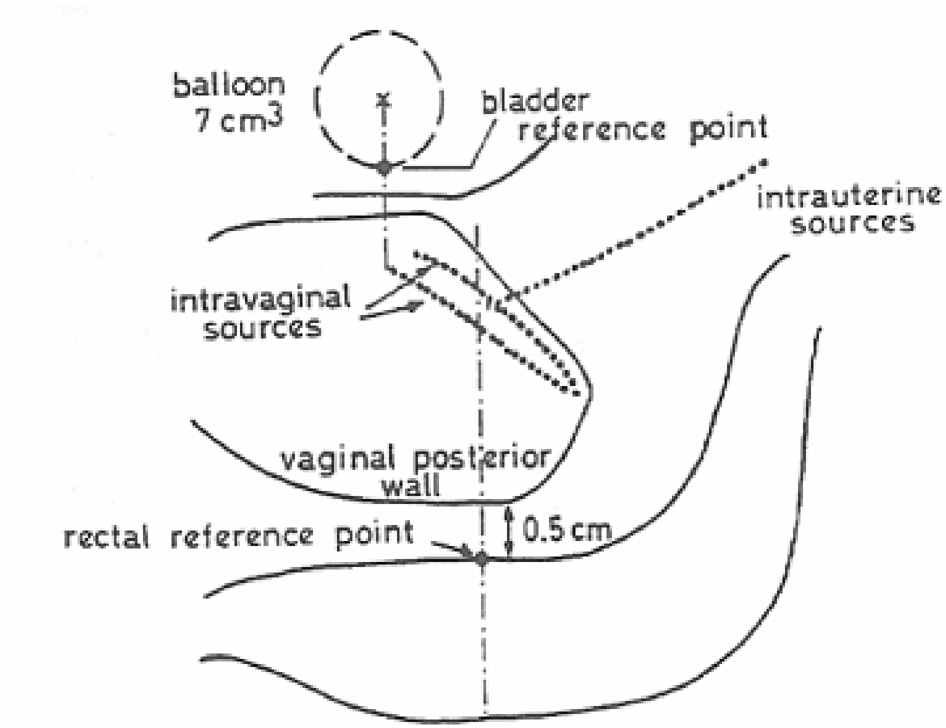
Reporting dimensions:
- **Width**
- **Thickness**
- **Height**

of the reference V

ICRU report 38, Bethesda, 1985.

Dose to Organs at risk: 2D

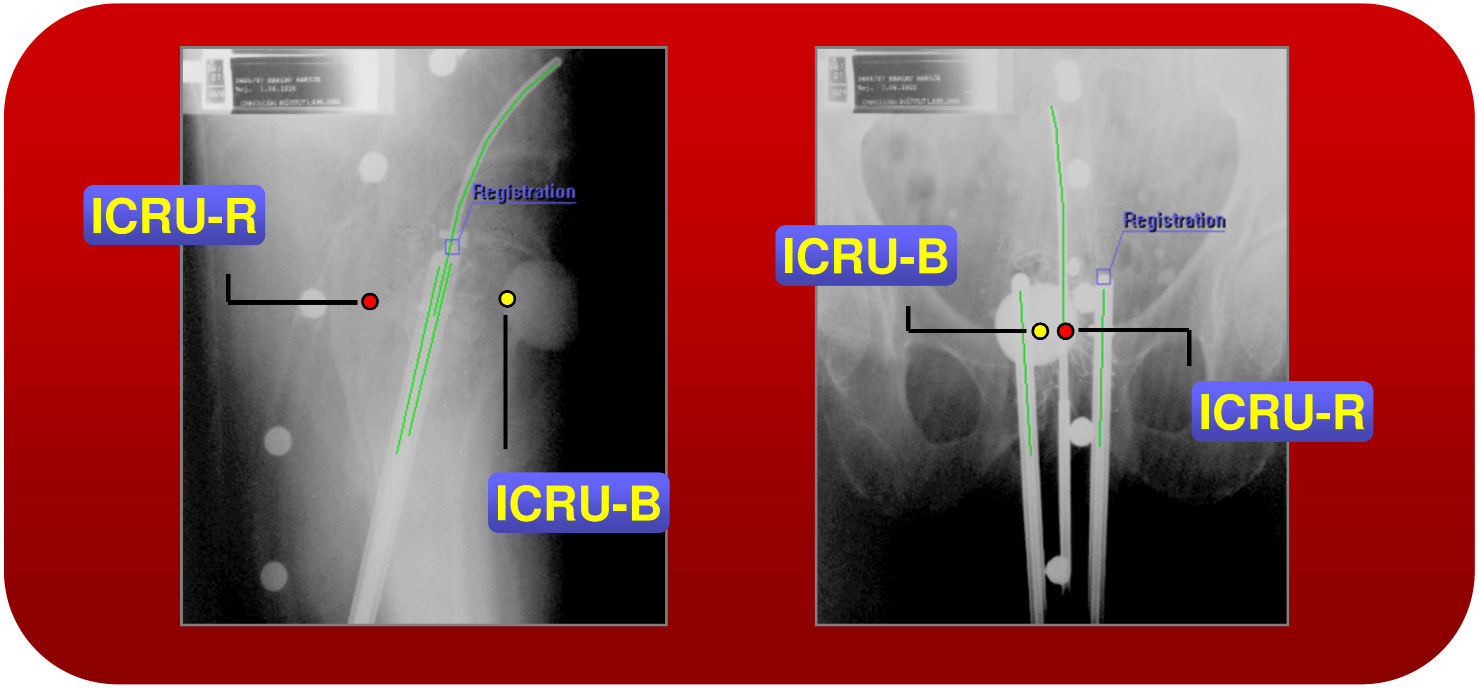
Dose to bladder and rectum: ICRU Points



Historical (1D)
Target
2D
3D/4D
OAR
2D
3D/4D

Dose to Organs at risk: 2D

Dose to bladder and rectum: ICRU Points



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

Historical (1D)

Target

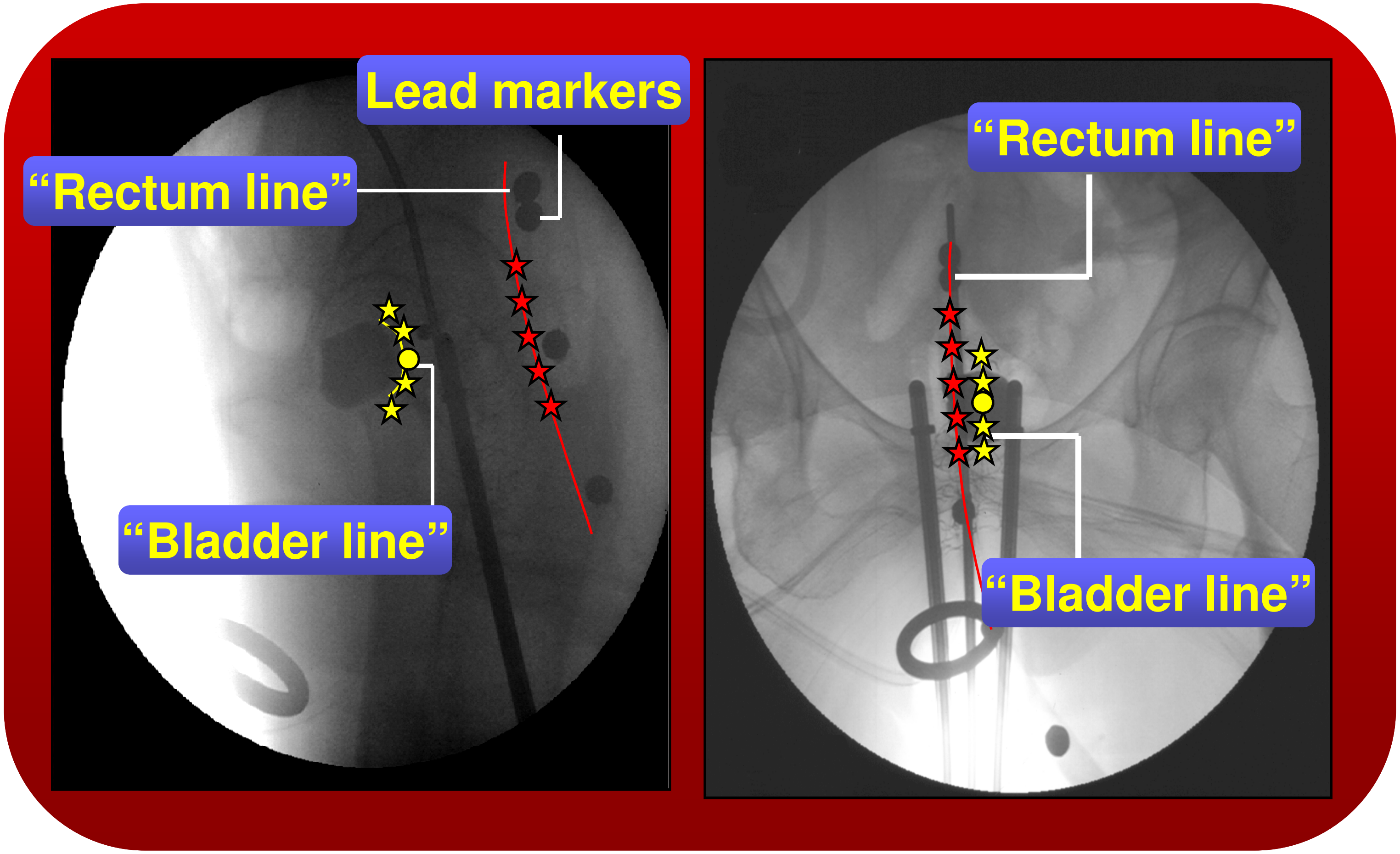
2D

3D/4D

OAR

2D

3D/4D

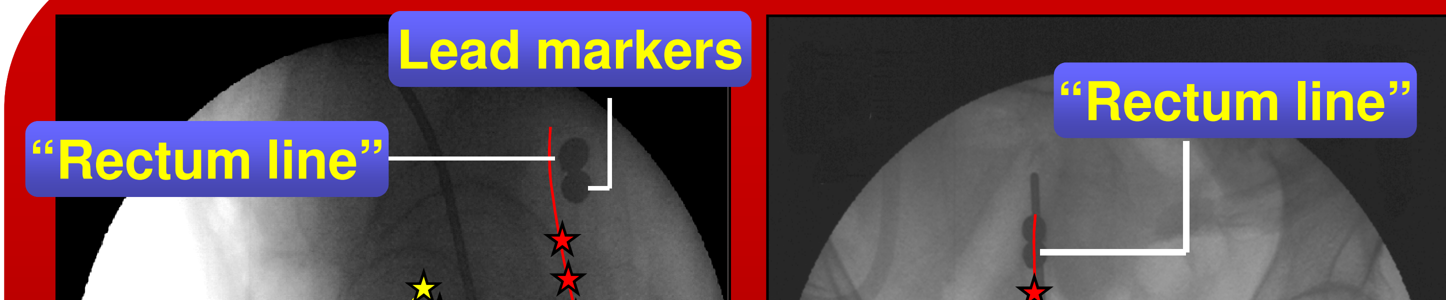


Deshpande DD, et al. 1997;42:163-6

Dose to Organs at risk: 2D

Do ICRU point-doses represent true D-max?

Looking for D-max: orthogonal radiographs



Reference point:

It may not be sufficient to record only the dose at one specific rectal point (ICRU-R)

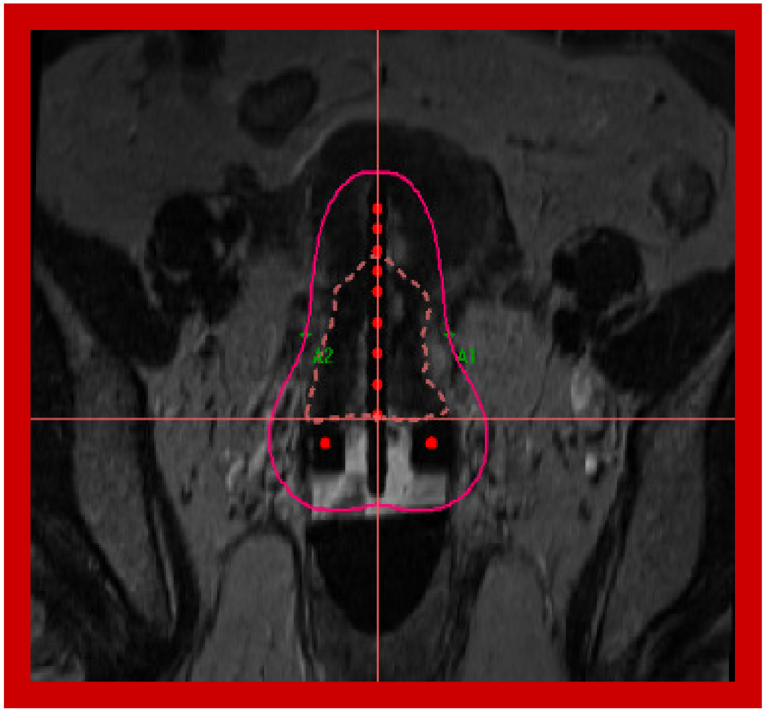
Rectum 1	-0.58	3.49	-3.19	10.632
Rectum 2	-1.01	3.65	-2.47	14.115
ICRU-R	-1.02	3.54	-1.48	21.298
Rektum 4	-1.21	3.68	-0.69	23.415
Rectum 5	-1.22	4.08	0.03	21.741

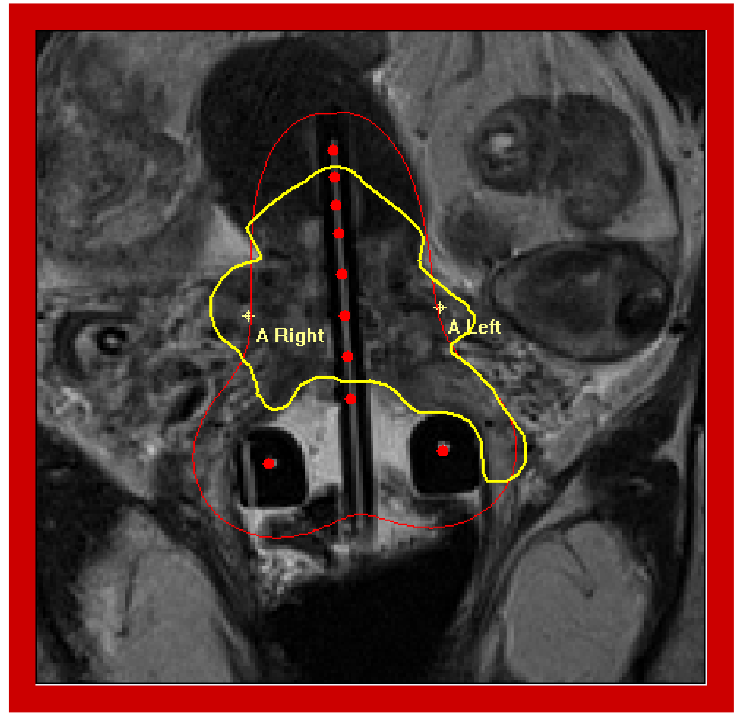
D max

D-max-R: within 1 cm from D-ICRU-R in ≅ 90%
D-max-B: 1.5-2 cm above D-ICRU-B

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

Basic Principles of ICA

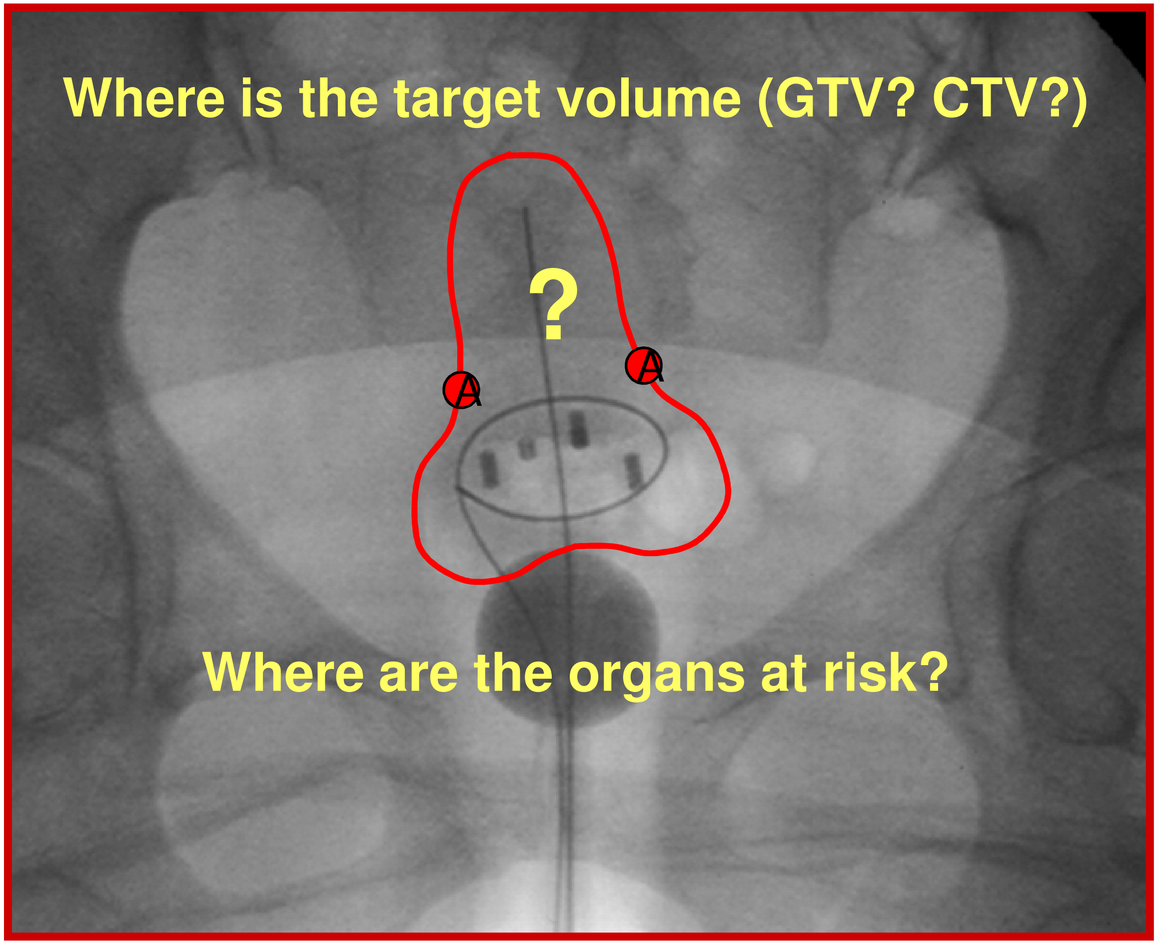




Target Dose: 2D

Main limitation of 2D approaches:

Absence of visual information on spatial relations between tumour and applicator



Thank you