IMAGING FOR BRACHYTHERAPY PLANNING

DR S.N.SENAPATI

PROF & HOD

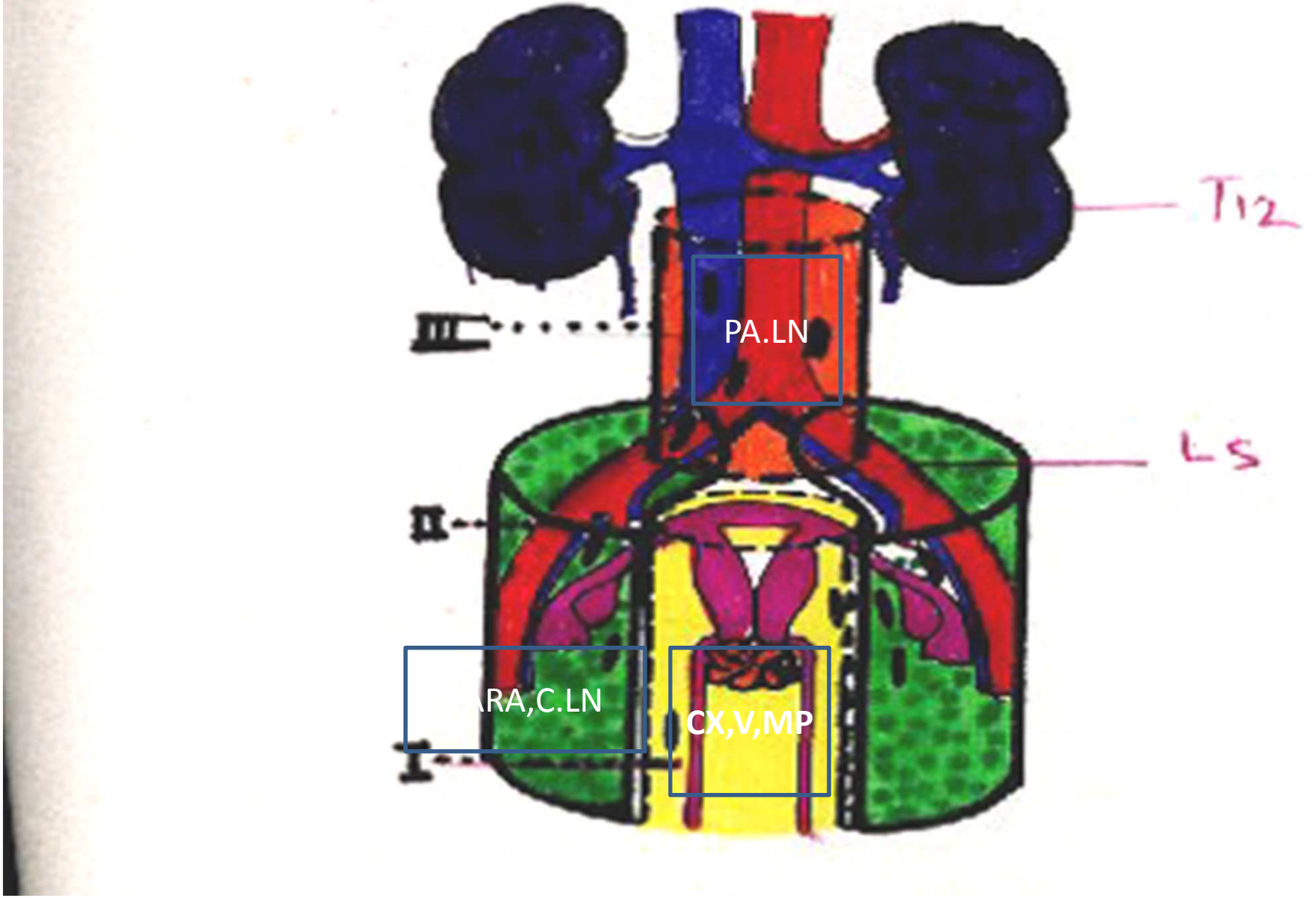
DEPT OF RADIATION ONCOLOGY,

AH REGIONAL CANCER CENTRE,

CUTTACK

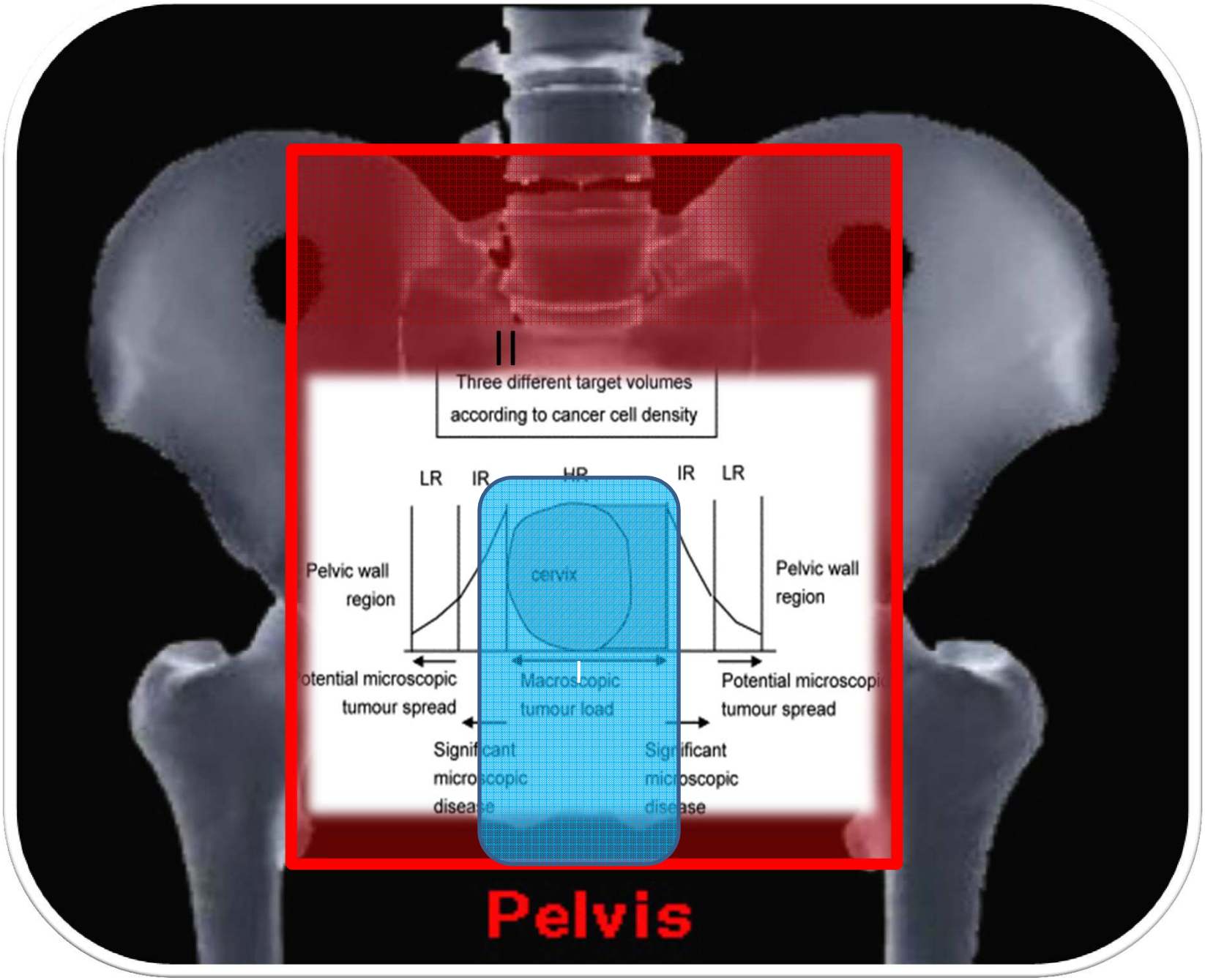
snsenapati2007@gmail.com

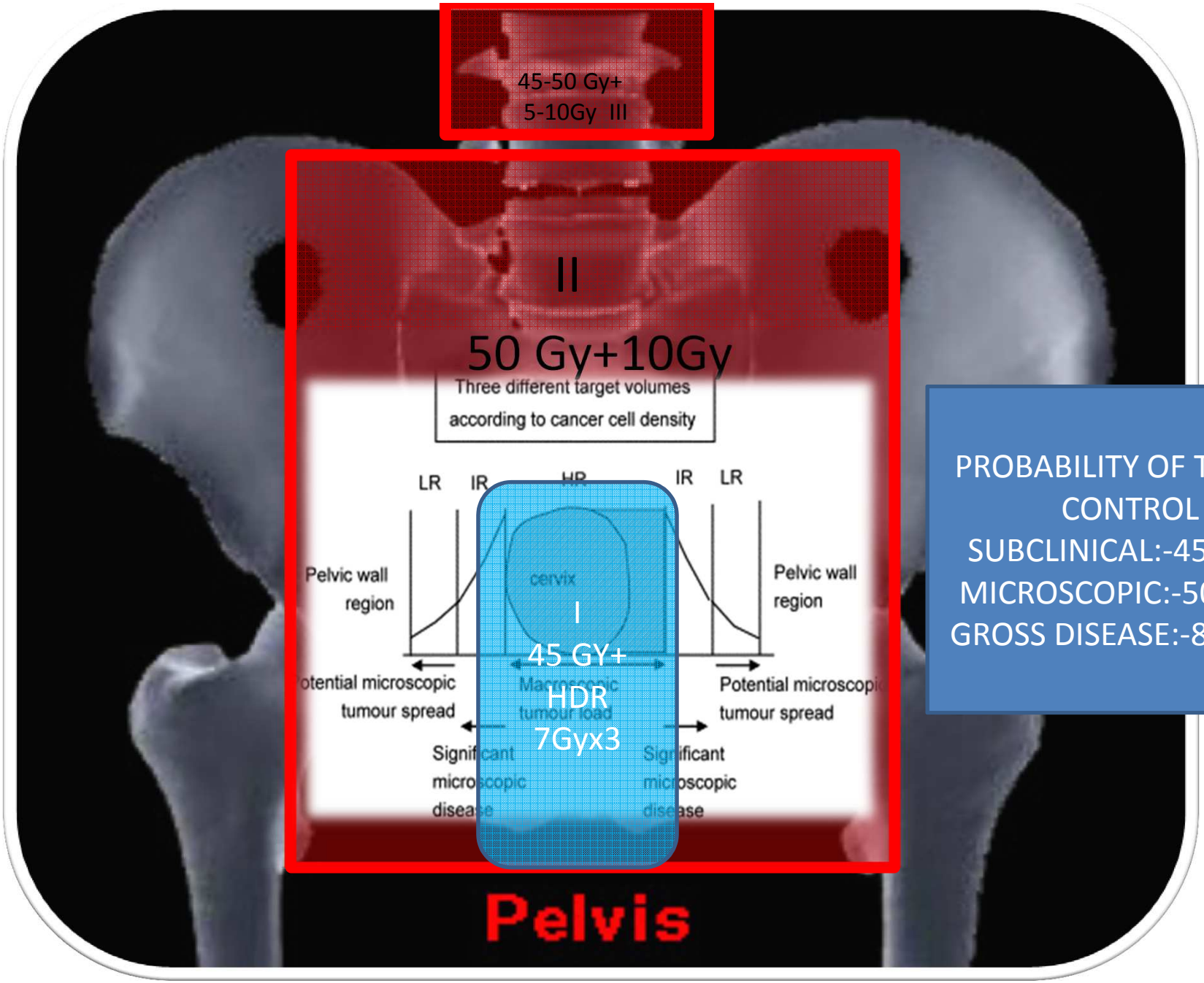
VOLUMES IN CARCINOMA CERVIX



Rule of 15

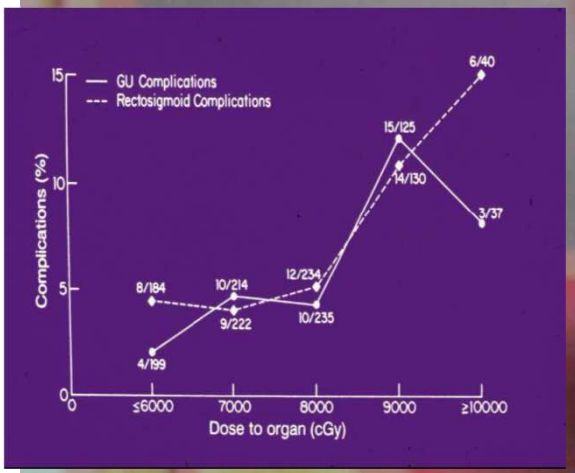
Stage	5 yr survival	%+ pelvic LN
I	85	15
II	70	30
III	55	45


II
Three different target volumes
according to cancer cell density
LR
IR
HR
IR
LR
Pelvic wall
region
cervix
Pelvic wall
region
otential microscopic
tumour spread
Macroscopic
tumour load
Potential microscopic
tumour spread
Significant
microscopic
disease
Significant
microscopic
disease
Pelvis



PROBABILITY OF TUMOR CONTROL
SUBCLINICAL:-45-50Gy
MICROSCOPIC:-50-60Gy
GROSS DISEASE:-80-85Gy

< 45 Gy



75-90

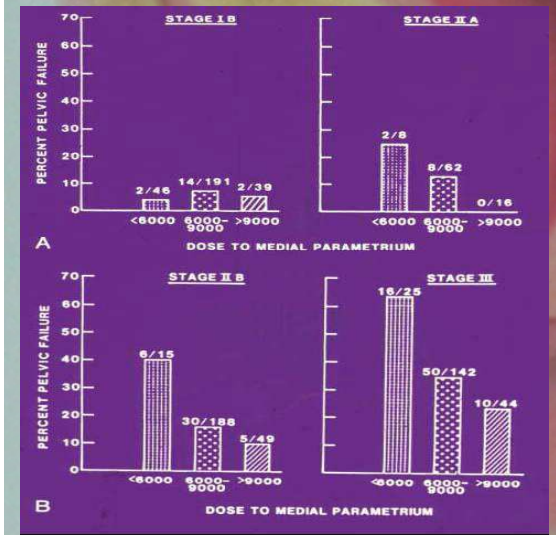
65-70Gy

60-65Gy

120Gy

80-90Gy

60-65Gy



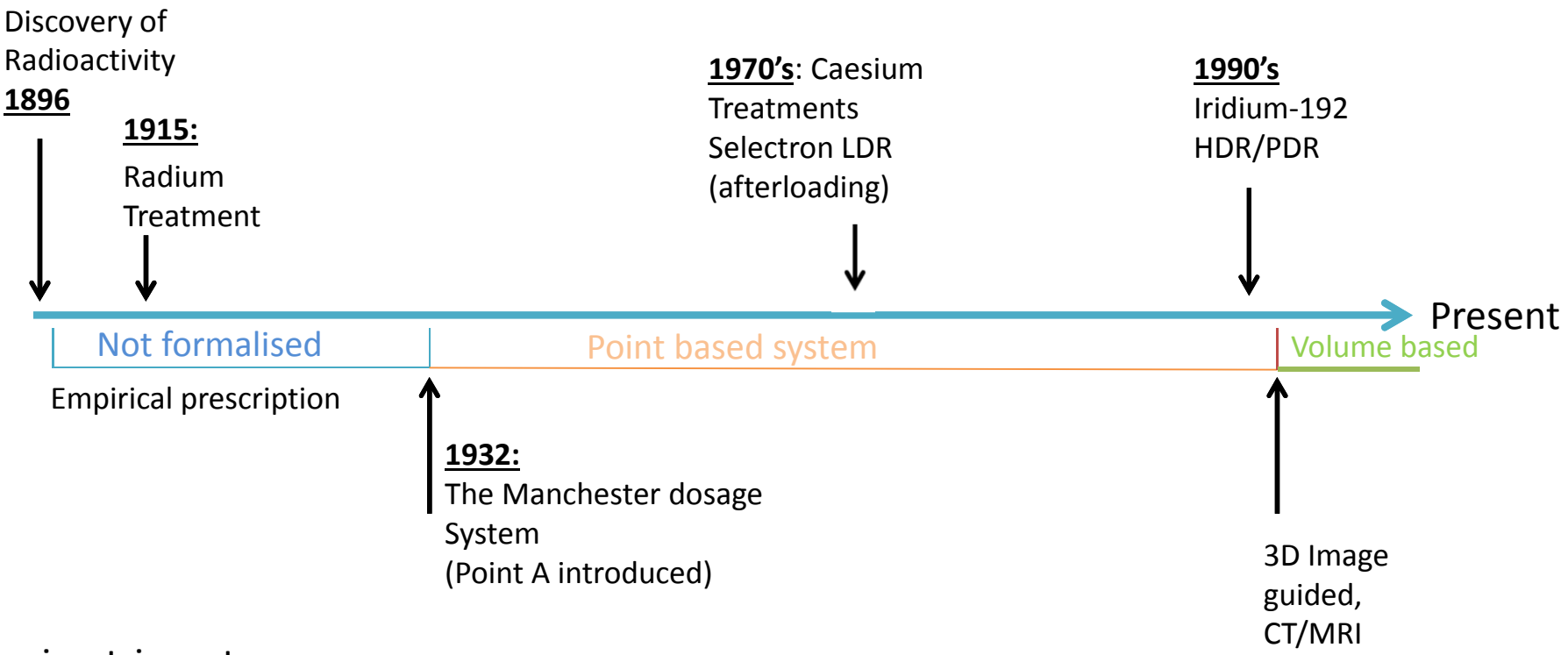
Brachytherapy is Necessary

- Brachytherapy: internally delivered radiation using radioactive sources
- Supplements external beam
- Tumor control probability correlated with RT dose and cervix ca volume Fletcher, J Radiol Electrol 56:383-400, 1975

	External beam only	External Beam + brachytherapy
4 y Pelvic Control 4 y Survival Lanciano JROBP 20:95, 1991	45% 19%	67% 46%
Local Control Montana Cancer 57:148, 1986	40%	52%

Brachytherapy Timeline

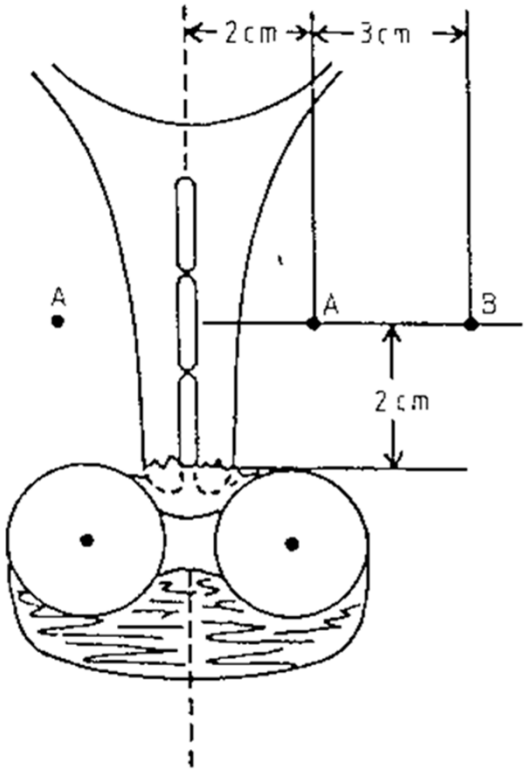
Technology



Dosimetric systems

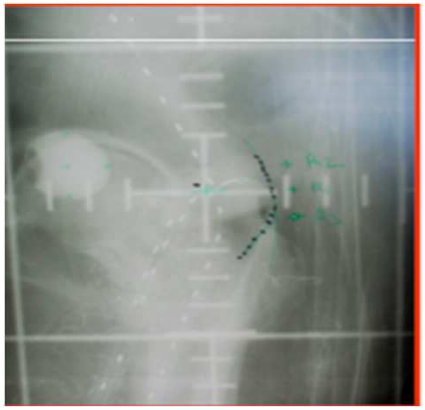
Limitations – 2D imaging
POINT-A

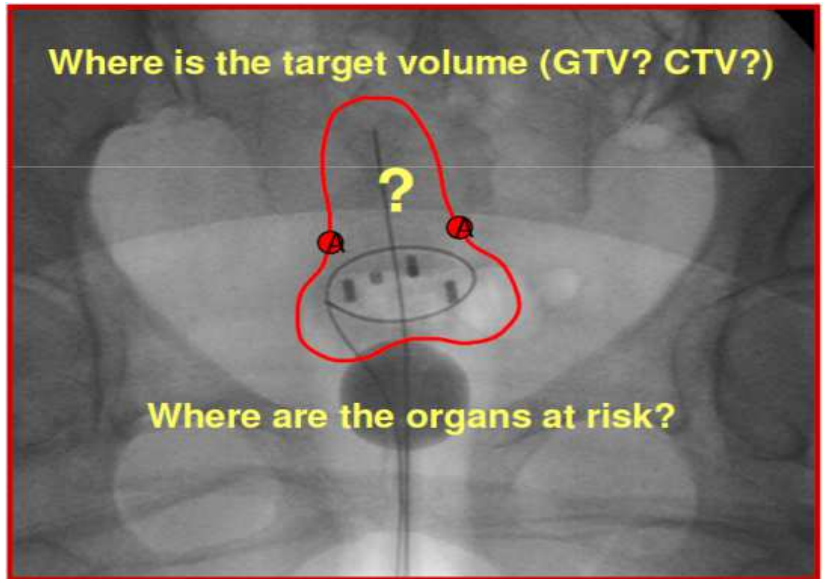
- **THEORETICAL REFERENCE POINT**
- **RELATES TO GENERIC ANATOMICAL POINT NOT INDIVIDUAL TUMOUR**
- **RELATIONSHIP WITH THE TUMOUR IS UNKNOWN**
- **VARIABLE DISTANCE TO TARGET AND OAR**
- **DOSE-EFFECT RELATIONSHIPS DIFFICULT TO ASSESS WITH POINT DOSES**
  - **POINT A WITH LOCAL CONTROL**
  - **ICRU BLADDER DOSE WITH BLADDER MORBIDITY**



2D PLANNING

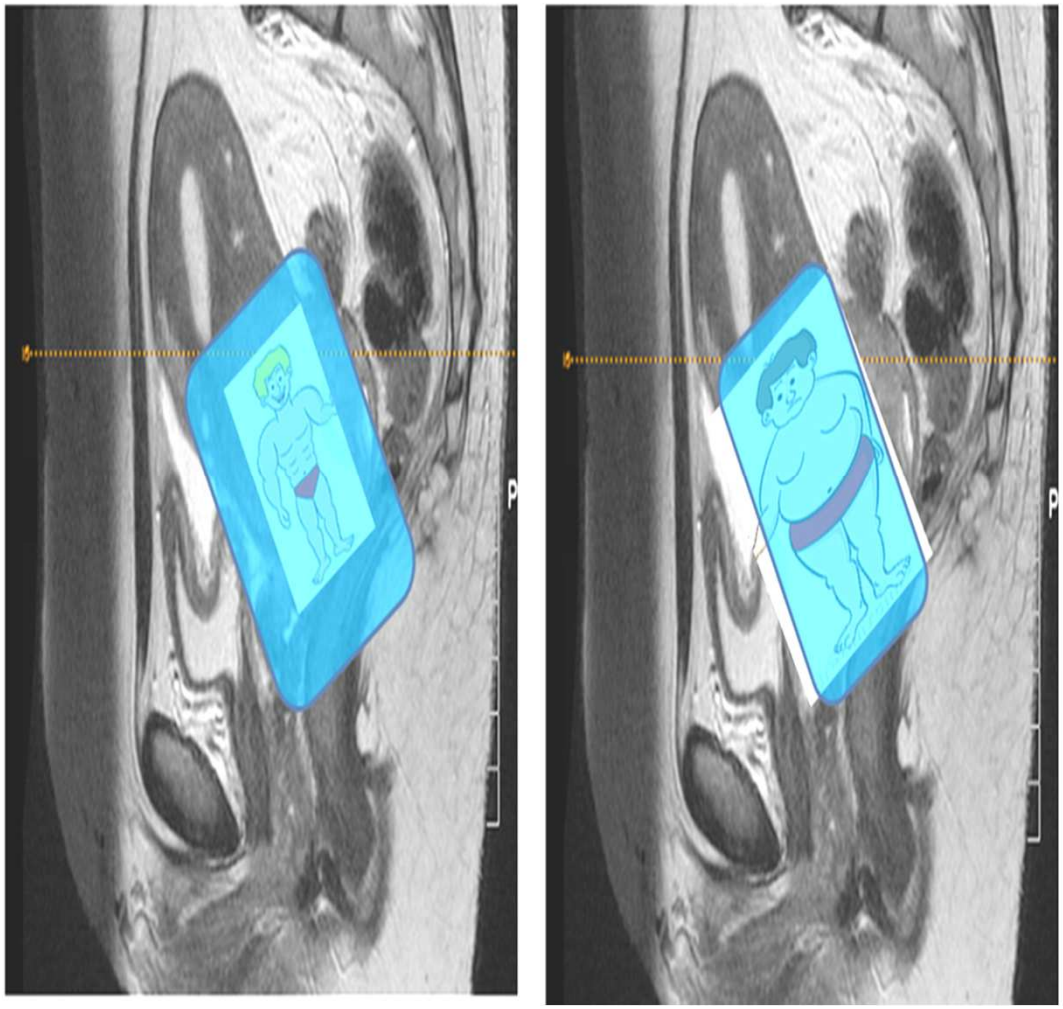
- **LIMITATION OF POINT A DOSIMETRY**
- **INADEQUATE INFORMATION ABOUT TARGET VOLUME ASSESSMENT**
- **NO VOLUMETRIC INFORMATION ON ORGAN AT RISK**





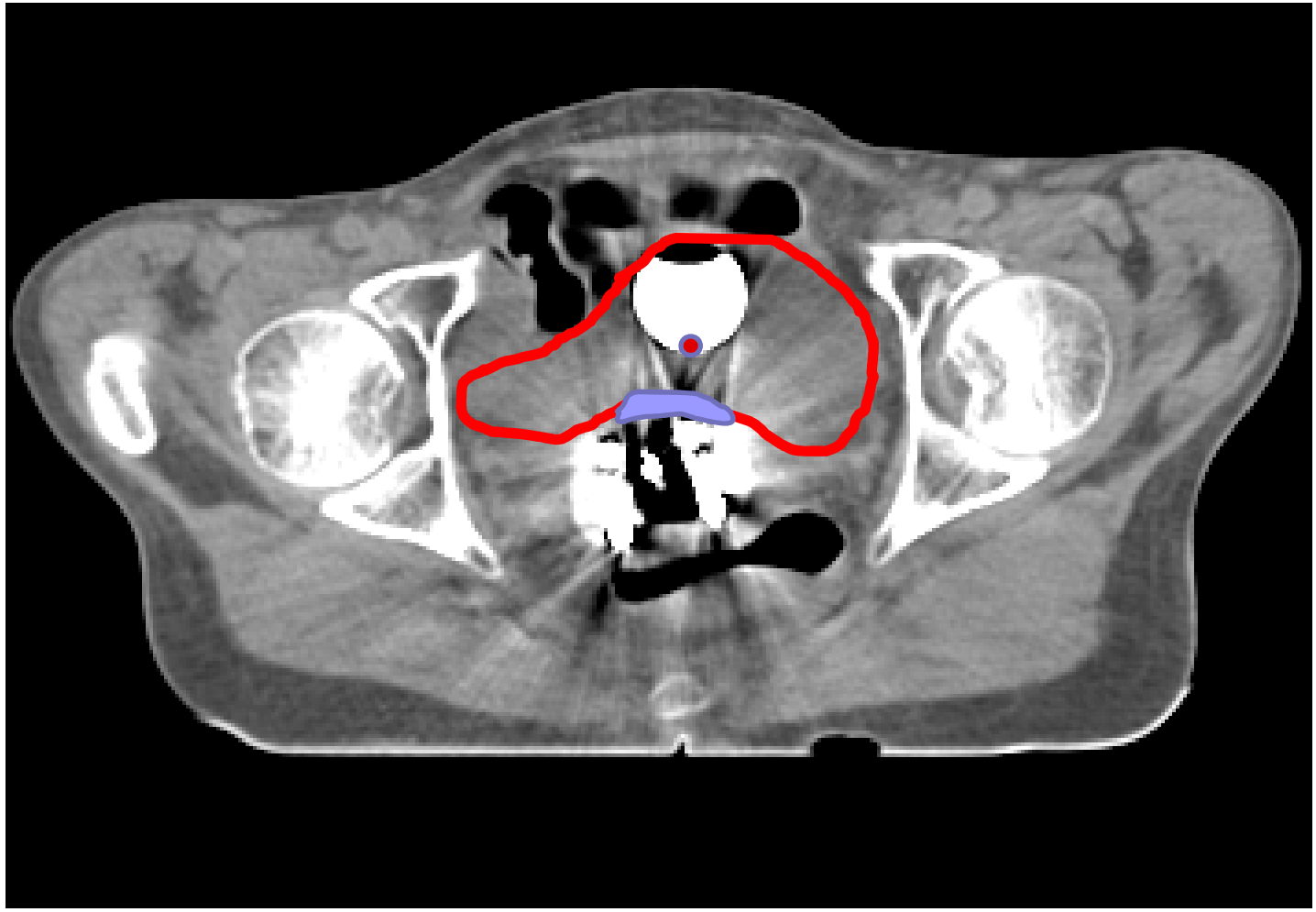
The Problems

- ONE SIZE FITS ALL?
- UNDER TREAT LARG TUMOURS
- OVER TREAT SMALL TUMOURS



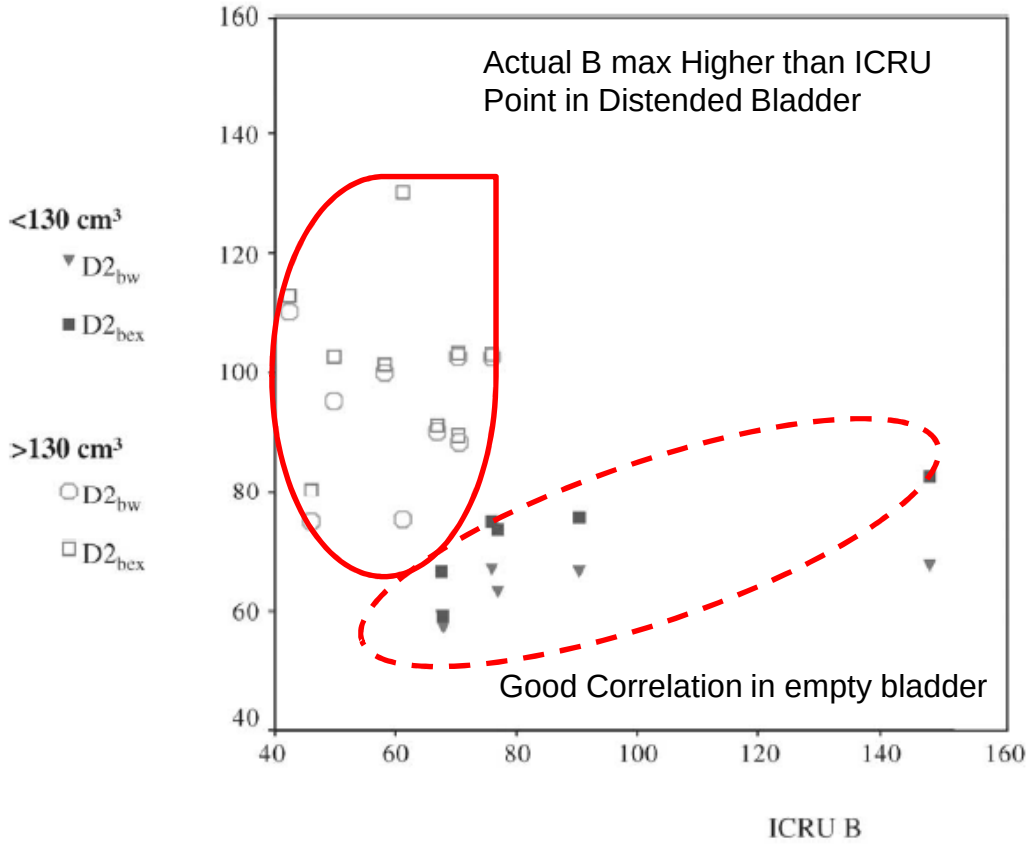
Fallacies of ICRU Bladder Point

Tandem Ovoid Application



Fallacies of ICRU Bladder Point

Function of Bladder Filling

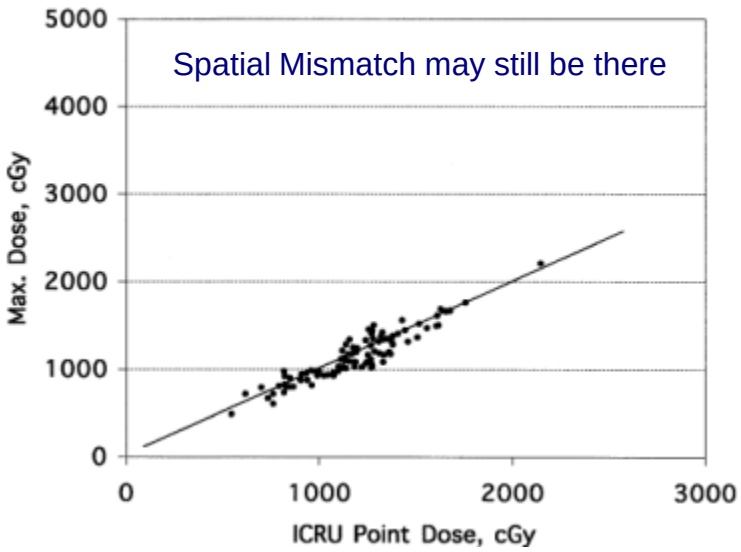


True B Max lies 1.5-3 cm cranial and lateral to ICRU point.
B Max is often 2-3 times higher than ICRU point dose

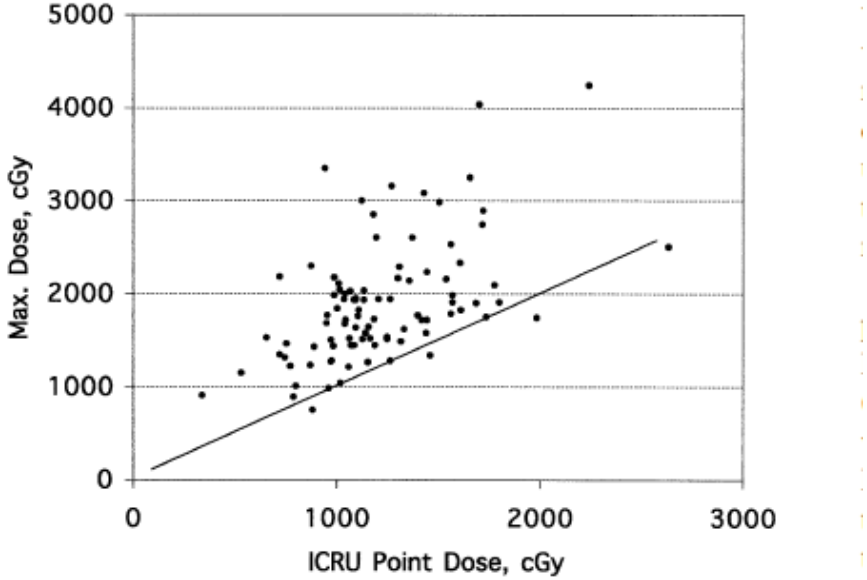
Watchner Gerstner R and O 2003

2D ICRU Point vs 3D CT based dosimetry

On comparing 2D with 3D, doses of OARs differed by 4-12%.
Rectal doses are 1-1.6 times than 2D Planning and bladder doses 1.4-2.2 times



Rectum



Bladder

ICRU Rectal point dose best correlated with 2 cc volume

ICRU Bladder Point Dose correlated with 13 cc volume. Gross Underreporting of Bladder doses.

Pelloski IJROBP 2005

International Journal of Radiation Oncology biology • physics
Official Journal of the American Society for Radiation Oncology ASTRO

Comparison between CT-based volumetric calculations and ICRU reference-point estimates of radiation doses delivered to bladder and rectum during intracavitary radiotherapy for cervical cancer

Christopher E. Pelloski, ., Matthew Palmer, B.S., Gregory M. Chronowski, , Anuja Jhingran,., John Horton, Patricia J. Eifel,

- Compared CT-based volumetric calculations and ICRU reference-point estimates of radiation doses to the bladder and rectum in patients with carcinoma cervix treated with definitive low-dose-rate intracavitary radiotherapy
- The minimal doses delivered to the 2 cm^3 of bladder and rectum receiving the highest dose (D_{BV2} and D_{RV2}, respectively) were determined from dose-volume histograms, and these estimates were compared with two-dimensionally derived estimates of the doses to the corresponding ICRU reference points.

- **CONCLUSION :** . ICRU rectal point may be a reasonable surrogate for the D_{RV2}
  - In contrast, the dose to the ICRU bladder point does not appear to be a reasonable surrogate for the D_{BV2}.

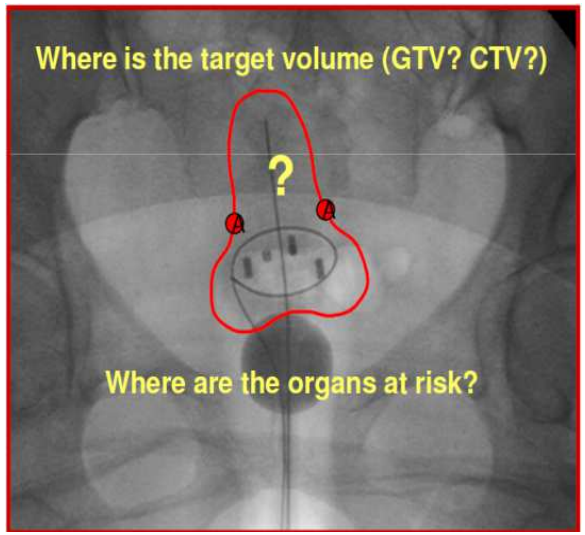
RECENT IMAGING
MRI,CT,USG,PET

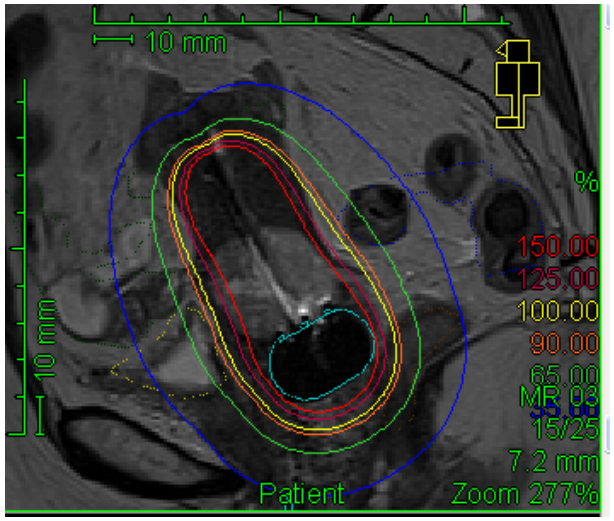
NEWER APPLICATORS

DEV IN TREATMENT
PLANNING SYSTEM

2D

VOLUME
BASED





WHY IMAGING

IMAGING PROCEDURES FOR DELINEATION OF THE GTV,CTV,PTV FOR DIFFERENT SITES OF BRACHYTHERAPY

SITE	1ST CHOICE	2ND CHOICE
MOBILE TONGUE	MRI	CT
BUCCAL MUCOSA	MRI,CT, US	
OROPHARYNX	MRI,ES	CT
NASOPHARYNX	ES, MRI	CT
CERVIX	MRI	CT, US (ENDO)
ENDOMETRIUM	MRI	ES, CT, US (ENDO)
BREAST	MAMMOGRAPHY,MRI	CT, US
BLADDER	ES, MRI, CT	US
PROSTATE	MRI	US (ENDO), CT
ANORECTAL	ES, MRI, US (ENDO)	CT
OESOPHAGUS	ES, ESOPHAGOGRAM	CT,MRI,US (ENDO)
BILE DUCT	CHOLANGIGRAM,ES	CT, US, MRI
SOFT TISSUE SARCOMA	MRI	CT
BRONCHUS	ES,CT,CHEST X-RAY	MRI
BRAIN	MRI	CT

CARCINOMA CERVIX
WHY IMAGE ASSISTED?

- TUMOR REGRESSION
- ORGAN MOTION
- INTER AND INTRA FRACTION VARIATION
- TARGET VOLUME LOCALIZATION
- CONTOURING
- APPLICATOR RECONSTRUCTION

WHY IMAGING IN BRACHYTHERAPY CARCINOMA CERVIX

- DIAGNOSTIC IMAGING
- LOCALISATION IMAGING WITH APPLICATOR IN PLACE
- DELINEATION OF GTV, HR/IR CTV AND
- DOSE VOLUME PARAMETERS

IMAGING

IMAGE ASSISTED TREATMENT

- **IMAGING AFTER APPLICATION FOR DEFINITIVE TREATMENT PLANNING (CR, US, CT, MRI) TO DERIVING TUMOR,ORGAN AT RISK,GTV,HIGH RISK CTV,INT RISK CTV**

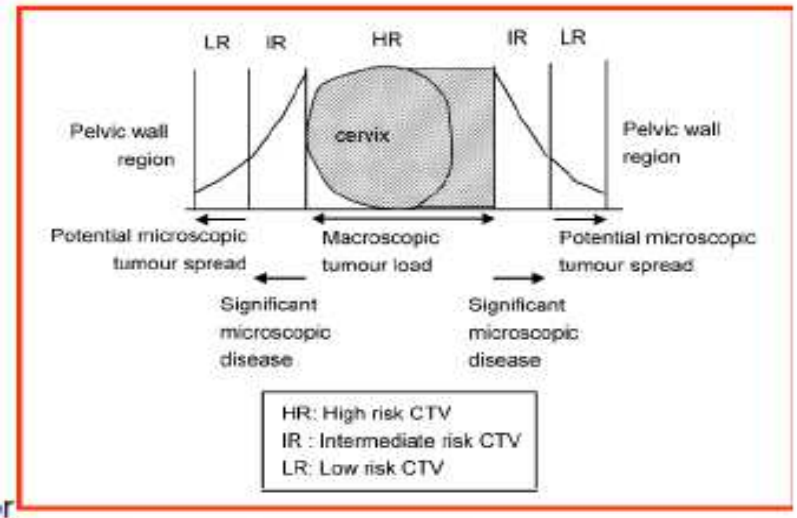
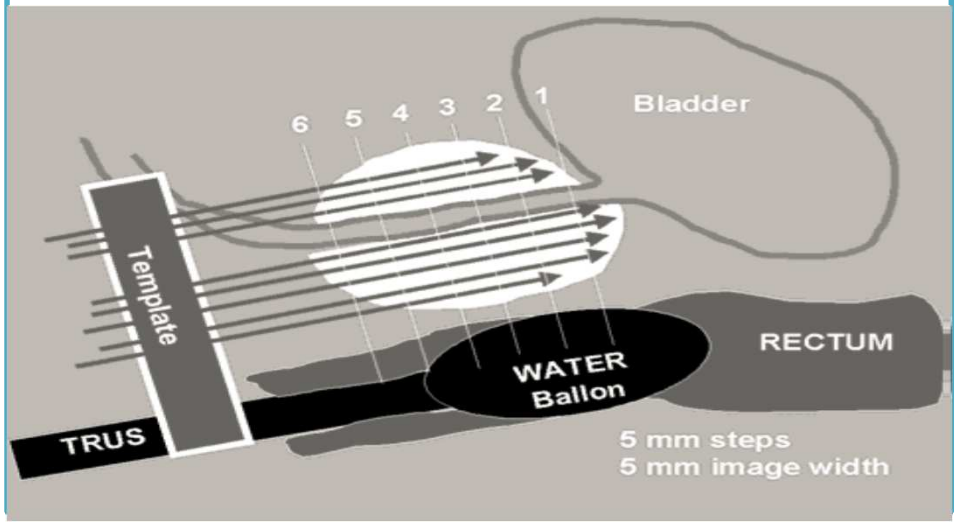


IMAGE GUIDED APPLICATION

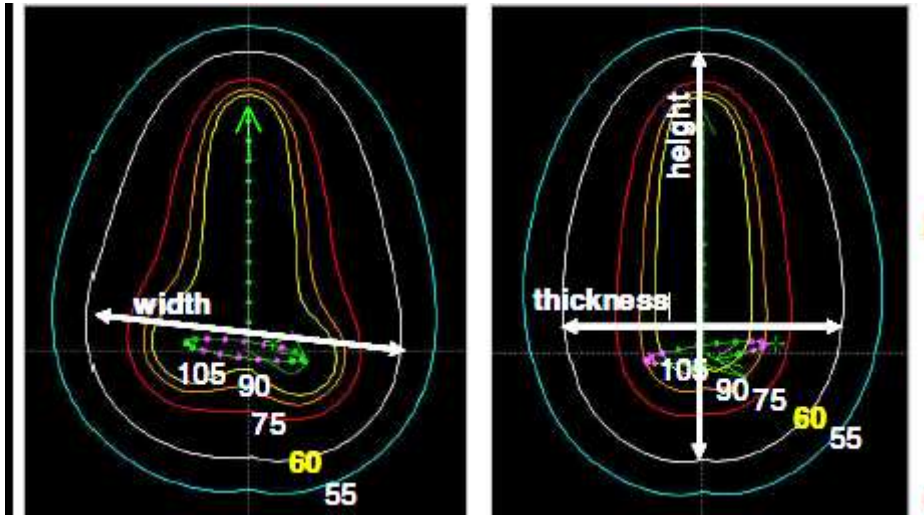
IMAGED GUIDED APPLICATION, THE APPLICATION IS DONE UNDER GUIDANCE OF AN IMAGE

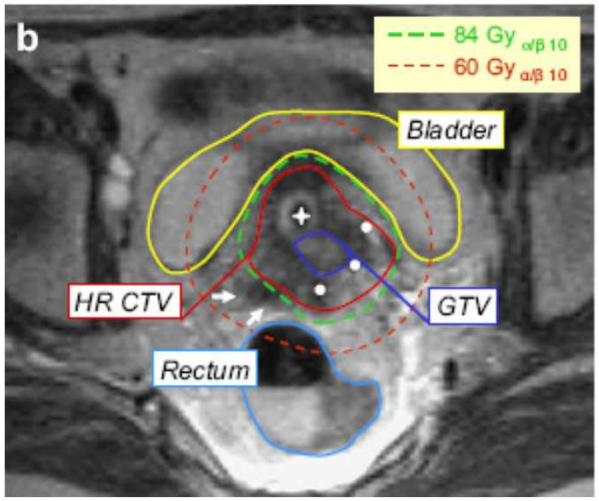
PROCEDURE.



CR, MRI, CT, US, ES

3D DELINEATION OF THE PTV, INDICATING WIDTH, LENGTH AND THICKNESS AND AS FAR AS POSSIBLE THE TOPOGRAPHY RELATED TO SURROUNDING STRUCTURES.





“INTERNAL” TOPOGRAPHY OF THE TUMOUR

“EXTERNAL” POSITIONING OF THE PATIENT IS NOT AS IMPORTANT AS IN EXTERNAL BEAM THERAPY

ORGANS AT RISK IS CRUCIAL

SOME DEFINATION

CTV coverage: evaluated using V100, D90

- D90: Dose covering 90% of the volume
- V100: Volume that receives the prescribed dose
- High dose volume in CTV was estimated using V200.

For organs at risk (OARs): D0.1cc, D1cc, and D2cc

(i.e., minimum dose received by 0.1-, 1-, and 2-cm3 tissue volume) were calculated.

- GTVD, CTVD : Dose received at the time of external beam radiotherapy
- GTVB, CTVB : Dose received at the time of brachytherapy

(GYN) GEC ESTRO Working Group (II)
3D dose volume parameters

Assessed DVH parameters for

- Tumour
  - GTV, HR CTV, IR CTV, D90, D100

- Organs at risk
  - Minimum dose in the most irradiated volume
  - D0.1cc, D1cc, D2cc

- Express dose in EQD2 (Gy)
  - Total dose (EBRT and BT) calculated with time and half life corrections in 2Gy equivalent (α/β ratio=10 target, α/β ratio=3 OAR)

Potter et al. Radiother Oncol 2006;78:67

Express dose in EQD2 (Gy)

- Total dose (EBRT and BT) calculated with time and half life corrections in 2Gy equivalent (α/β ratio=10 target, α/β ratio=3 OAR)

$$EQD2_{total} = EQD2_{EBRT} + EQD2_{ICR}$$
$$= Nd\left[(d + \alpha/\beta)/(2 + \alpha/\beta)\right]$$
$$+ N_B d_B\left[(d_B + \alpha/\beta)/(2 + \alpha/\beta)\right]$$

Biologically Equivalent Dose

Equivalent Dose in 2 Gy Fractions (EQD2)

BED= $nd(1+d/\alpha/\beta)/(1+2/\alpha/\beta)$

EQD2= BED/1.2

n = # fractions

d = dose/fraction

α/β for tumor ~ 10

α/β for normal tissue ~ 3

Example:

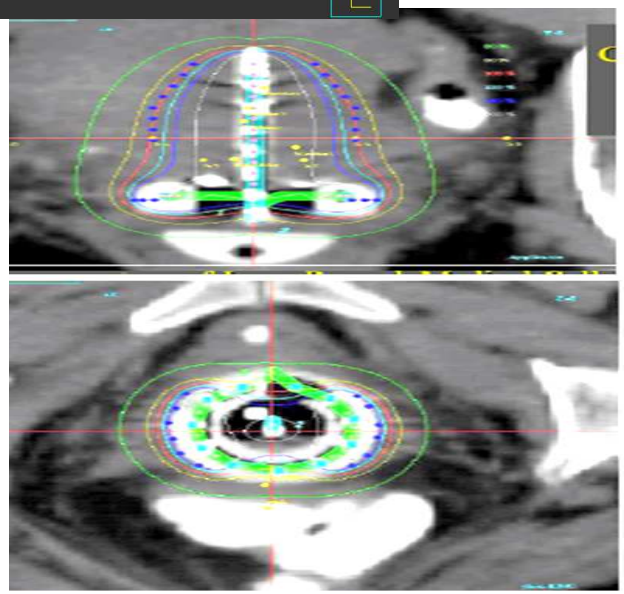
(5 fractions) x (5.5 Gy) x (1+5.5 Gy/10) / 1.2 = 35.5 Gy_{10}

IMAGING MODALITIES

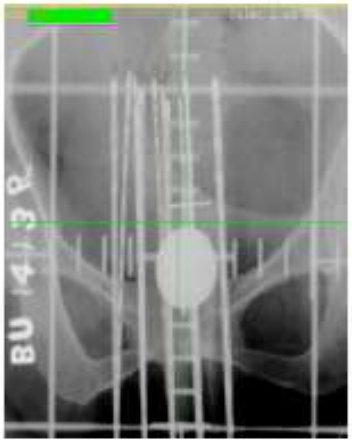
- **ULTRASOUND,**
- **COMPUTED TOMOGRAPHY,**
- **MAGNETIC RESONANCE**
- **PET CT SCAN**

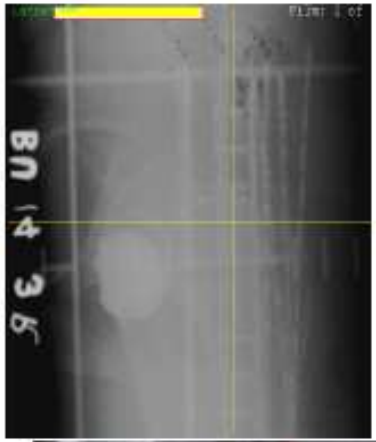
CT SCAN IN BRACHYTHERAPY

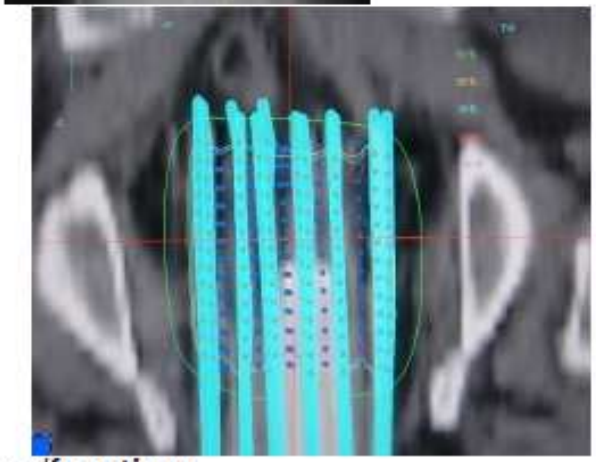
- WIDELY ACCEPTIBLE DUE TO EASILY ACCESSIBLE
- BLADDER, RECTUM WELL VISUALIZED
- METAL ARTIFACT
- POOR DIFFERENTIATION BETWEEN UTERUS,CERVIX,TUMOR ,PARACERVICAL AREA

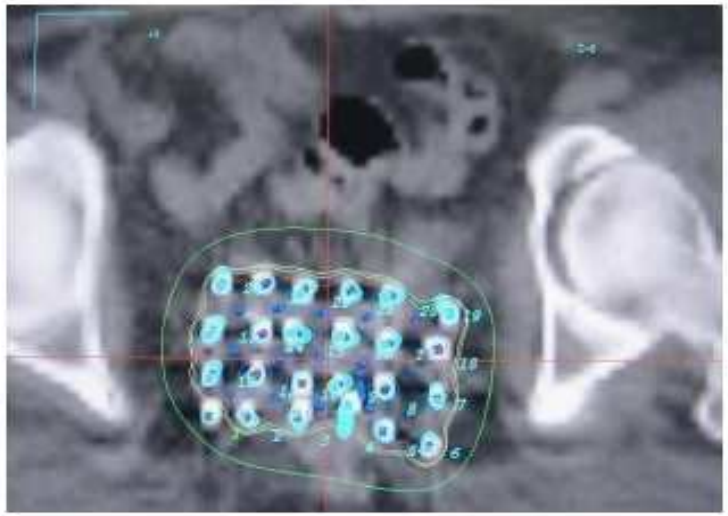


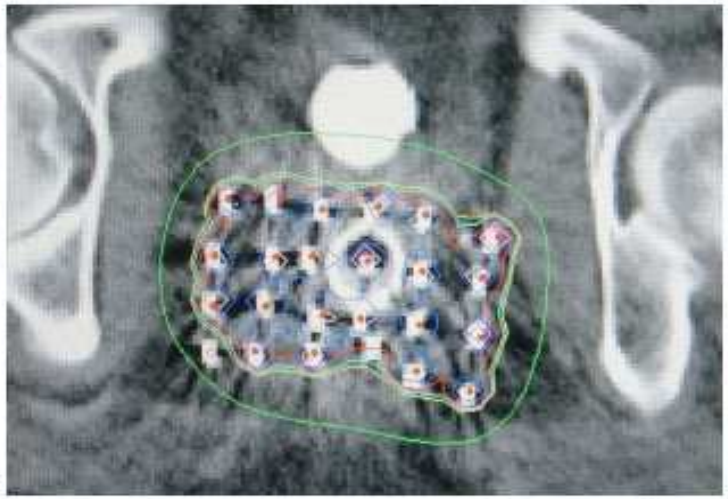
CT SCAN IN INTERSTITIAL IMPLANT











- Dosimetry
- Dose : 3.4 – 4 Gy /fraction
- 2 fractions per day 6 hours apart
- No of fractions : 4-6 depending on the response

International Journal of Radiation Oncology biology • physics
Official Journal of the American Society for Radiation Oncology ASTRO

Conformal Brachytherapy Planning for Cervical Cancer Using Transabdominal Ultrasound

Sylvia Van Dyk, D.App.Sc. ,Kailash Narayan, Franzcr.,Richard Fisher,., David Bernshaw, Franzcr

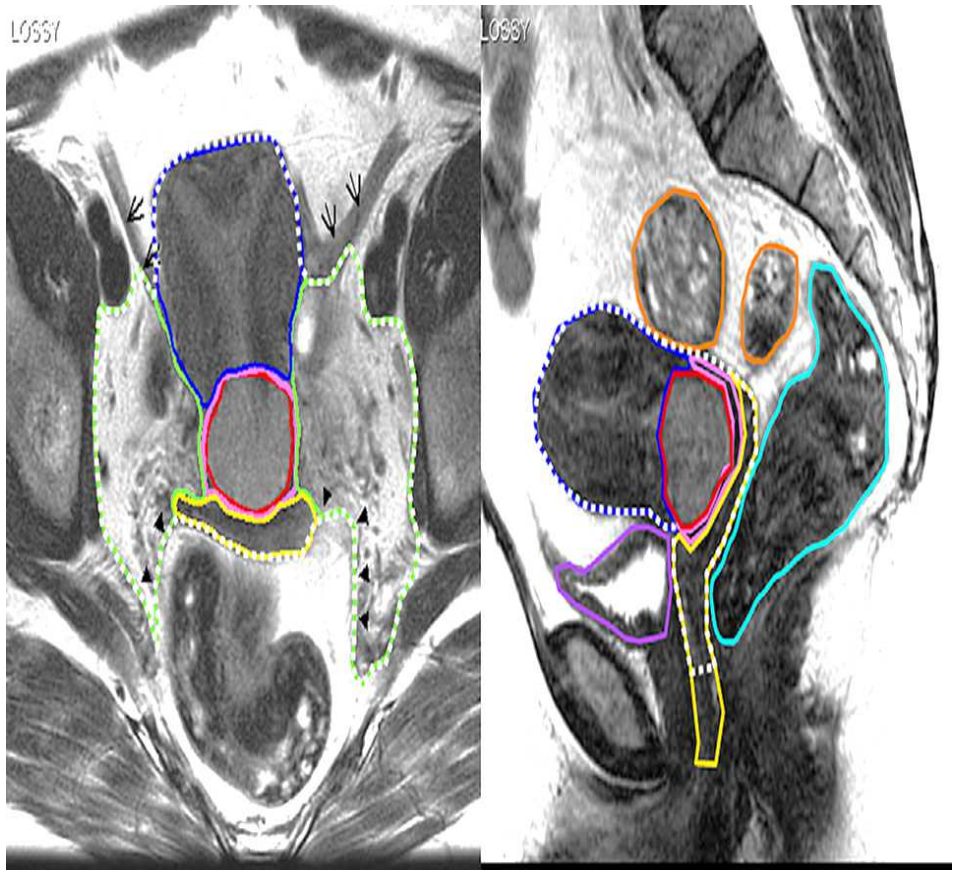
- Seventy-one patients with locoregionally advanced cervix cancer were included.
- The protocol consisted of US-assisted tandem insertion and conformal US-based planning
- Retrospectively, individual standard , US, and MRI plans were extrapolated for five fractions and superimposed onto the two-dimensional sagittal MRI images for comparison
- US plan assessed on two-dimensional MRI image was comparable for target volume (p = 0.11), rectal point (p = 0.8), and vaginal mucosa (p = 0.19). Local control was 90%. Late bowel morbidity (G3, G4) was <2%.

Conclusions

Transabdominal ultrasound offers an accurate, quick, accessible, and cost-effective method of conformal brachytherapy planning.

MR BASED BRACHYTHERAPY

- MULTIPLANNAR IMAGE
- GOOD SOFT TISSUE CONTRAST
- DIFFERNTIATION BETWEEN UTERUS,CERVIX,TUMOR
- RECTUM,BLADDER,RECTOSIGMOID WELL VISUALISED
- SPECIAL MR COMPATIBLE APPLICATOR
- NOT AVAILABLE IN MANY CENTRES



(PARA)SAGITTAL (PARALLEL), PARACORONAL (PARALLEL) AND PARATRANSVERSE (90º) IMAGES (MRI) RELATED TO THE AXIS OF THE CERVIX CANAL AND THE UTERINE CAVITY IN UTERINE CANCER

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IMAGING PRINCIPLE

CT IMAGES

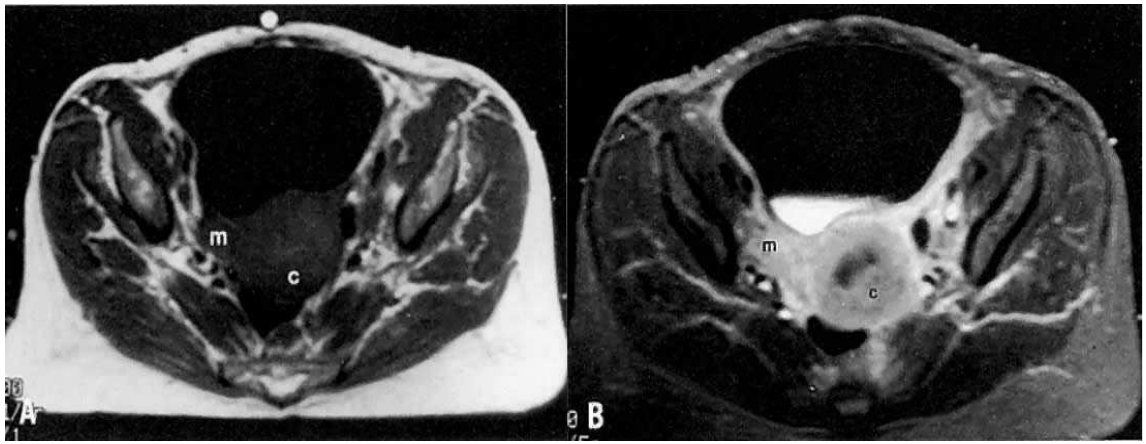
- CT COMPATIBLE APPLICATORS
- IV AND RECTAL CONTRAST : TO BETTER OPACIFY THE BLADDER AND RECTOSIGMOID.
- IF ORAL CONTRAST :-SCAN SHOULD BE PERFORMED 30 MINUTES AFTER ADMINISTRATION
- FOLEY CATHETER BULB SHOULD BE INFLATED WITH AIR
- SLICES THICKNESS :- 3 MM OR LESS
- EXTEND OF SCAN: FROM AT LEAST 1 CM ABOVE THE TIP OF THE TANDEM TO THE BOTTOM OF THE ISCHIUM.

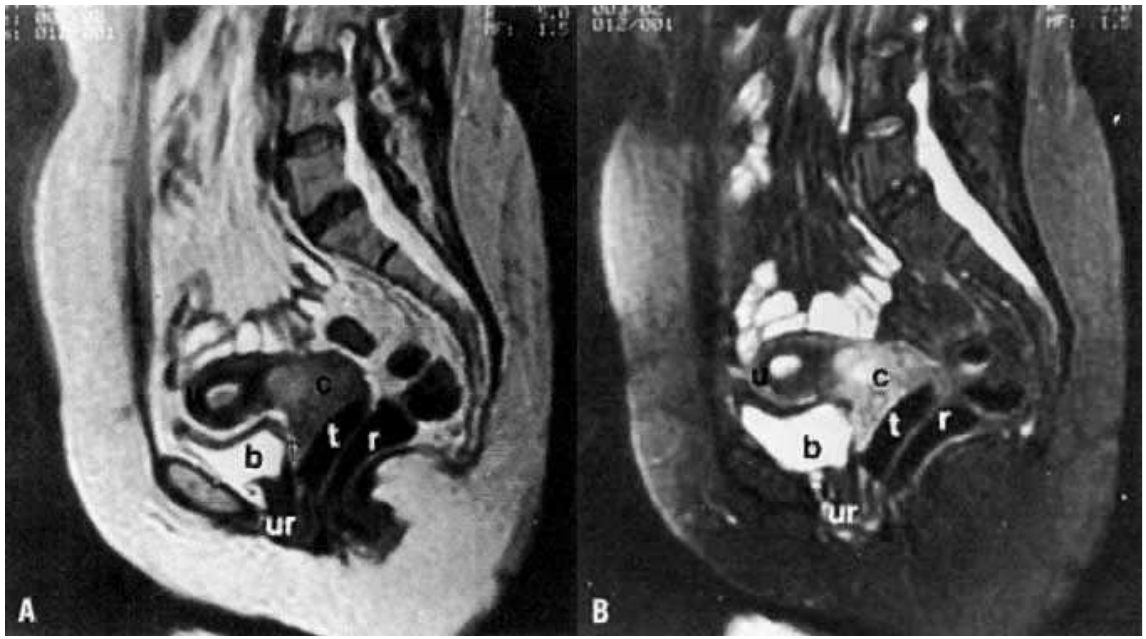
MRI

- A NON-FERROMAGNETIC APPLICATOR
- T2 WEIGHTED MRI
- WHEN MOVING A PATIENT BETWEEN THE IMAGING UNIT AND THE TREATMENT ROOM: FIXATION OF THE APPLICATOR IS REQUIRED.
- INFUSE 50 CC OF WATER INTO THE BLADDER
- INFUSE 7CC OF WATER IN FOLEY BULB

MRI IMAGES CA CERVIX

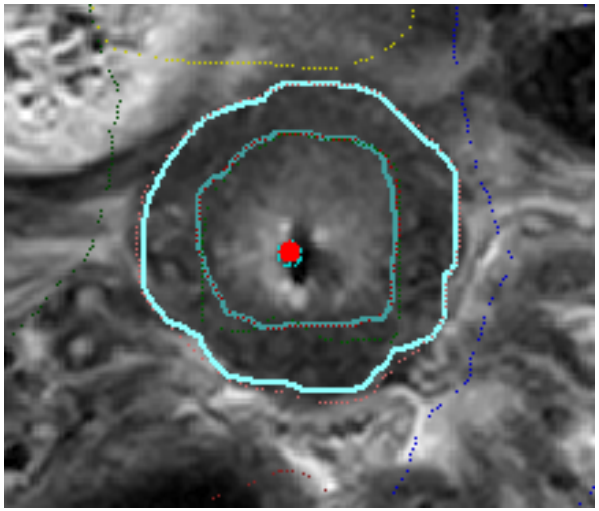
- Best possible imaging modality : MRI
- T2: hyperintense mass relative to normal stroma
- T1: isointense to normal stroma and may not be detectable
- T1: optimal sequence for assessment of lymphadenopathy.
- Fat saturation sequence can be used to differentiate between hemorrhage and fat
- With fat saturation techniques, fat appears dark (fat-saturated) and hemorrhage remains high in signal intensity.



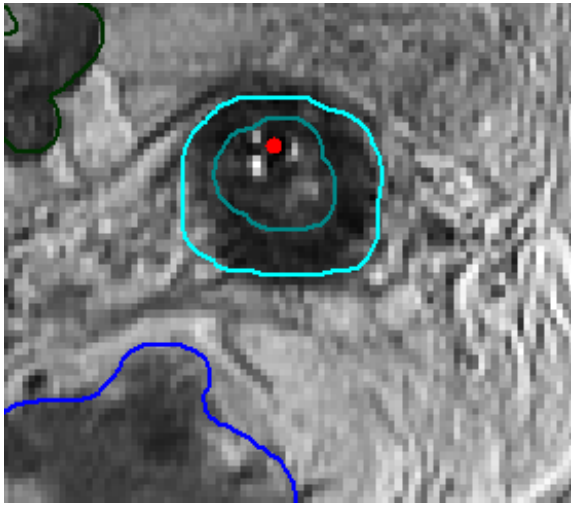


Example images for comparison

4mm (1mm gap)



2.5mm(2.5mm gap)

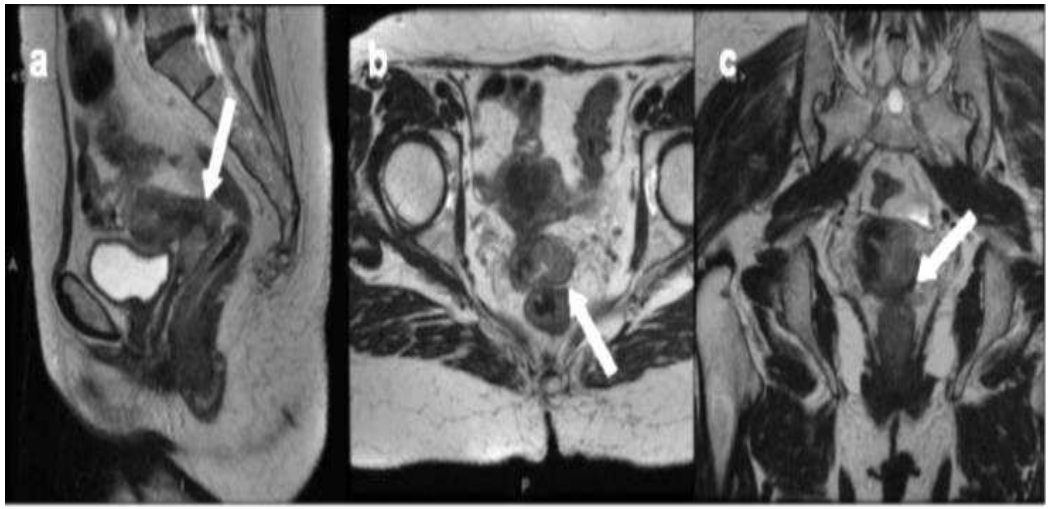


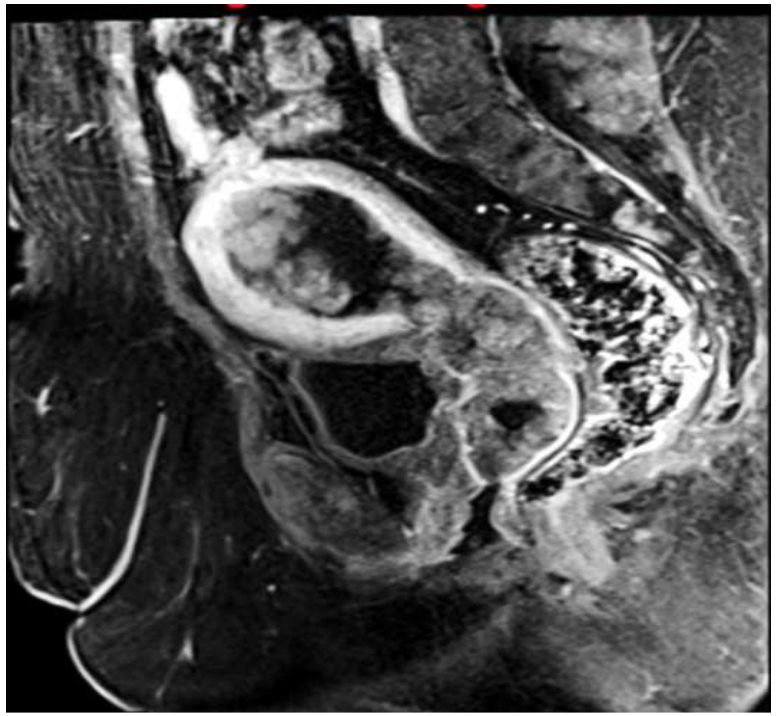
- 2.5mm slice has more clearly defined boundaries due to reduction in partial volume effects
- Uterus typically curves out of image plane so edge boundary becomes more poorly defined with greater slice thickness
- Applicator demonstrates more partial volume in 4mm slice

CONTD.

- FAST SPIN ECHO (FSE): REDUCE MOTION ARTIFACT
- GADOLINIUM IS ROUTINELY USED IN THE EVALUATION OF ENDOMETRIAL AND OVARIAN DISEASE.
- GADOLINIUM IS NOT ROUTINELY USED IN THE STAGING OF CERVICAL CANCER AS IT HAS NOT BEEN SHOWN TO IMPROVE OVERALL STAGING ACCURACY

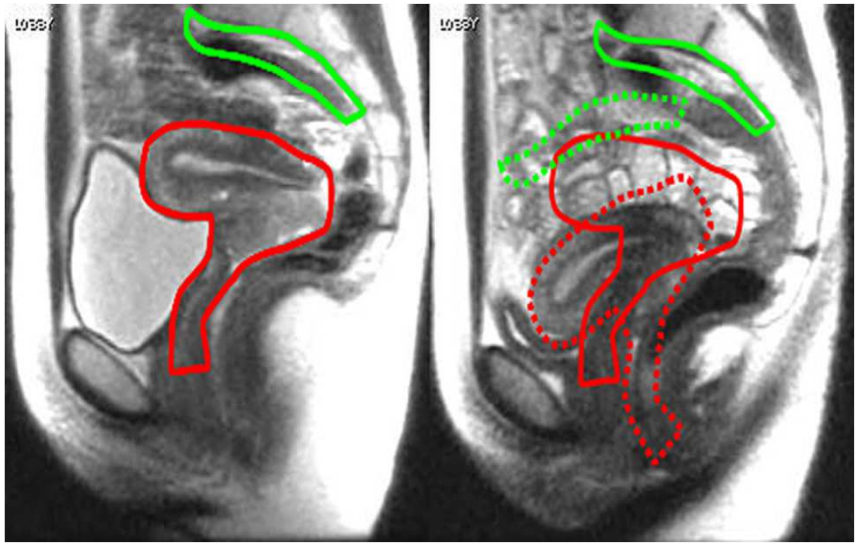
HELP DIFFERENTIATE VIABLE TUMOR FROM DEBRIS AND AREAS OF NECROSIS, AND ASSESS FOR BLADDER OR RECTAL INVOLVEMENT.





Inter and Intra fraction movement

- Fundus of uterus – max documented movement 48mm AP
- Uterus changes from anteverted to retroverted in 11%
- Cervix movement recorded
    - AP 2.3-16mm
    - Sup-inf 2.7-8mm
    - Lat 0.3-10mm
- Nodal movement – 5-9mm
- Intrafraction movement
    - cervix 0.1-3mm
    - >5mm in <5% of the time
    - Less with VMAT and Rapid Arc techniques



Tip of the fundus movement/bladder full vs empty

Jadon et al. Clin Oncol 2014:26;185

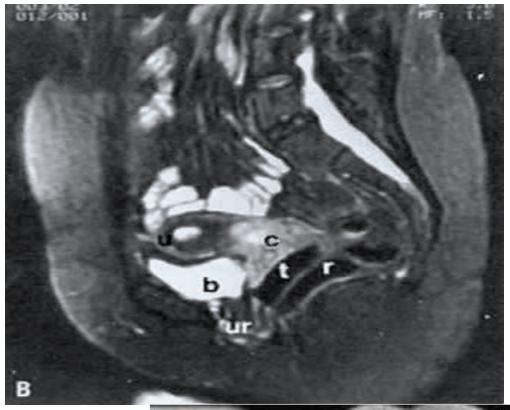

CHEMORADIATION VS RADIATION ALONE
MRI PROCEDURES

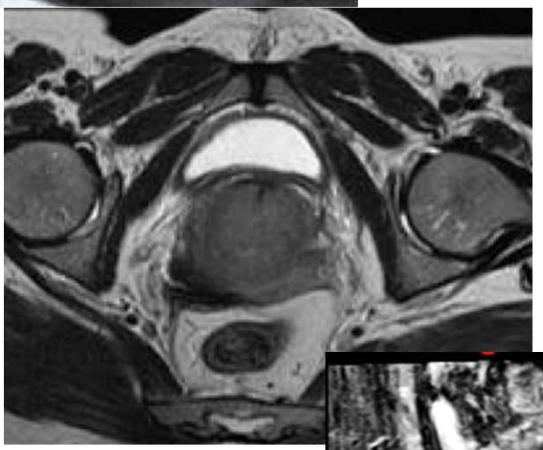
MRI PROCEDURES

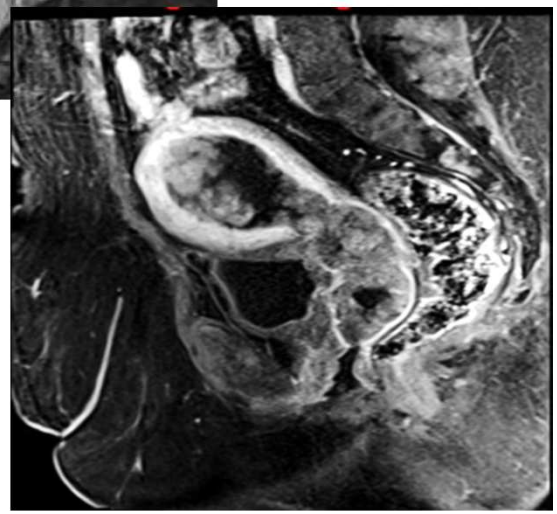
- MRI:-1.5 TESLA MAGNET
- BOWEL MOTION :-FAST FOR 4-6 HOURS
- BUSCOPAN 20 MG IV OR IM JUST BEFORE THE EXAMINATION.
- THE AREA OF COVERAGE:-AORTIC BIFURCATION DOWN THROUGH THE INTROITUS WITH 24-28 CM FIELD OF VIEW
- 5MM SLICE THICKNESS WITH 1 MM GAP, 16 KHZ BANDWIDTH, 256-521 X 256 MATRIX AND NEX OF 2. AN ECHO TRAIN LENGTH (ETL) OF 8 WILL BE USED FOR THE FSE T2 SEQUENCES.

MRI SEQUENCE

- **LOCALIZER, SAGITTAL PLANE**
- **SAGITTAL PLANE OF SECTION, FSE T2-WEIGHTED IMAGE.**
- **AXIAL PLANE OF SECTION, FSE T2-WEIGHTED IMAGE.**
- **AXIAL PLANE OF SECTION, T1-WEIGHTED IMAGE; SCAN TO RENAL HILUM IF PELVIC LYMPHADENOPATHY PRESENT.**
- **ONLY IF CANCER EXTENSION TO THE URINARY BLADDER OR RECTUM IS SUSPECTED AFTER REVIEWING THE NON-CONTRAST IMAGES, GADOLINIUM WILL BE ADMINISTERED AND A SAGITTAL PLANE OF SECTION, POSTCONTRAST T1 WILL BE OBTAINED.**
- **SEQUENCES REQUIRED FOR ASSESSING POSITION OF APPLICATOR: (B) AND (C) AS ABOVE WITH APPLICATOR IN PLACE.CAN USE SINGLE SHOT FSE T2, IF ADEQUATE.**

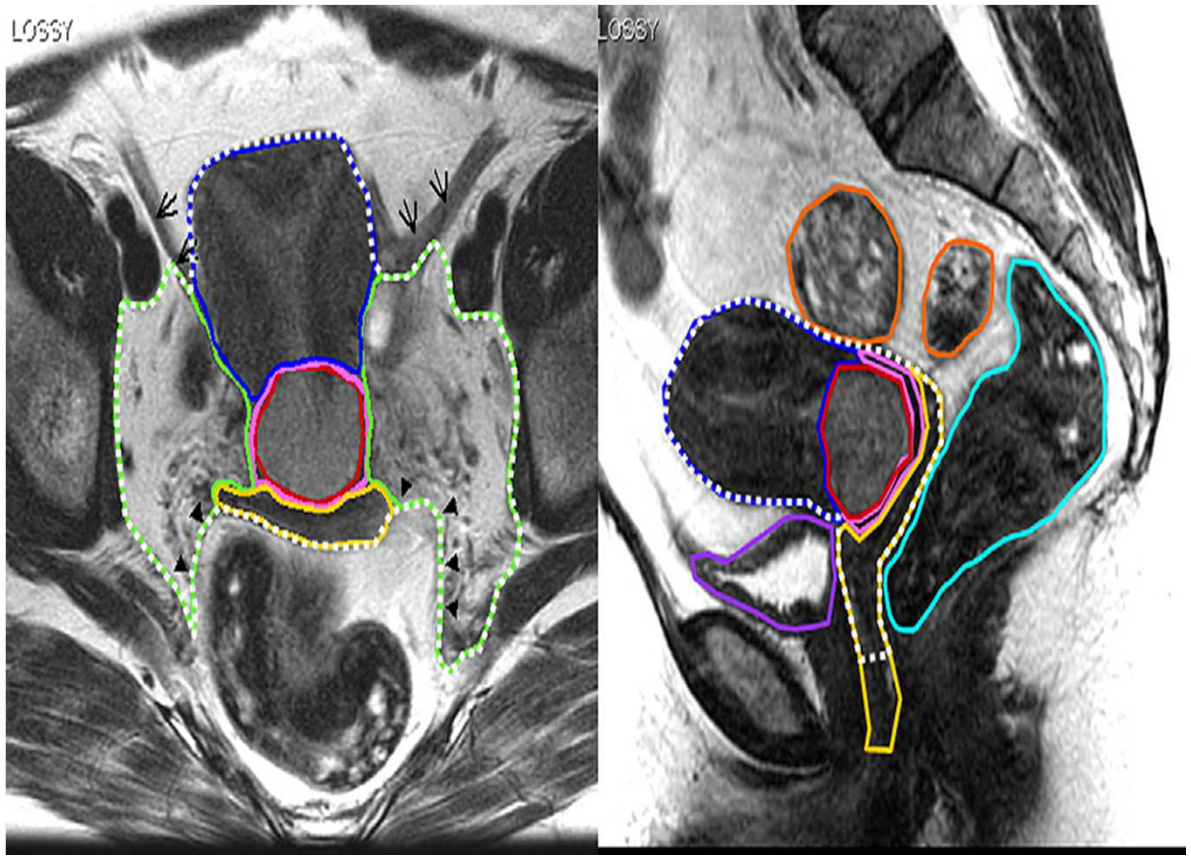






INFORMATION TO BE GATHERED FROM MRI

TUMOR WIDTH,HEIGHT,THICKNES
BOTH THE PARAMETRIUM
TYPE OF INFILTRATION
UTERUS,VAGINA
VAGINA ANT WALL
VAGINA POST WALL
PARAMETRIAL IINV
VAGINAL EXTESION
BLADDER EXTENSION
RECTUM INVOLVEMENT



APPLICATORS VS IMAGING

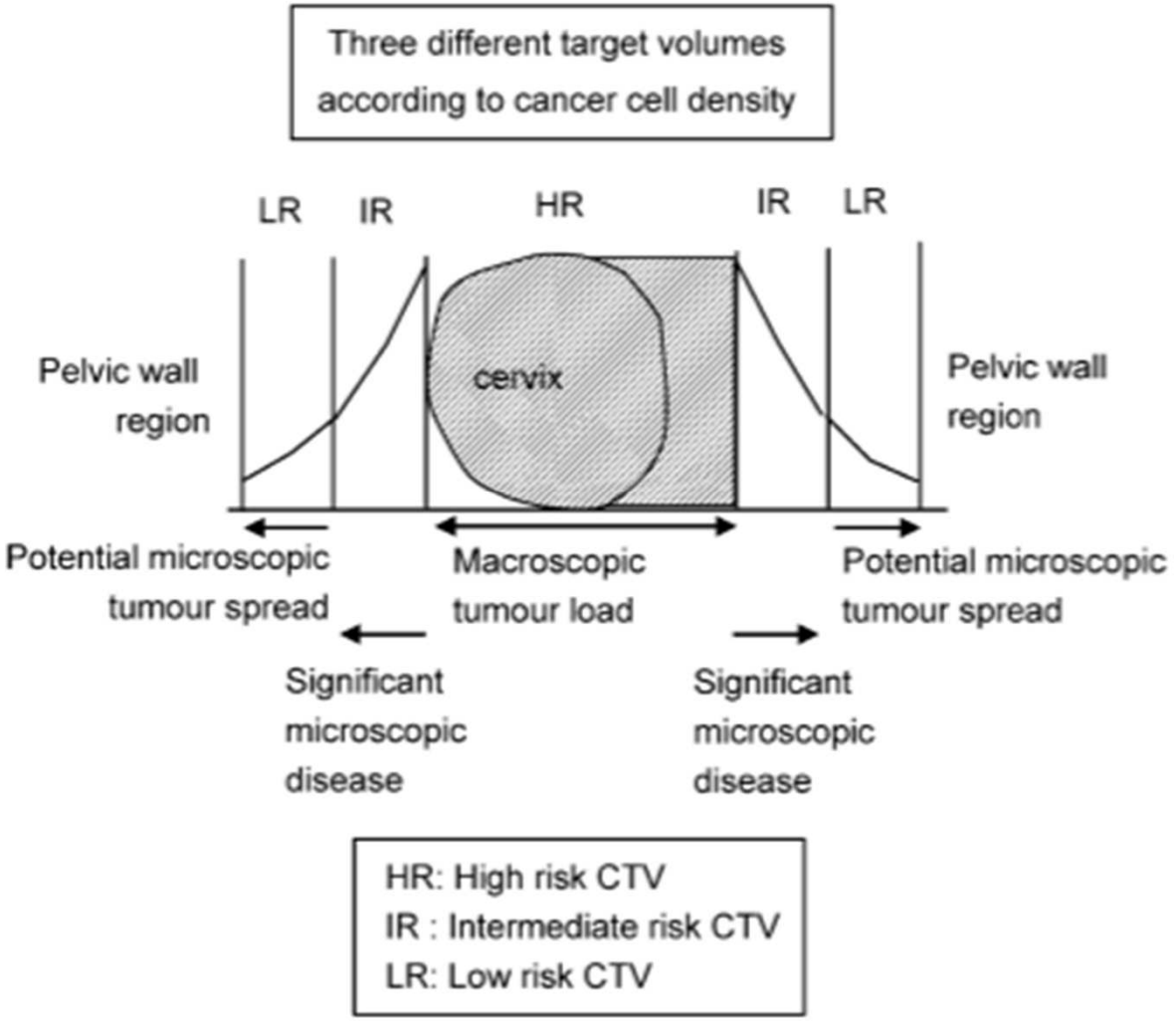
VISIBILITY,
RELIABILITY
REPRODUCIBILITY OF THE APPLICATOR

IMAGE QUALITY OF THE TUMOUR AND THE ORGANS AT RISK

- **ULTRASOUND BY ECHOGENIC NEEDLE TIPS (FOR EXAMPLE FOR PROSTATE)**
- **CT BY APPLICATORS NOT PRODUCING METALLIC ARTIFACTS**
- **MRI BY NON-METALLIC APPLICATORS AND NEEDLES**
- **(FOR EXAMPLE FOR GYNAECOLOGY)**

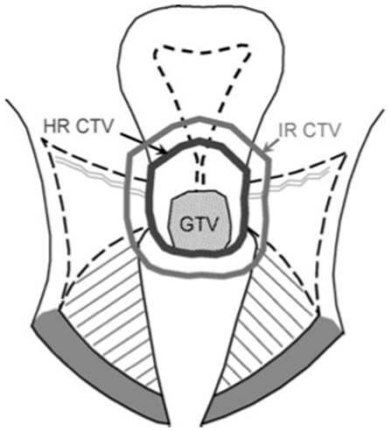
TARGET VOLUME DELINEATION

Target volume delineation

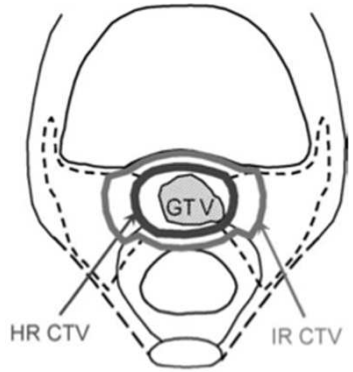


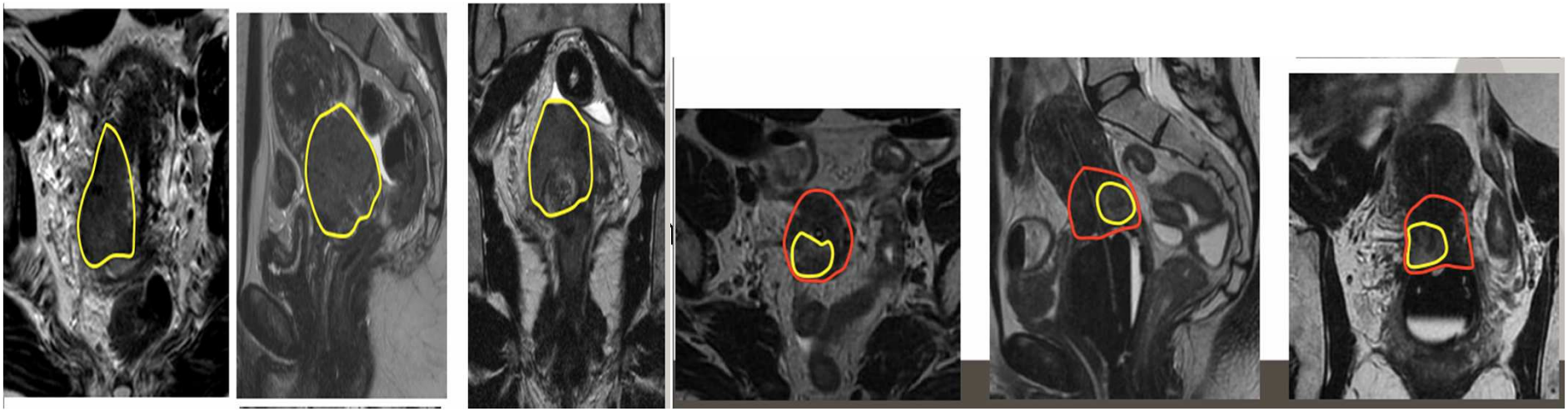
GTV D Vs GTV B

GTV D

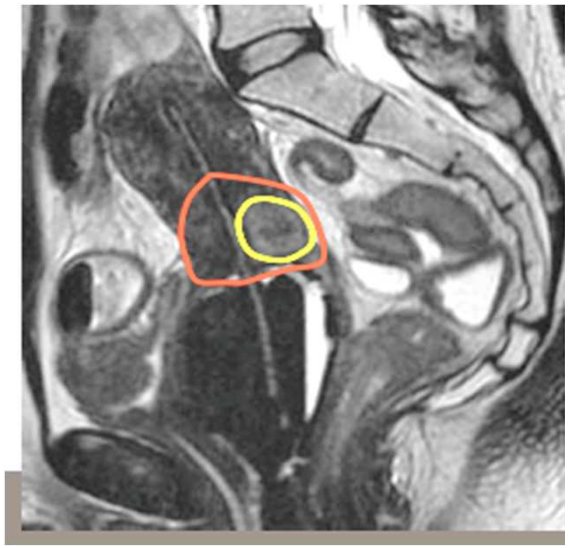


GTV BT

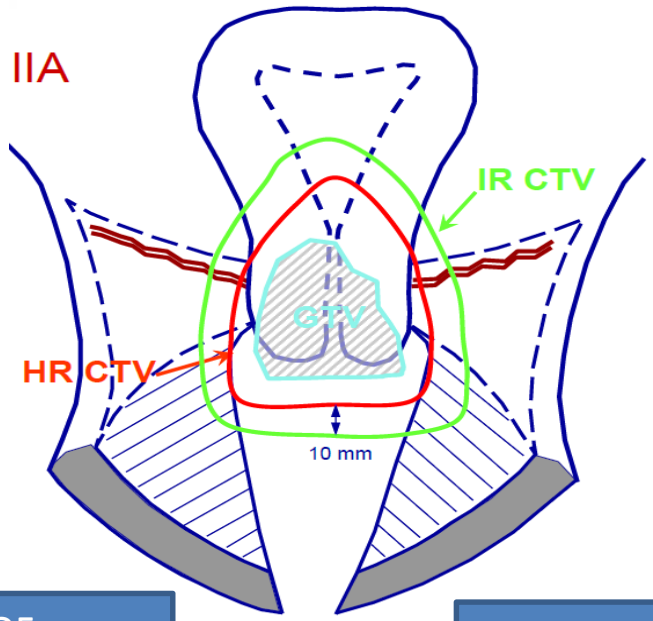




HRCTV:



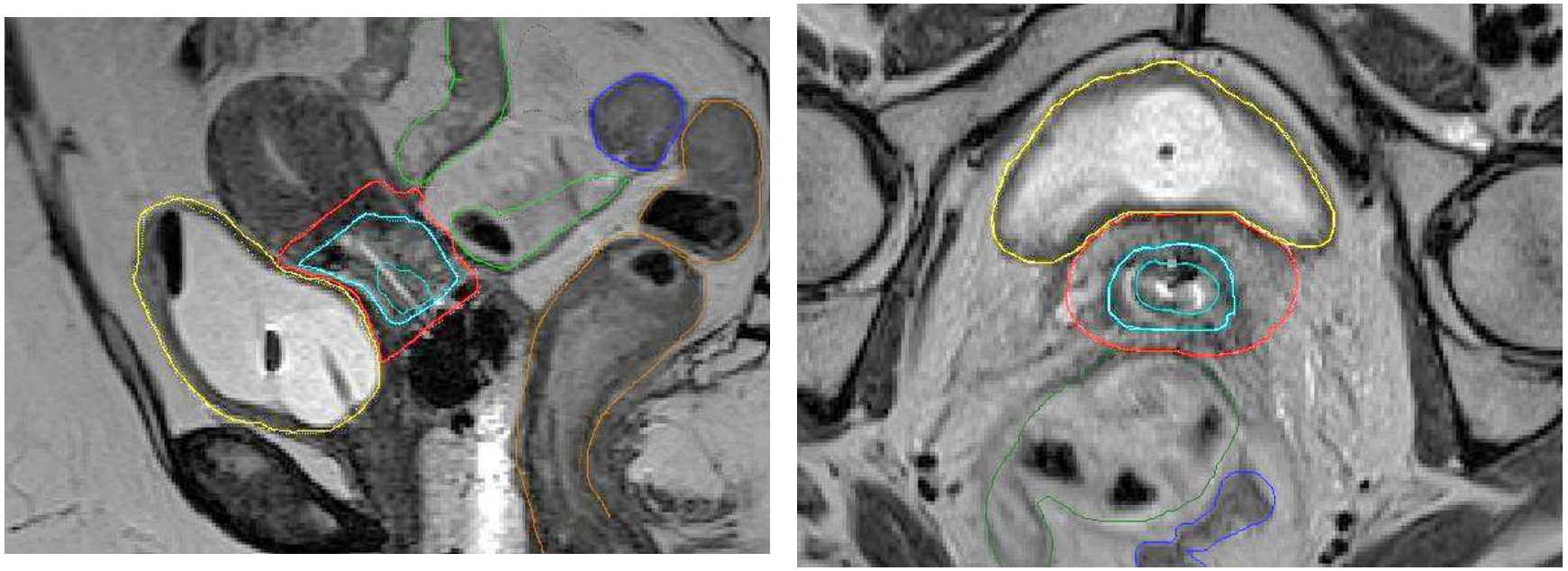
- EXTENT OF GTV AT THE TIME OF BRACHY
- WHOLE CERVIX
- PRESUMED TUMOR
- RESIDUAL GREY ZONE ON MRI
- GRAY ZONE:-PATHOLOGICAL RESIDUAL DISEASE AS DEFINED BY PALPABLE INDURATION



IRCTV:

- EXTENT OF GTV AT THE TIME OF DIAGNOSIS
- HRCTV
- SAFETY MARGIN
  - CRANIAL:-1 TO 1.5 CM
  - ANT-POST:-.5CM
  - LATERAL:- 1CM

NO PTV



GTV HRCTV IRCTV

Bladder Rectum Sigmoid Bowel

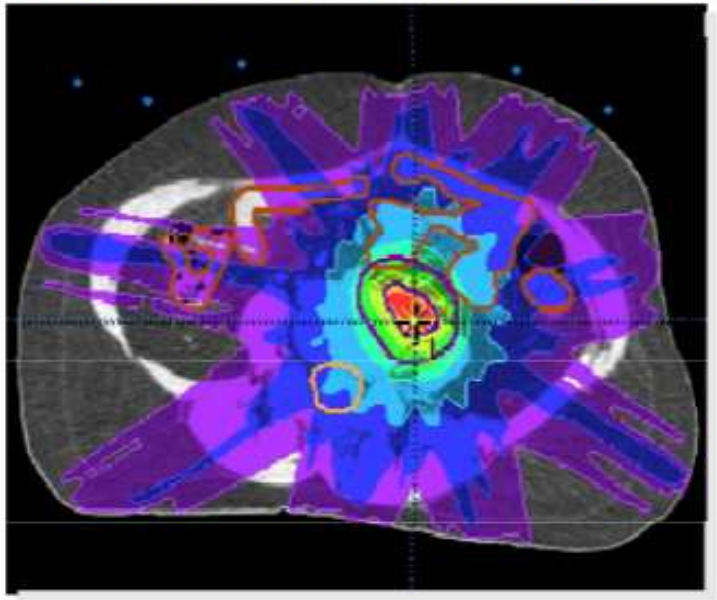
Brachy better than IMRT

Brachytherapy

Moves with patient

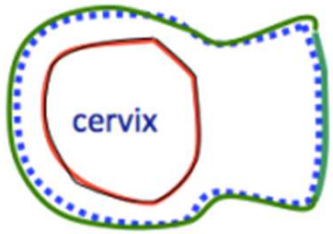
IMRT

Does not move with patient
Difficult to adjust with response

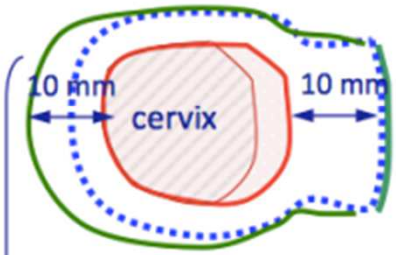


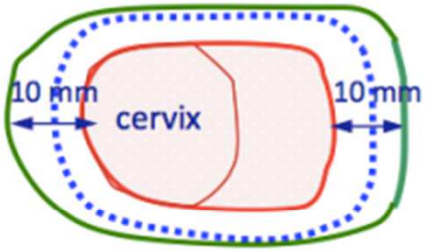
CTV BT

Complete remission

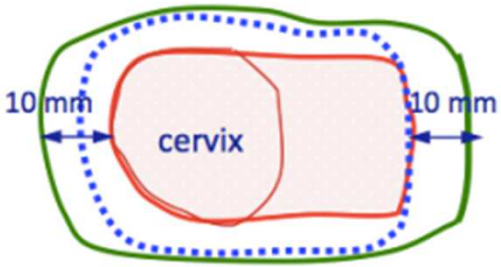


Partial remission





Stable disease



Legend

HR-CTV

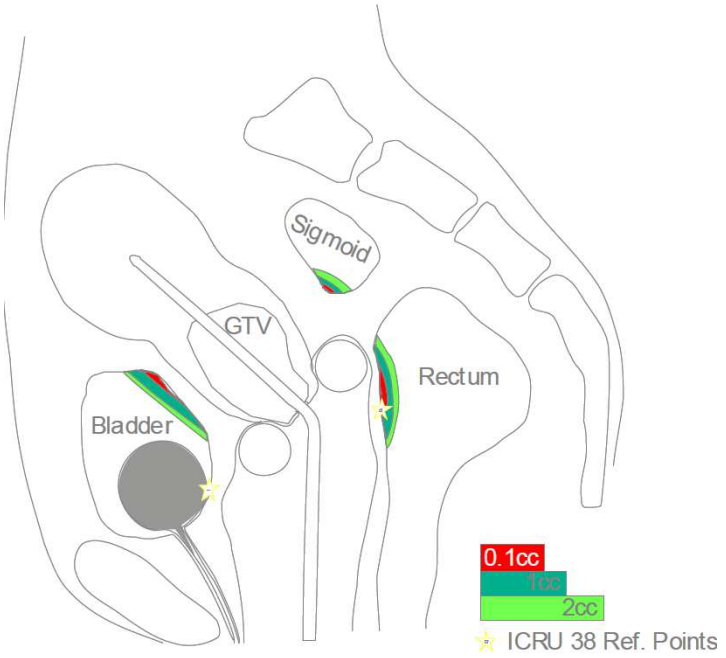
IR-CTV

Initial tumour extension
(at diagnosis)

Residual disease

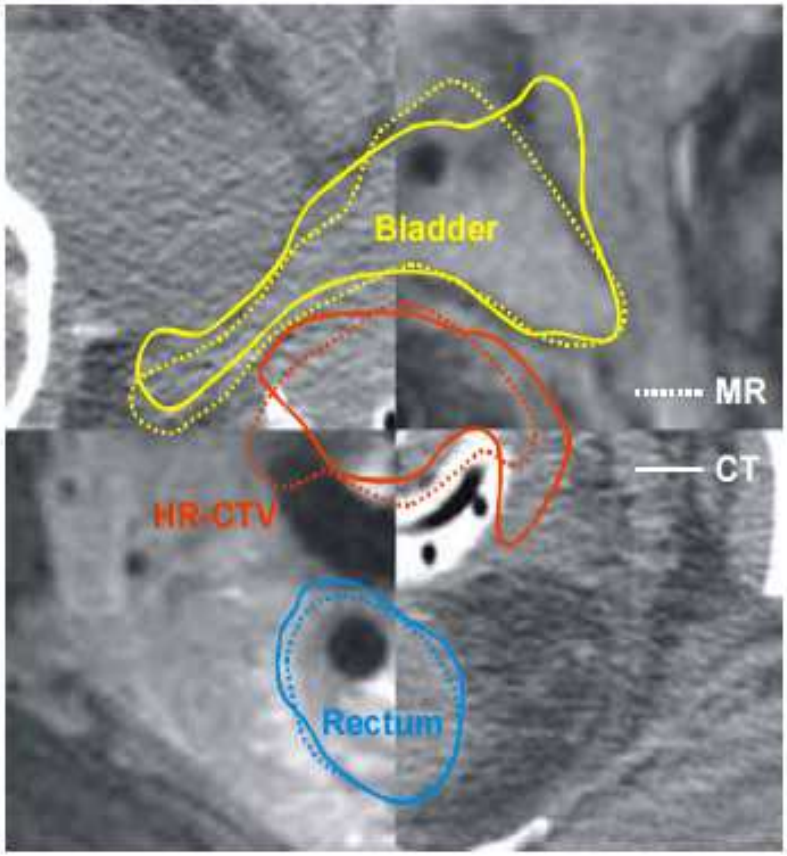
OAR DELINEATION

- ✓ **BLADDER: CONTOUR ORGAN AS OUTER WALL. PRIOR TO IMAGING EMPTY BLADDER AND INSTILL 50 CC OF SALINE**
- ✓ **RECTUM/BLADDER : CONTOUR ORGAN AS OUTER WALL**
- ✓ **SIGMOID : RECTO SIGMOID FLEXURE AND ENDS WHERE SIGMOID DISLODGES >2 CM FROM UTERUS/PARAMETRIUM.**
- ✓ **VAGINA : GAUZE IMPREGNATED WITH 1:10 GADOLINIUM OR WATER BASED JELLY AND CONTOUR WALLS. 4 MM THICKNESS**



CT versus MR contouring

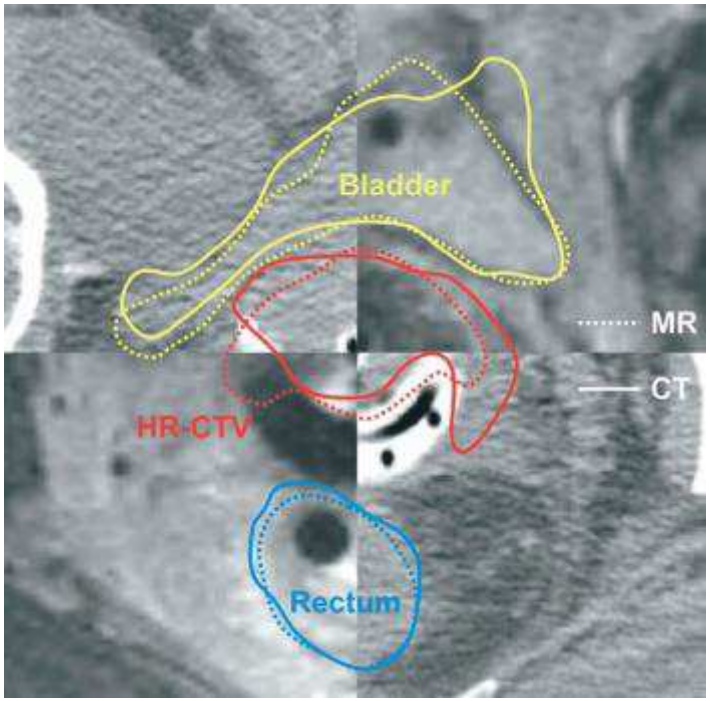
Viswanathan et al. Int J Radiat Oncol Biol 2007;68(2):491-498.



- Width of contoured tumor larger on MRI
- OAR differences depend on filling status
- Nodal dose may be estimated
- Point A constant

OAR Delineation: Technique

Choice of Imaging Modality: CT vs MRI



OARs	MRI	CT
Bladder		
Volume (cm^3)	62.5 ± 31.6	84.5 ± 57.5
$D_{0.1cm^3}$	7.5 ± 1.0	6.5 ± 1.5
D_{1cm^3}	6.1 ± 0.6	5.5 ± 1.4
D_{2cm^3}	5.6 ± 0.6	5.0 ± 1.2
Rectum		
Volume (cc)	45.3 ± 15.3	62.8 ± 16.8*
$D_{0.1cm^3}$	5.0 ± 0.9	5.0 ± 1.1
D_{1cm^3}	4.2 ± 0.7	4.2 ± 0.9
D_{02cm^3}	3.9 ± 0.7	3.9 ± 0.8
Sigmoid		
Volume (cc)	36.5 ± 25.2	29.8 ± 16
$D_{0.1cm^3}$	5.5 ± 1.1	5.5 ± 1.9
D_{1cm^3}	4.5 ± 0.9	4.3 ± 1.5
D_{2cm^3}	4.0 ± 0.8	3.9 ± 1.4

Slight over-contouring on CT as compared to MRI. No difference in OAR doses. Either could be used for Dose Volume reporting for OARs

Vishwanathan IJROBP 2012
Krishnatry, Patel JJCO,

GEC ESTRO: Dose Documentation

PHYSICAL - BIOLOGICAL DOCUMENTATION OF GYNAECOLOGICAL HDR BT

PATIENT , ID-number	**mum001**						**tumour entity**	
EXTERNAL BEAM THERAPY			**TUMOUR**		**OAR**		**FIGO, TNM**	**IIB**
dose per fraction	2		D_{iso} [α/β=10Gy]		D_{iso} [α/β=3Gy]			
fractions without central shield	20		40.0		40.0			
fractions with central shield	0		0.0		0.0		**GTV at diag.**	**cm^3**
total dose	**40.0**		**40.0**		**40.0**			
							chemoth.	**WEEKLY**
BRACHYTHERAPY	**F 1**	**F 2**	**F 3**	**F 4**	**F 5**	**F 6**		
date	23/8/11	30/8/11	7/9/11				**dose values in Gy**	
physicist	svj	svj	svj	svj				
MR / CT	MR	MR	MR	MR			TOTAL	TOTAL
applicator(s): type	VIENNA	VIENNA					BT	BT + EBT
applicator(s): dimensions	30/60MM	30/60MM						
eval plan, remarks							*mean*	*stddev*
TRAK [cGy at 1m]							**0.00**	
prescribed dose PD	7	7	7	0	0			
PD $_{iso}$ [α/β=10Gy]	9.9	9.9	9.9	0.0	0.0	0.0	29.8	**69.8**
volume of PD [cm^3]							***#DIV/0!***	*#DIV/0!*
PDx2	14.0	14.0	14.0	0.0	0.0	0.0		
PDx2 $_{iso}$ [α/β=10Gy]	28.0	28.0	28.0	0.0	0.0	0.0	84.0	124.0
volume of PDx2 [cm^3]							*#DIV/0!*	*#DIV/0!*
pres. point level (A / My / [mm])								
pres. point [mm $_{left}$ / mm $_{right}$]								
dose to + A left	7.0	7.0	7.0	0.0	0.0			
A_{left} - D_{iso} [α/β=10Gy]	9.9	9.9	9.9	0.0	0.0	0.0	29.8	**69.8**
dose to - A right	7.0	7.0	7.0	0.0	0.0			
A_{right} - D_{iso} [α/β=10Gy]	9.9	9.9	9.9	0.0	0.0	0.0	29.8	**69.8**

PLANNING BRACHYTHERAPY

- EXAMINATION UNDER ANAESTHESIA
- PROPER APPLICATOR PLACEMENT
- MR IMAGING :-
  - T2 FSE,T1,SAG,AXIAL,CORONAL,CONTRAST
- CONTOURING:-
  - TUMOR:-GTV,HIGH RISK CTV,INTERMEDIATE RISK CTV
  - OAR:-D0.1CC,D-1CC,D-2CC
- TREATMENT PLANNING SYSTEM
  - CATHETER RECONSTRUCTION,
  - LOADING PATTERN,
  - OPTIMISATION
- PLAN EVALUATION:-
  - EQD2,DOSE TO GTV,HR CTV(D90,D100,V100)
  - DOSES TO OAR:- BLADDER,RECTUM,SIGMOD(D0.1CC,D-1CC,D-2CC)

IS IT REALLY NECESSARY

CLINICAL IMPACT OF MRI ASSISTED DOSE VOLUME ADAPTATION AND DOSE ESCALATION IN BRACHYTHERAPY OF LOCALLY ADVANCED CERVIX CANCER.

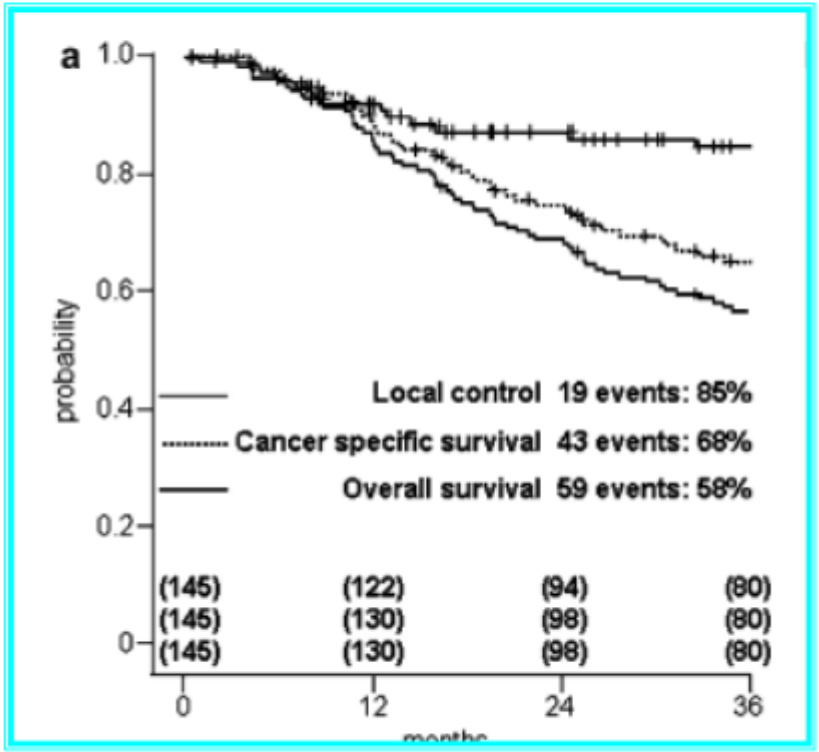
	CONV BRACHY 1998-2000	MRI BASED BRACHY 2001-2003	p
D90	81 GY	90 GY	
OVERALL SURVIVAL	53%	64%	0.03
CSS	71%	90%	0.13
>5 CM LOCAL CONTROL	64%	82%	0.09
OS	28%	58%	0.003
CSS	40%	62%	0.07
LATE MORBIDITY	10%	2%	

Potter et al. Radiother Oncol 2007:83;148

MR T/R Brachytherapy Outcomes

Rad Onc 2011:100:116-123

- 156 patients
- Historical comparison
- Med FU 42 mo
- CR 97%
- Significant ↑
  - 3y OS 53 to 68%
  - CSS 62 to 74%
  - Tumors > 5cm
    - OS 28 to 65%



Pötter et al. Rad Oncol 2007

DOSE–VOLUME HISTOGRAM PARAMETERS AND LOCAL TUMOR CONTROL IN MAGNETIC RESONANCE IMAGE–GUIDED CERVICAL CANCER BRACHYTHERAPY

JOHANNES C. A. DIMOPOULOS, M.D.,* STEFAN LANG, PH.D.,* CHRISTIAN KIRISITS, D.SC.,* ELENA F. FIDAROVA, M.D.,* DANIEL BERGER, M.SC.,* PETRA GEORG, M.D.,* WOLFGANG DÖRR, D.V.M., PH.D.,† AND RICHARD PÖTTER, M.D.*

*Department of Radiotherapy, Medical-University of Vienna, Vienna, Austria; and †Department of Radiotherapy and Radiation Oncology, Medical Faculty Carl Gustav Carus, University of Technology, Dresden, Germany

Purpose: To investigate the value of dose–volume histogram (DVH) parameters for predicting local control in magnetic resonance (MR) image-guided brachytherapy (IGBT) for patients with cervical cancer.

Methods and Materials: Our study population consists of 141 patients with cervical cancer (Stages IB–IVA) treated with 45–50 Gy external beam radiotherapy plus four times 7 Gy IGBT with or without cisplatin. Gross tumor volume (GTV), high-risk clinical target volume (HRCTV), and intermediate-risk clinical target volume (IRCTV) were contoured, and DVH parameters (minimum dose delivered to 90% of the volume of interest [D90] and D100) were assessed. Doses were converted to the equivalent dose in 2 Gy (EQD2) by applying the linear quadratic model (α/β = 10 Gy). Groups were defined for patients with or without local recurrence (LR) in the true pelvis for tumor size at diagnosis (GTV at diagnosis [GTVD] of 2–5 cm (Group 1) or greater than 5 cm (Group 2) and for tumor size response at IGBT (HRCTV) of 2–5 cm (Group 2a) or greater than 5 cm (Group 2b).

Results: Eighteen LRs were observed. The most important DVH parameters correlated with LR were the D90 and D100 for HRCTV. Mean D90 and D100 values for HRCTV were 86 ± 16 and 65 ± 10 Gy, respectively. The D90 for HRCTV greater than 87 Gy resulted in an LR incidence of 4% (3 of 68) compared with 20% (15 of 73) for D90 less than 87 Gy. The effect was most pronounced in the tumor group (Group 2b).

Conclusions: We showed an increase in local control in IGBT in patients with cervical cancer with the dose delivered, which can be expressed by the D90 and D100 for HRCTV. Local control rates greater than 95% can be achieved if the D90 (EQD2) for HRCTV is 87 Gy or greater.

Cervical cancer, Magnetic resonance (MR) image-guided brachytherapy, Target, Dose–volume histogram (DVH).

Table 4. D90 and D100 of three target structures for patients with/without LR and tumor size/response Groups 1, 2, 2a, and 2b

		GTV		HR CTV		IR CTV	
Subgroup	*n*	D100 (Gy)	D90 (Gy)	D100 (Gy)	D90 (Gy)	D100 (Gy)	D90 (Gy)
1; 2–5cmDIAG	65	95 ± 27	131 ± 39	65 ± 11	89 ± 17	51 ± 8	65 ± 10
LR	2	92 ± 13	124 ± 19	69 ± 1	92 ± 3	53 ± 1	69 ± 1
No LR	63	95 ± 27	131 ± 39	65 ± 12	89 ± 17	51 ± 8	65 ± 10
p		>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
2; >5cmDIAG	76	86 ± 19	116 ± 29	65 ± 8	83 ± 15	55 ± 5	66 ± 8
LR	16	80 ± 12	111 ± 24	59 ± 6	73 ± 11	53 ± 5	61 ± 6
No LR	60	87 ± 20	117 ± 31	66 ± 8	86 ± 15	56 ± 4	67 ± 8
p		>0.05	>0.05	**<0.05**	**<0.05**	**<0.05**	**<0.05**
2a; >5cmDIAG • 2–5cmBT	45	90 ± 21	122 ± 32	67 ± 8	88 ± 15	56 ± 4	68 ± 7
LR	5	90 ± 15	134 ± 29	62 ± 4	83 ± 7	52 ± 7	64 ± 4
No LR	40	90 ± 22	121 ± 33	68 ± 8	88 ± 15	56 ± 4	68 ± 7
p		>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
2b; >5 cmDIAG • >5 cmBT	31	79 ± 14	106 ± 22	61 ± 8	77 ± 13	55 ± 5	63 ± 8
LR	11	76 ± 9	101 ± 12	57 ± 7	69 ± 9	53 ± 4	60 ± 6
No LR	20	81 ± 17	109 ± 25	64 ± 7	81 ± 13	56 ± 5	65 ± 8
p		>0.05	>0.05	**<0.05**	**<0.05**	>0.05	>0.05

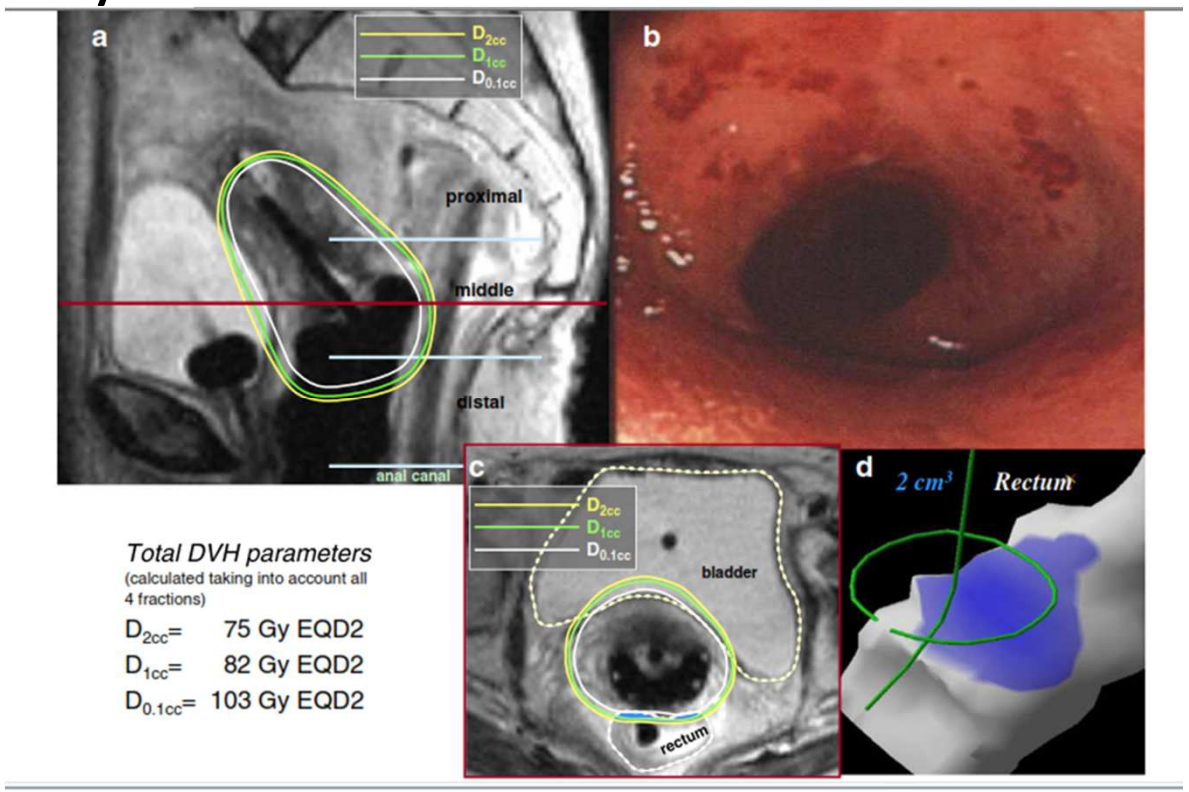
Abbreviations: GTV = gross tumor volume; CTV = clinical target volume; HR = high risk; IR = intermediate risk; Dx = minimum dose delivered to x% of the volume of interest; LR = local recurrence; 2–5cmDIAG = tumors 2–5 cm at diagnosis; >5cmDIAG = tumors greater than 5 cm at diagnosis; >5cmDIAG • 2–5cmBT = tumors greater than 5 cm at diagnosis and HRCTV of 2–5cm at the time of brachytherapy; >5 cmDIAG • >5 cmBT = tumors greater than 5 cm at diagnosis and HRCTV greater than 5 cm at the time of brachytherapy.

Dose values expressed as mean ± 1 SD equivalent doses for 2 Gy fractions (EQD2; α/β = 10 Gy).

Bold values indicate significant *p* values.

Reference tolerance doses

- For D2cc (Gy)
  - Rectum, bowel, sigmoid – 75Gy
  - Bladder – 95Gy



DVH analysis and late side effects

Georg et al. Int J Radiat Oncol Biol Phys. 2011 Feb 1;79(2):356-62

- **Rectum: D2cc rectum >75 Gy predicted ≥ G2 side effects**
- **Sigmoid: No dose limit identified given low number of sigmoid specific side effects**
- **Bladder: D2cc >95 Gy appeared to increase side effects though further analysis needed**

Dose effect relationship for late side effects and IGABT - Rectum

- Probability of EQD2 for G2-4 side effects (Gy) for the incidence rates shown (95% CI)

Dose volume	5%	10%	20%	*p* value
D2cc	67 (30-79)	78 (66-110)	90 (78-171)	0.0178
D1cc	71 (0-89)	87 (69-209)	104 (87-443)	0.0352
D0.1cc	83	132	186	0.1364

Georg et al. IJROBP 2012;82(2):653

Dose effect relationship for late side effects and IGABT - Bladder

- Probability of EQD2 for G2-4 side effects (Gy) for the incidence rates shown (95% CI)

Dose volume	5%	10%	20%	*p* value
D2cc	70 (0-95)	101 (29-137)	134 (110-371)	0.0274
D1cc	71 (0-107)	116 (17-169)	164 (129-498)	0.0268
D0.1cc	61 (0-155)	178 (0-368)	305 (129-498)	0.0369

Georg et al. IJROBP 2012;82(2):653

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 79, No. 2, pp. 356–362, 2011

0360-3016/$–see front matter

doi:10.1016/j.ijrobp.2009.11.002

DOSE–VOLUME HISTOGRAM PARAMETERS AND LATE SIDE EFFECTS IN MAGNETIC RESONANCE IMAGE–GUIDED ADAPTIVE CERVICAL CANCER BRACHYTHERAPY

PETRA GEORG, M.D.,* STEFAN LANG, PH.D.,* JOHANNES C. A. DIMOPOULOS, M.D.,* WOLFGANG DÖRR, D.V.M., PH.D.,*† ALINA E. STURDZA, M.D.,* DANIEL BERGER, PH.D.,* DIETMAR GEORG, PH.D.,* CHRISTIAN KIRISITS, D.SC.,* AND RICHARD PÖTTER, M.D.*

*Department of Radiotherapy, Medical University of Vienna, Vienna, Austria; and †Department of Radiotherapy and Radiation Oncology, Medical Faculty Carl Gustav Carus, University of Technology Dresden, Dresden, Germany

Table 1. Dose levels (in grays) and side effects (Group 1 vs. Group 2) for the rectum, sigmoid colon, and urinary bladder

OAR	n	D_{ICRU}	D_{2cc}	D_{1cc}	$D_{0.1cc}$
Bladder	141	72 ± 15	95 ± 22	108 ± 31	162 ± 75
Group 1 (G0)	118	71 ± 15	94 ± 20	107 ± 28	158 ± 65
Group 2 (G1–G4)	23	76 ± 16	101 ± 29	117 ± 42	182 ± 116
p		0.144	0.197	0.159	0.168
Rectum	141	67 ± 13	65 ± 12	69 ± 14	86 ± 27
Group 1 (G0)	130	66 ± 12	64 ± 12	69 ± 14	84 ± 26
Group 2 (G1–G4)	11	80 ± 19	75 ± 13	80 ± 16	103 ± 31
p		0.002*	0.003*	0.007*	0.022*
Sigmoid	141		62 ± 12	67 ± 14	84 ± 32
Group 1 (G0)	138		62 ± 12	66 ± 14	83 ± 33
Group 2 (G1–G4)	3		77 ± 11	84 ± 14	104 ± 24
p			0.028*	0.037*	0.279

Abbreviations: OAR = organ at risk; D_{ICRU} = dose at the International Commission on Radiation Units and Measurements reference point; D_{2cc}, D_{1cc}, $D_{0.1cc}$ = most exposed 2, 1, and 0.1 cm^3 of tissue; G = Grade.

* Statistically significant ($p < 0.05$).

ELSEVIER

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DOSE–VOLUME HISTOGRAM PARAMETERS AND LATE SIDE EFFECTS IN MAGNETIC RESONANCE IMAGE–GUIDED ADAPTIVE CERVICAL CANCER BRACHYTHERAPY

PETRA GEORG, M.D.,* STEFAN LANG, PH.D.,* JOHANNES C. A. DIMOPOULOS, M.D.,* WOLFGANG DÖRR, D.V.M., PH.D.,*† ALINA E. STURDZA, M.D.,* DANIEL BERGER, PH.D.,* DIETMAR GEORG, PH.D.,* CHRISTIAN KIRISITS, D.SC.,* AND RICHARD PÖTTER, M.D.*

*Department of Radiotherapy, Medical University of Vienna, Vienna, Austria; and †Department of Radiotherapy and Radiation Oncology, Medical Faculty Carl Gustav Carus, University of Technology Dresden, Dresden, Germany

Table 2. Dose levels (in grays) and side effects (Group 3 vs. Group 4) for the rectum, sigmoid colon, and urinary bladder

OAR	n	D_{ICRU}	D2 cc	D1 cc	D0.1 cc
Bladder	141	72 ± 15	95 ± 22	108 ± 31	162 ± 75
Group 3 (G0–G1)	127	71 ± 15	94 ± 20	106 ± 28	157 ± 63
Group 4 (G2–G4)	14	78 ± 15	108 ± 33	126 ± 48	208 ± 140
p		0.133	0.021*	0.019*	0.016*
Rectum	141	67 ± 13	65 ± 12	69 ± 14	86 ± 27
Group 3 (G0–G1)	133	66 ± 12	64 ± 12	69 ± 14	85 ± 26
Group 4 (G2–G4)	8	83 ± 22	75 ± 15	80 ± 18	100 ± 30
p		0.001*	0.014*	0.030*	0.122
Sigmoid	141		62 ± 12	67 ± 14	84 ± 32
Group 3 (G0–G1)	138		62 ± 12	66 ± 14	83 ± 33
Group 4 (G2–G4)	3		77 ± 11	84 ± 14	104 ± 24
p			0.028*	0.037*	0.279

Abbreviations as in Table 1.

* Statistically significant ($p < 0.05$).

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ASTRO

Comparative Study of LDR (Manchester System) and HDR Image-guided Conformal Brachytherapy of Cervical Cancer: Patterns of Failure, Late Complications, and Survival

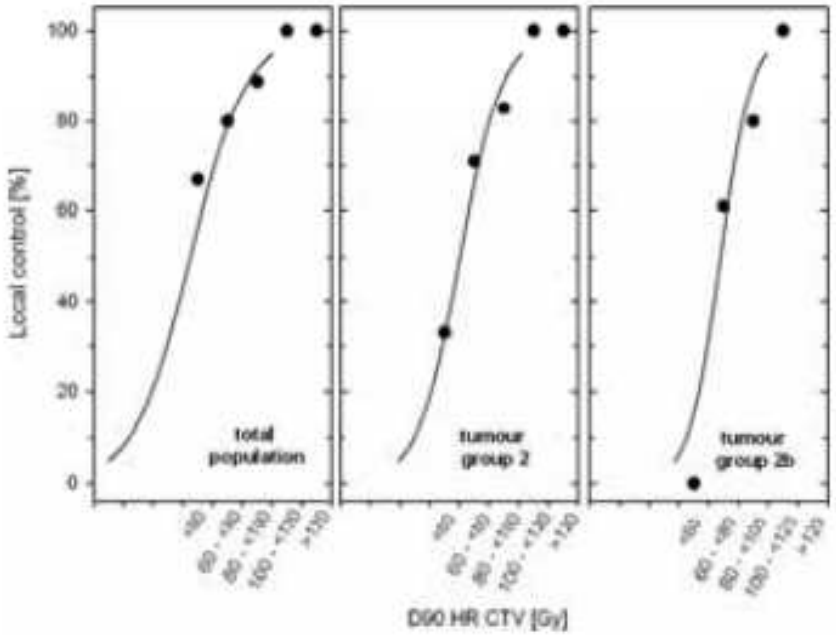
Kailash Narayan, F.R.A.N.Z.C.R.correspondenceemail, Sylvia van Dyk, Dip App Sci, David Bernshaw, F.R.A.N.Z.C.R., Chrishanthi Rajasooriyar, M.D. , Srinivas Kondalsamy-Chennakesavan,

- Retrospective study of 217 patients of advanced carcinoma cervix.
- 90 patients received LDR and 123 patients received HDR brachytherapy
- **Conclusion** of the study-- Image-guided HDR planning led to a large decrease in late radiation effects in patients treated by HDR. Patterns of failure and survival were similar in patients treated either by LDR or HDR.

Tumor control related to dose

Dimopoulos JC et al. Int J Radiat Oncol Biol Phys. 2009 Sep 1;75(1):56-63

- **D90 for HRCTV > 87 Gy**
  - **LR 4% (3 of 68)**
- **D90 for HRCTV ≤ 87 Gy**
  - **LR 20% (15 of 73)**
- **The effect was most pronounced in patients that had tumors >5cm w a poor response**



TAKE HOME MESSAGE
IMAGE ASSISTED BRACHYTHERAPY

- BRACHY THERAPY IS AN INTEGRAL PART OF TREATMENT
- MRI IS THE BEST MODALITY OF IMAGING
- T2 FSE IMAGING TO DELINEATE THE TUMOR
- CONTOURING:-
  - TUMOR:-GTV,HIGH RISK CTV,INTERMEDIATE RISK CTV
  - OAR:-0.1CC,1CC,2CC
  - BETTER TUMOR CONTROL AND LESS MORBIDITY

Strategize your approach

- **Experience matters**
  - **Training programs**
- **Follow guidelines**
- **Standardize approach**

"I like to practice before
I start acupuncture treatment!"