IMAGE GUIDED RADIOTHERAPY IN CARCINOMA PROSTATE

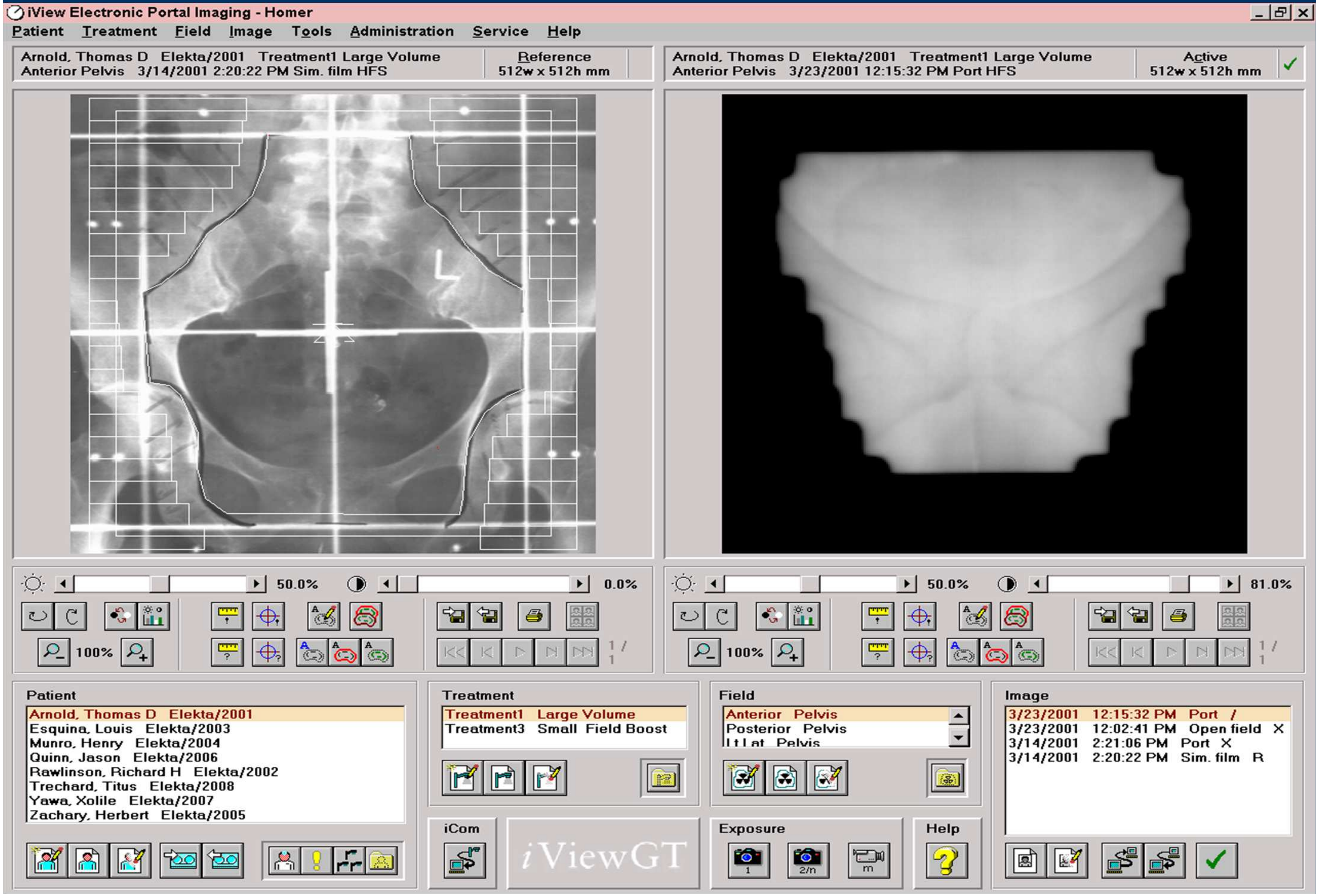
Dr. G.K. Rath
Professor & Head
Department of Radiation Oncology
Chief,
DR BRAIRCH, AIIMS, New Delhi

WHAT IS THE MOST ACCURATE TECHNIQUE OF RADIOTHERAPY ?

Those who precisely know the answer, please raise their hands

WHAT IS IGRT?

Those who precisely know the answer, please raise their hands


iView Electronic Portal Imaging - Homer
Patient Treatment Field Image Tools Administration Service Help
Arnold, Thomas D Elekta/2001 Treatment1 Large Volume
Anterior Pelvis 3/14/2001 2:20:22 PM Sim. film HFS
Reference
512w x 512h mm
Arnold, Thomas D Elekta/2001 Treatment1 Large Volume
Anterior Pelvis 3/23/2001 12:15:32 PM Port HFS
Active
512w x 512h mm
50.0%
0.0%
100%
50.0%
81.0%
100%
Patient
Arnold, Thomas D Elekta/2001
Esquina, Louis Elekta/2003
Munro, Henry Elekta/2004
Quinn, Jason Elekta/2006
Rawlinson, Richard H Elekta/2002
Trechard, Titus Elekta/2008
Yawa, Xolile Elekta/2007
Zachary, Herbert Elekta/2005
Treatment
Treatment1 Large Volume
Treatment3 Small Field Boost
Field
Anterior Pelvis
Posterior Pelvis
Image
3/23/2001 12:15:32 PM Port /
3/23/2001 12:02:41 PM Open field X
3/14/2001 2:21:06 PM Port X
3/14/2001 2:20:22 PM Sim. film R
iCom
iViewGT
Exposure
Help

- KVCT
- MVCT

DOSE ESCALATION → IMPROVED RESULTS

- Positive biopsy after RT-19-65%
- The rate of positive biopsies decreased linearly as dose escalated (by3DCRT)

    81 Gy-7% pos biopsy rate,

    75.6 Gy-48%,

    70.2 Gy-45%,

    64.8 Gy-57%

Zelefsky et al. Int. J. Radiation Oncology Biol. Phys. *1998;41;491-500*

DOSE ESCALATION → IMPROVED RESULTS

MDACC 4 YR PSA free survival rates:

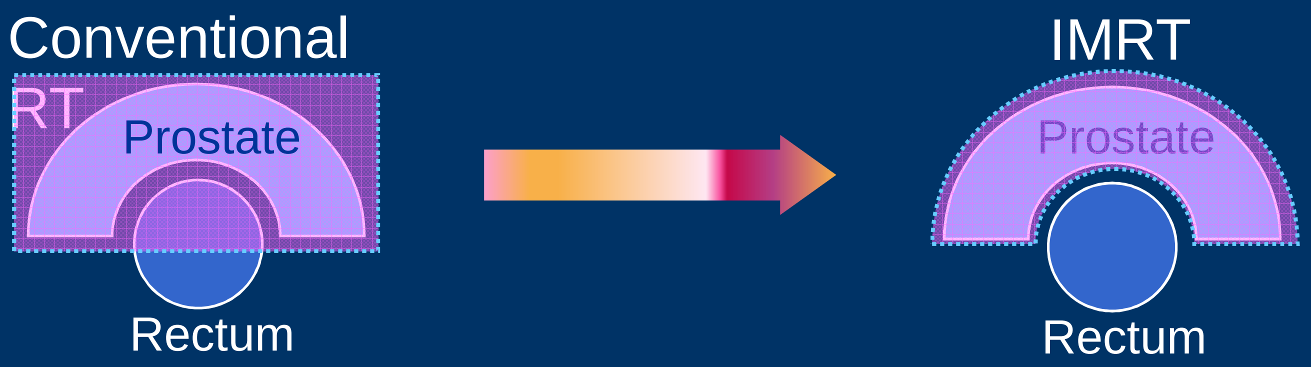
<67 Gy-(n=500)-54%

67-77 Gy-(n=495)-71%

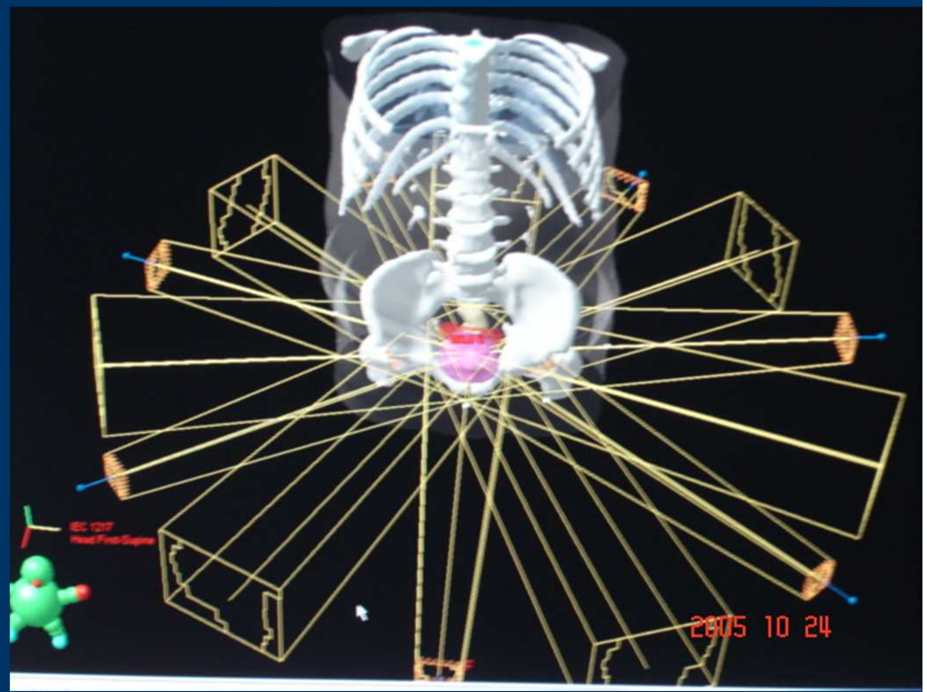
>77 Gy-(n=132)-77%

Pollack et al. Int. J. Radiation Oncology Biol. Phys 1997;39;1011-18

IMRT GIVES IMPROVED CONFORMITY



- Improved clinical outcomes
- Less complications and side effects
- More effective treatment
- Cost efficient technology
- Reduced need for invasive procedures



IMRT- TOOL FOR DOSE ESCALLATION

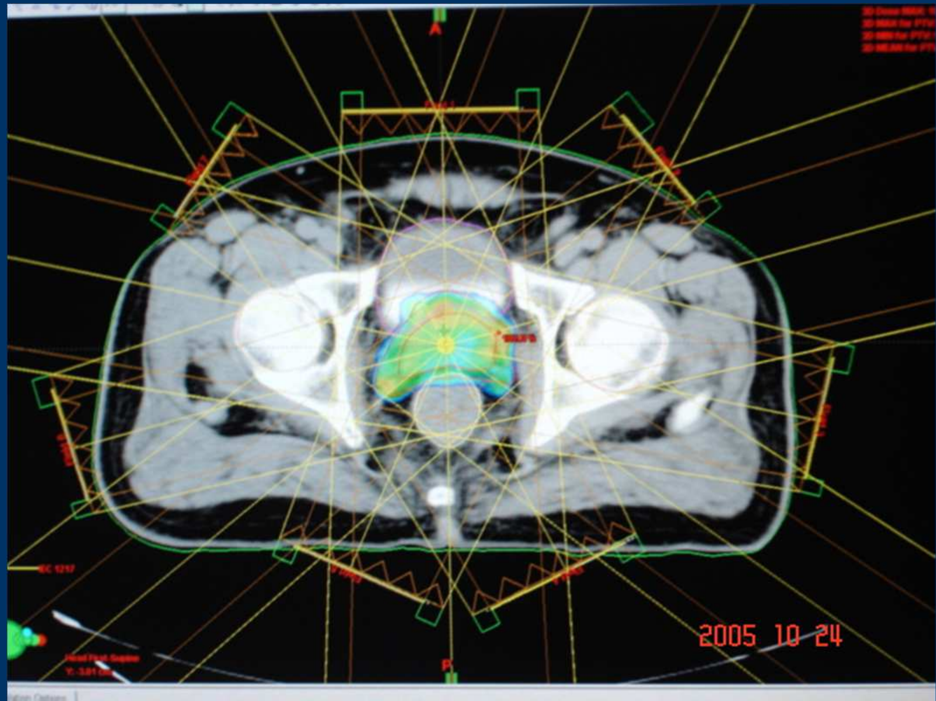


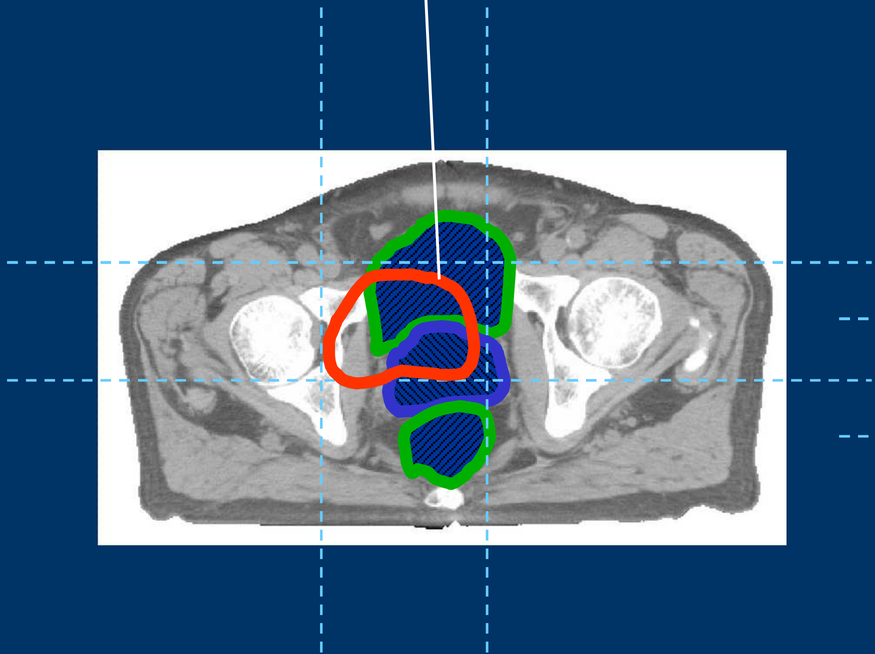
Table 1. Clinical Goals for 81 and 86.4 Gy Prostate IMRT Treatment Plans at MSKCC

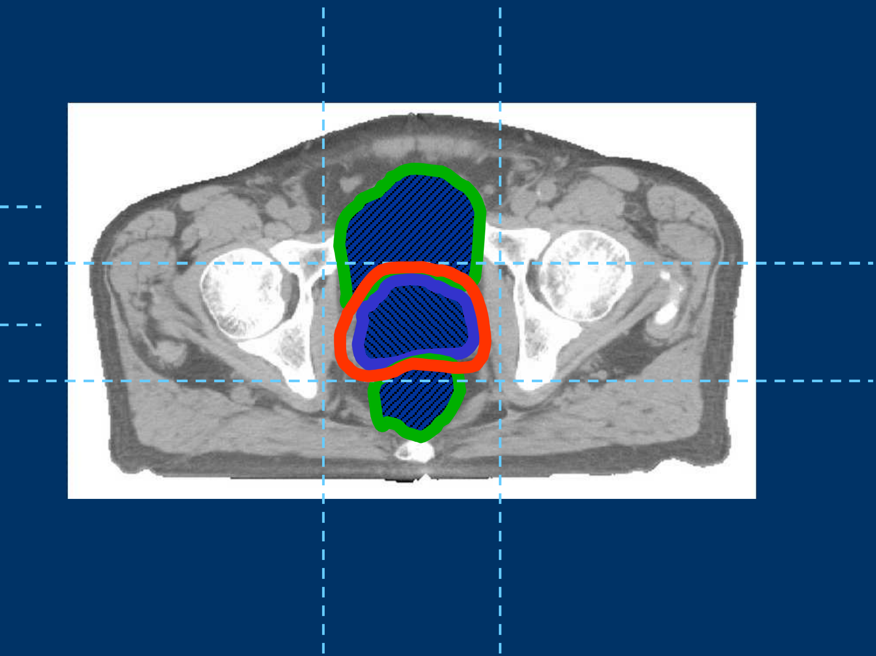
Structure	*81 Gy Plan*	*86.4 Gy Plan*
Planning target volume	Maximum dose ≤90 Gy	Maximum dose ≤96 Gy
	≥90% of PTV must receive ≥77 Gy	≥85% of CTV must receive ≥86.4 Gy
Rectal wall	No more than 30% can receive ≥75.6 Gy	Same as 81 Gy plan
	No more than 53% can receive ≥47 Gy	Same as 81 Gy plan
Bladder wall	No more than 53% can receive ≥47 Gy	Same as 81 Gy plan

EFFICIENT TREATMENT ALSO REQUIRES ACCURACY!

Radiation shaped to target but missing target

The right target





CAUTION

With tight margins being taken in highly conformal radiotherapy techniques there is a risk of precisely missing the target with organ motion.

PROSTATE MOTION

- Two phenomena potentially affecting radiation delivery in Prostate cancer

  (A) Motion

  (B) Deformation

- These changes can happen

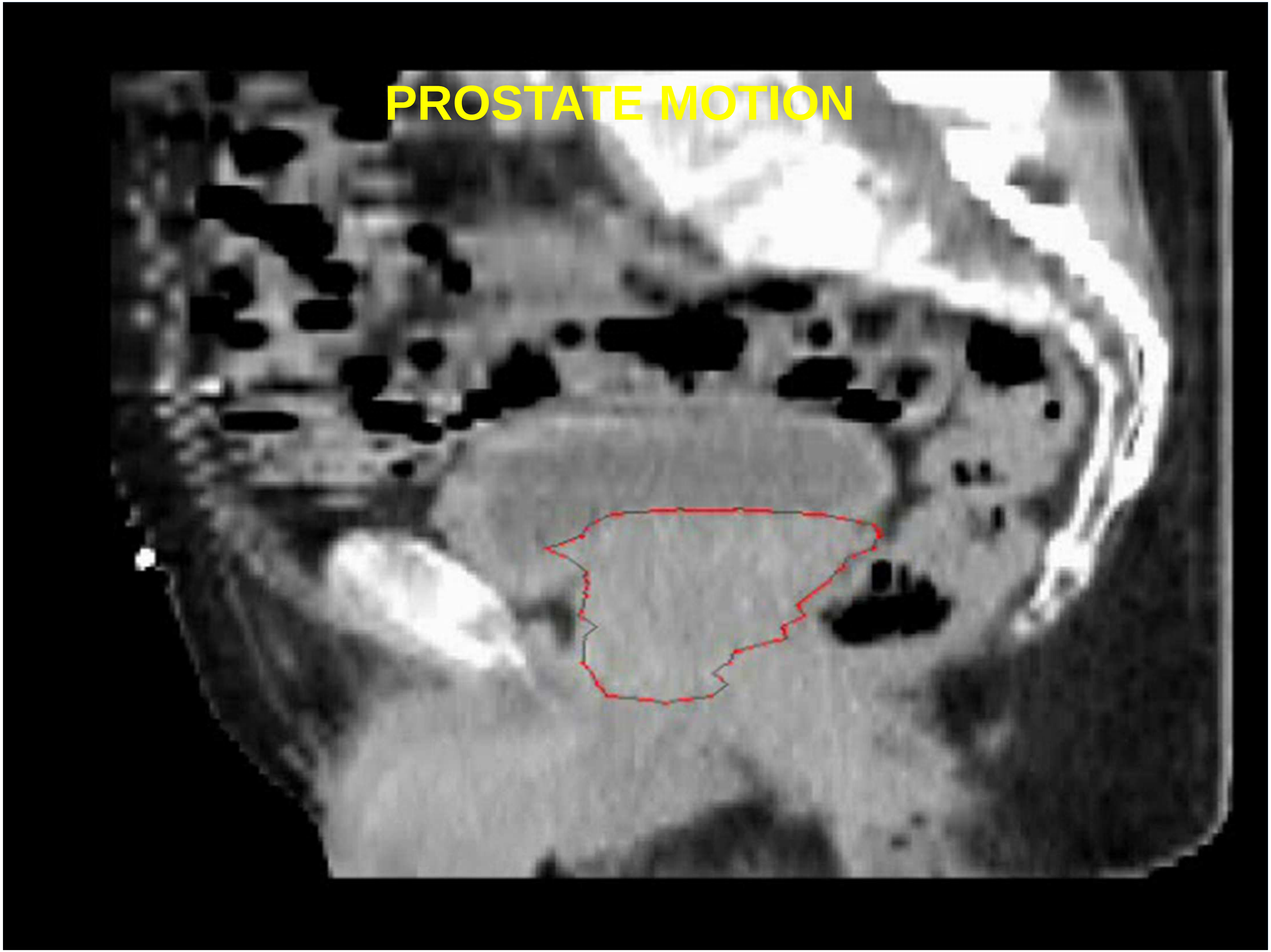
  (A) Interfraction motion

  (B) Intrafraction motion

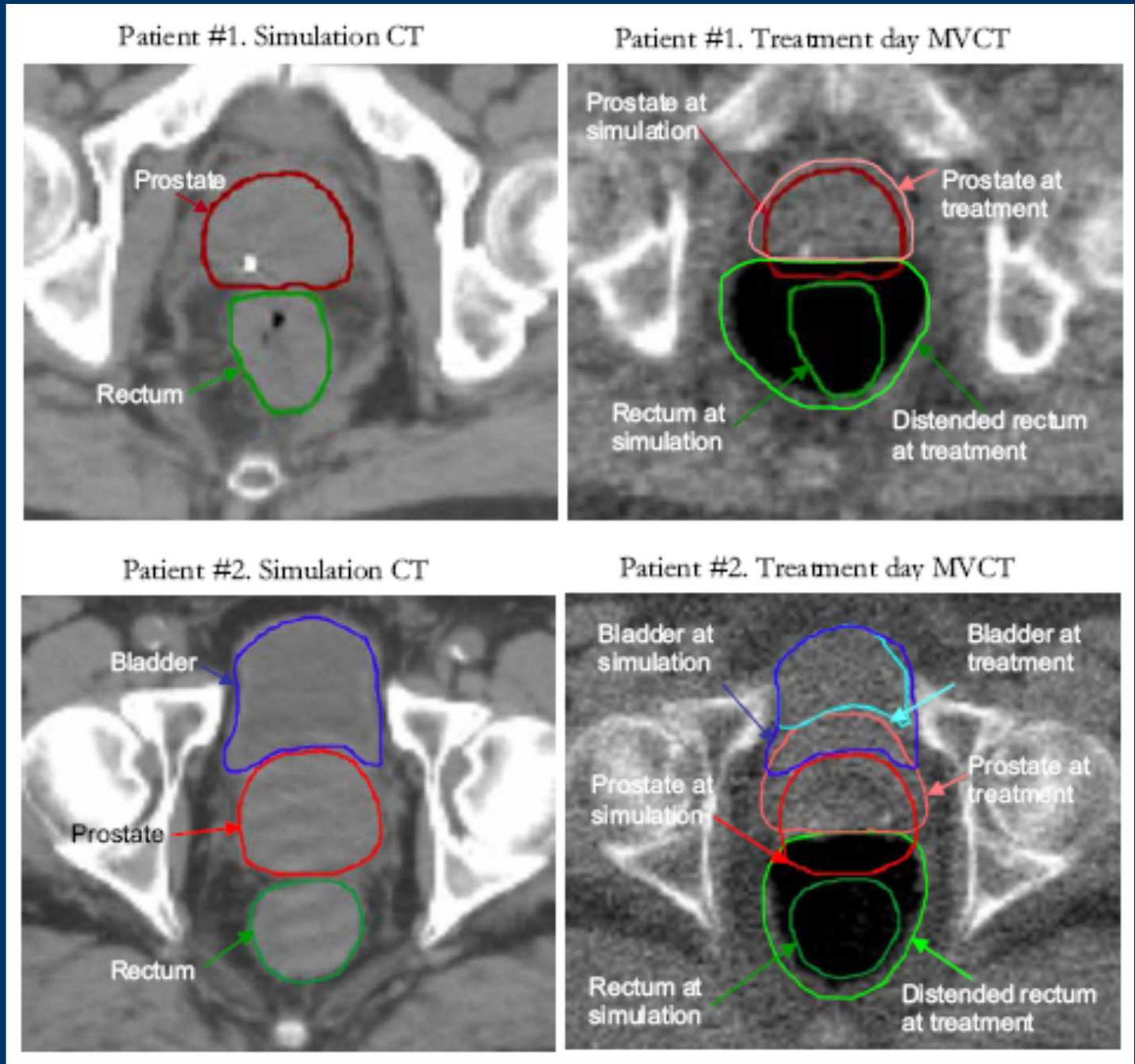
  (C) Interfraction deformation

PROSTATE MOTION

- Position depends on the status of rectal filling
- Is known to translate and rotate under influence of rectal filling changes
- Full rectum has mobile gas pockets, associated with increased prostate motion
- Apex is largely immobile
- Motion well described by rotation but undergoes deformation due to distension


PROSTATE MOTION

COMPARISION OF PATIENT ANATOMY ON SIMULATION AND TREATMENT DAY



INTERFRACTIONAL PROSTATE MOTION AMONG NORMAL, OVERWEIGHT, AND OBESE

Table 1: Summary of inter-fraction prostate shift for three patient subgroups

	Control	Overweight	Obese	All patients
Fractions	143	320	232	695
AP Shift (mm)	0.3 ± 4.1	−0.1 ± 5.3	0.7 ± 4.1	0.2 ± 4.7
LR Shift (mm)	0.5 ± 4.1	1.1 ± 2.9	−0.3 ± 5.5	−0.5 ± 4.0
SI Shift (mm)	0.0 ± 0.4	−0.1 ± 0.8	−0.2 ± 1.1	−0.1 ± 0.9

Wong et al, Int. J. Radiation Oncology Biol. Phys 2007;69: S740

INTRAFRACTION MOTION

Table 1. Standard deviations for all patients (population averages) for all POIs grouped by rectal status

POI	Rectal status (mm)		
	Full	Empty	*P*
Apex	1.26	1.04	0.050
Inferior posterior	1.20	1.0	0.056
Midanterior	0.98	0.79	0.047
Midposterior	1.72	0.79	0.0001
Anterior base	1.38	1.04	0.009
Posterior base	1.44	0.85	0.0001
Seminal vesicles	1.56	0.68	0.0001
Pubis, inferior	0.45	0.62	0.981
Pubis, superior	0.41	0.54	0.988
Sacrum	0.40	0.42	0.688
Abdomen	1.36	1.78	0.927

Ghilezan et al, Int. J. Radiation Oncology Biol. Phys. 2005; 62, 406–417.

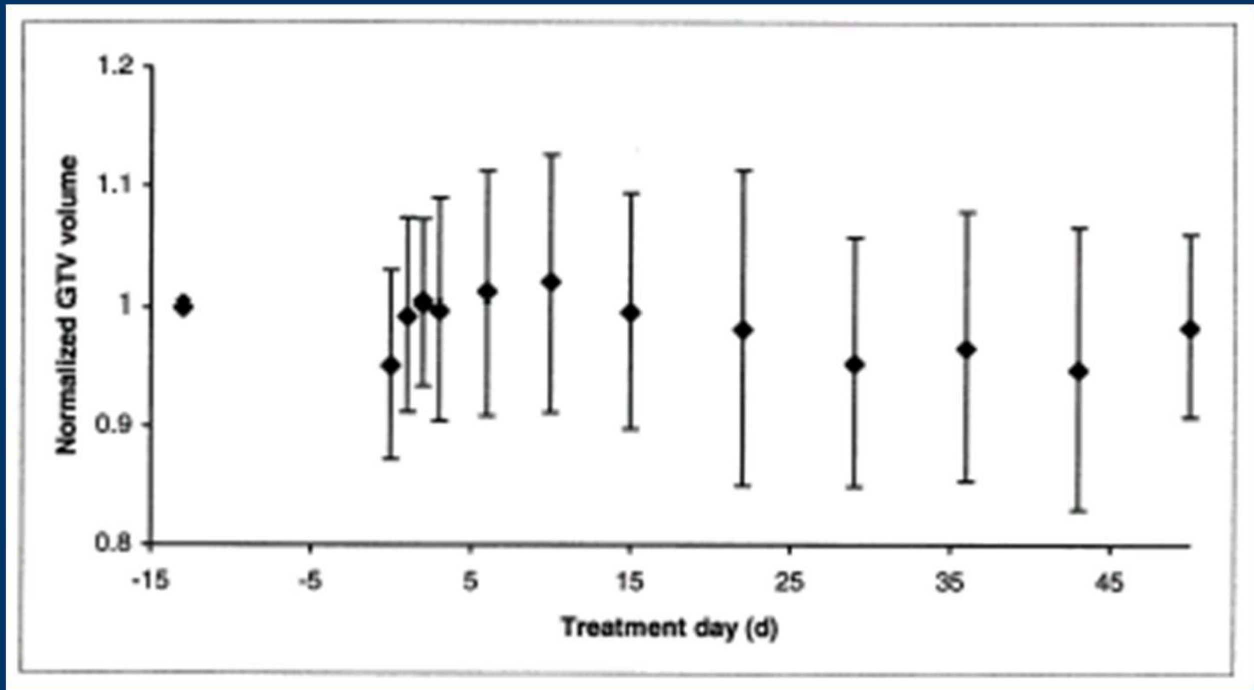
INTRAFRACTION MOTION

Author (year)	Patients (*n*)	Imaging method	Displacement (mm)
Dawson (2000)	4	Fluoroscopy 3 Rx-opaque markers: apex	In normal breathing <1 in all directions 0.9–5.3 in CC (prone)
Huang (2002)	20	Before and after Tx BAT ultrasound alignment on 10 Tx	Anterior 0.2 +/- 1.3 Superior 0.1 +/- 1.0 Left 0.01 +/- 0.4
Khoo (2002)	10	Sagittal and axial MRI	**Axial** Anterior 0.4 +/- 1.1, Posterior 0.5 +/-1.7 Left 0.1+/- 1.0, Right 0.1 +/- 0.9 **Sagittal** Anterior 0.2 +/- 0.9, Posterior 0.4 +/-1.6 Superior 0.2 +/- 1.3, Inferior 0.1 +/- 1.2
Kitamura (2002)	10	Real-time fluoroscopy 1 marker (apex)	**Supine** AP 0.3 +/- 0.4, CC 0.3 +/- 0.2, LL 0.3 +/- 0.1 **Prone** AP 1.6 +/- 0.4, CC 1.4 +/- 0.5, LL 0.5 +/- 0.4
Mah (2002)	42	Cine MRI axial and sagittal No implanted markers	AP 0.17+/- 2.9 Sagittal AP 0.26 +/- 3.3 Axial CC 0.02 +/- 3.36, LL 0.00 +/- 1.47

INTRAFRACTION MOTION

Author (year)	Patients (*n*)	Imaging method	Displacement (mm)
Malone (2000)	40	Fluoroscopy 3 gold markers (apex, posterior, Base)	Prone + immobilization group Mean 3.3 +/- 1.8 >/=4-mm displacements AP 8% of pts, CC 23% of pts
Nederveen (2002)	10	Fluoroscopy Multiple markers but only 1 tracked	AP 0.3+/-0.5 CC 0.4+/-0.7
Padhani (1999)	55	Axial cine MRI No implanted markers	Median AP 4.2 mm 74% of pts—mainly AP displacements 29% of them> 5 mm
Shimizu (2000)	10	Fluoroscopy before and after Tx delivery 1 marker in tumor (9 pts) and near tumor (1 pt)	Median of absolute displacement AP 0.7, CC 0.85 LL 0.6
Vigneault (1997)	2	On-line EPID 1 marker (apex)	No displacement Observed

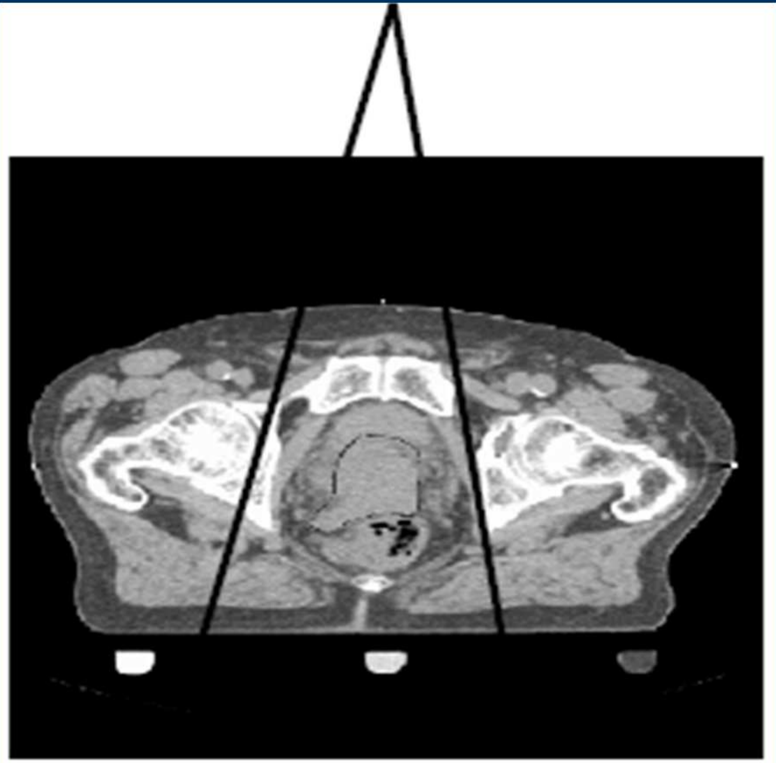
VOLUME CHANGES



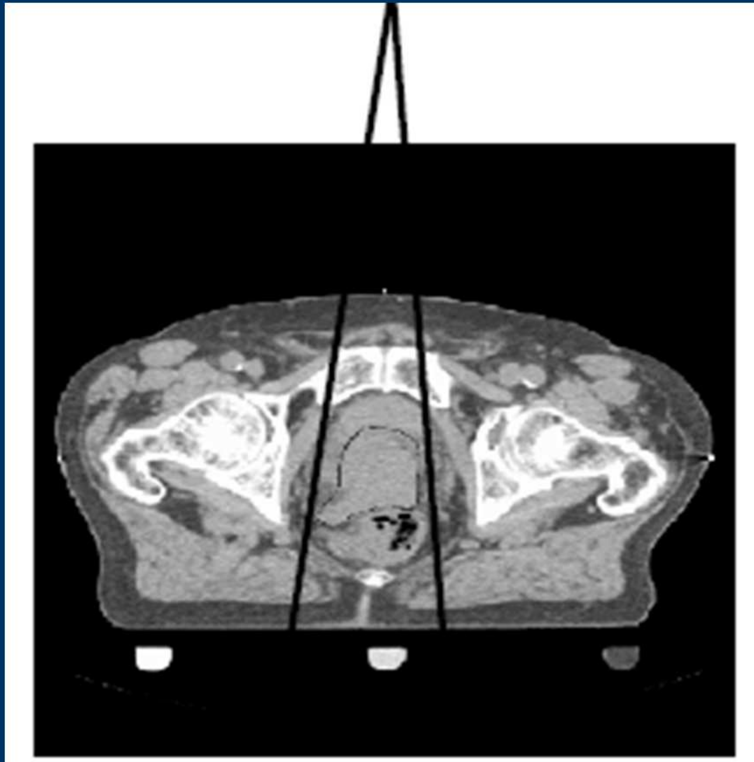
The average volume change was 0.05 cm3/day, which was not significantly different from zero ($p > 0.05$)

Deurloo et al. Int J Radiat Oncol Biol Phys. 2005; 61:228-38

HOW TO SOLVE THESE PROBLEMS?



1. Use large margins, irradiating too much healthy tissues



2. Use small margins, and risk missing the target

3. Or Use IGRT

IMAGE GUIDED RADIOTHERAPY

- IGRT refers broadly to treatment delivery using modern imaging methods like CT, PET and USG in target and non target structures and in RT definition, design and delivery

- It includes but is not limited to 3DCRT,IMRT,SRT, SRS & brachytherapy

IGRT IN PROSTATE

IMAGE GUIDED EBRT

IMAGE GUIDED BRACHYTHERAPY

IGRT : AVAILABLE OPTIONS

IGRT encompasses the following present day Technology

- Volumetric
  - CT on rails
  - Tomotherapy
  - MV cone beam CT
  - KV cone beam CT
- Planar X ray based
  - EPID
  - Cyber knife
- Video based
  - Real Time video guided IMRT
- Ultrasound based
  - BAT

TECHNIQUES OF TUMOR TRACKING IN CA PROSTATE

- **Skin Markers**

  Not adequate for IGRT as margins required will be 1.5 –2cm

- **Internal markers**

  A. Endorectal balloon
  Not very useful but can reduce rectal radiation dose
  Renders rectal dosimetry more predictable by making rectal anatomy more reproducible

  B. Implanted fiducials
  Deformation is a problem with use of fiducials
  Less inter user variation
  Good marker stability

  C. Implanted transponders for electromagnetic tracking

  D. CT based Bony Anatomy tracking

  E. CT based Soft Tissue Tracking

IMAGE GUIDANCE

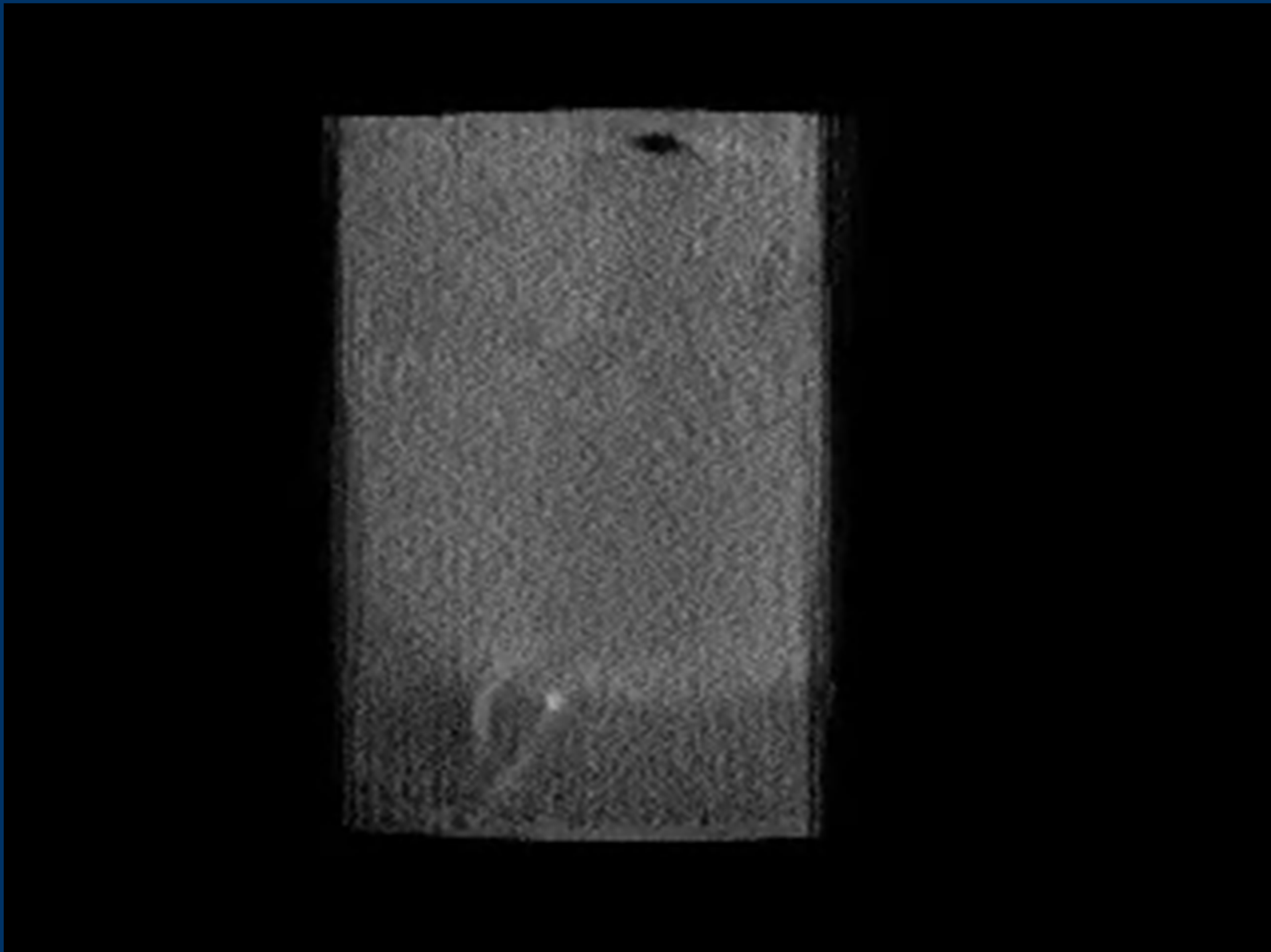
- Online

  Daily image guidance with daily adjustments

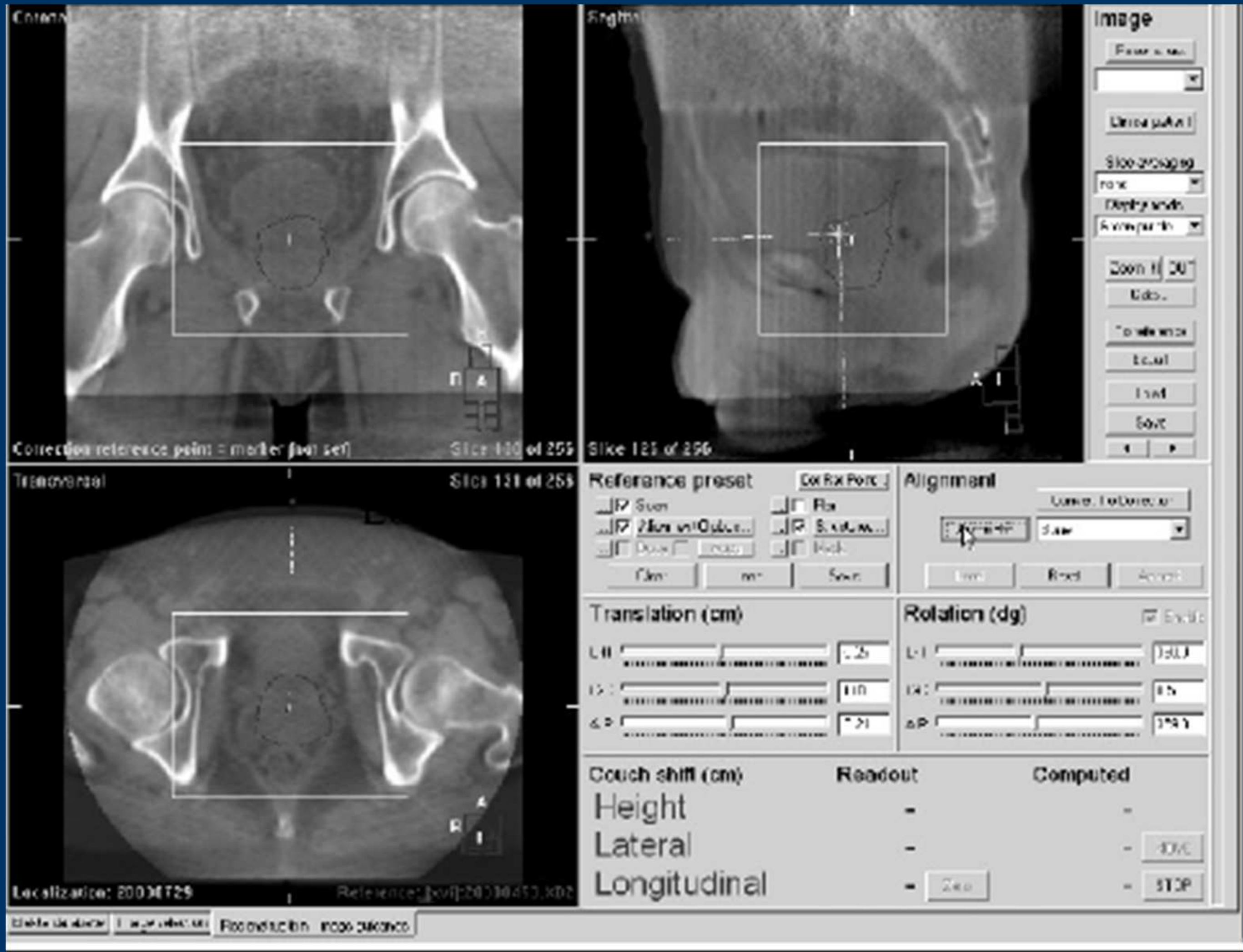
- Offline

  Follow a certain imaging schedule and apply offsets on data when imaging not performed

KV CONE BEAM CT



IGRT AUTOMATIC BONE LOCALIZATION

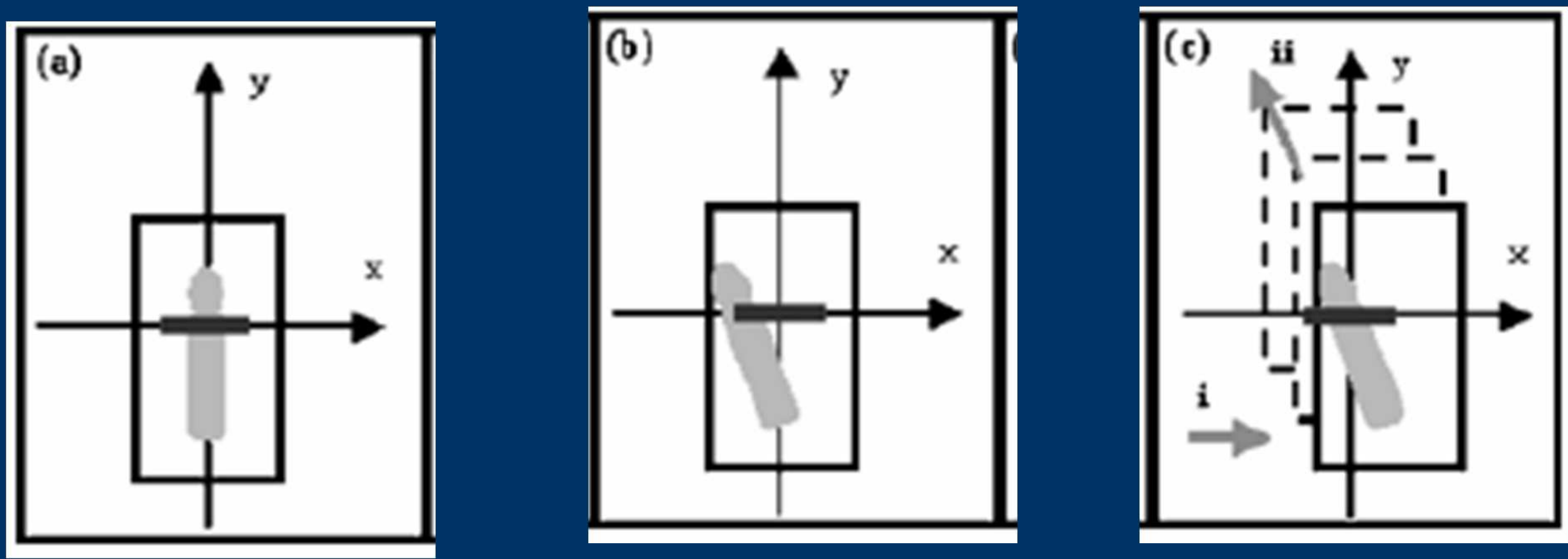


HOW TO CORRECT FOR DISPLACEMENTS

- Couch corrections
- Gantry and collimator angle adjustments
- Modification of MLC leaf positions

COUCH CORRECTIONS

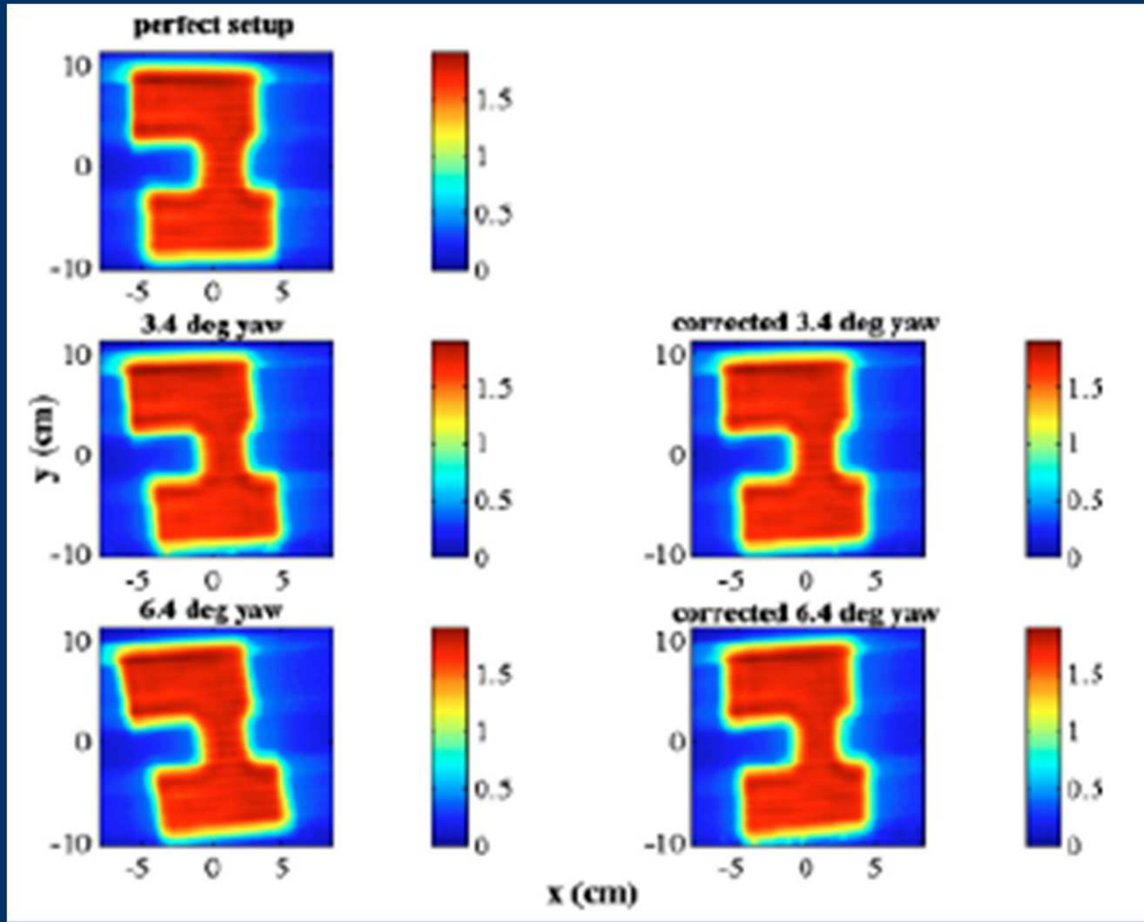
Correction by lateral couch shift (Tomotherapy)



Boswell et al. Med Phys. 2005; 32:1630-9.

COUCH CORRECTIONS

Comparison of rotated and corrected dose distributions (Tomotherapy)



Boswell et al. Med Phys. 2005 ;32:1630-9.

ELEKTA SYNERGY-S IGRT AT AIIMS

HEXAPOD COUCH AT AIIMS

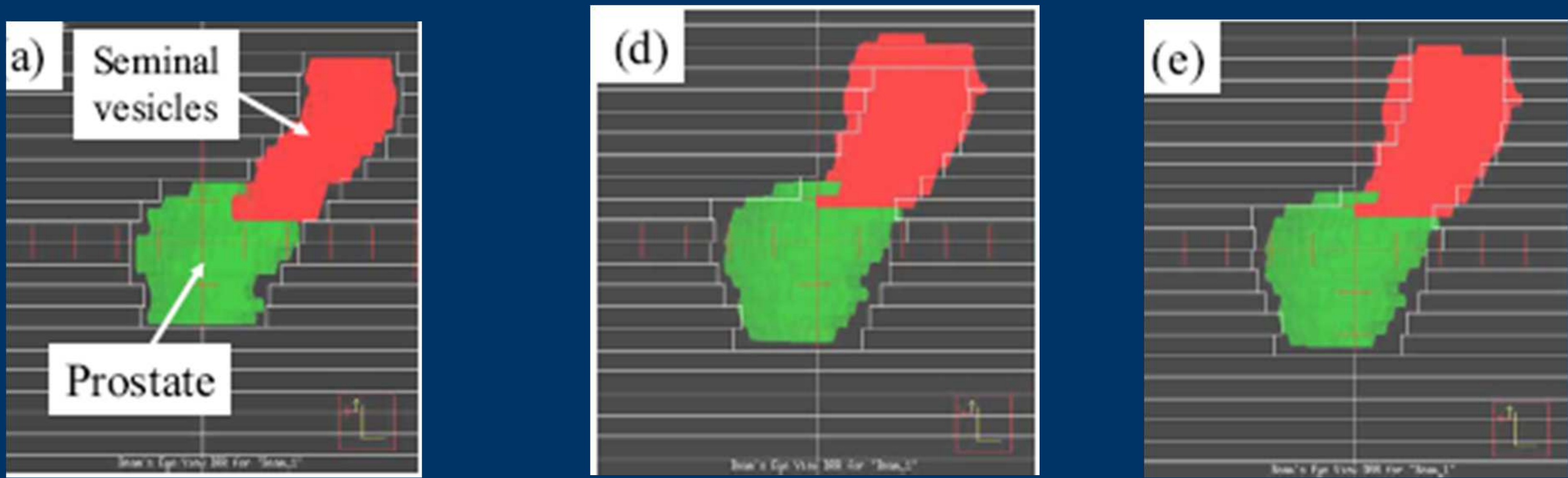
6 DEGREES OF FREEDOM

STRATEGY FOR ONLINE CORRECTION OF ROTATIONAL ORGAN MOTION IN IGRT OF PROSTATE CANCER

- Gantry and collimator angle adjustments were used to correct for prostate rotation without rotating the table.

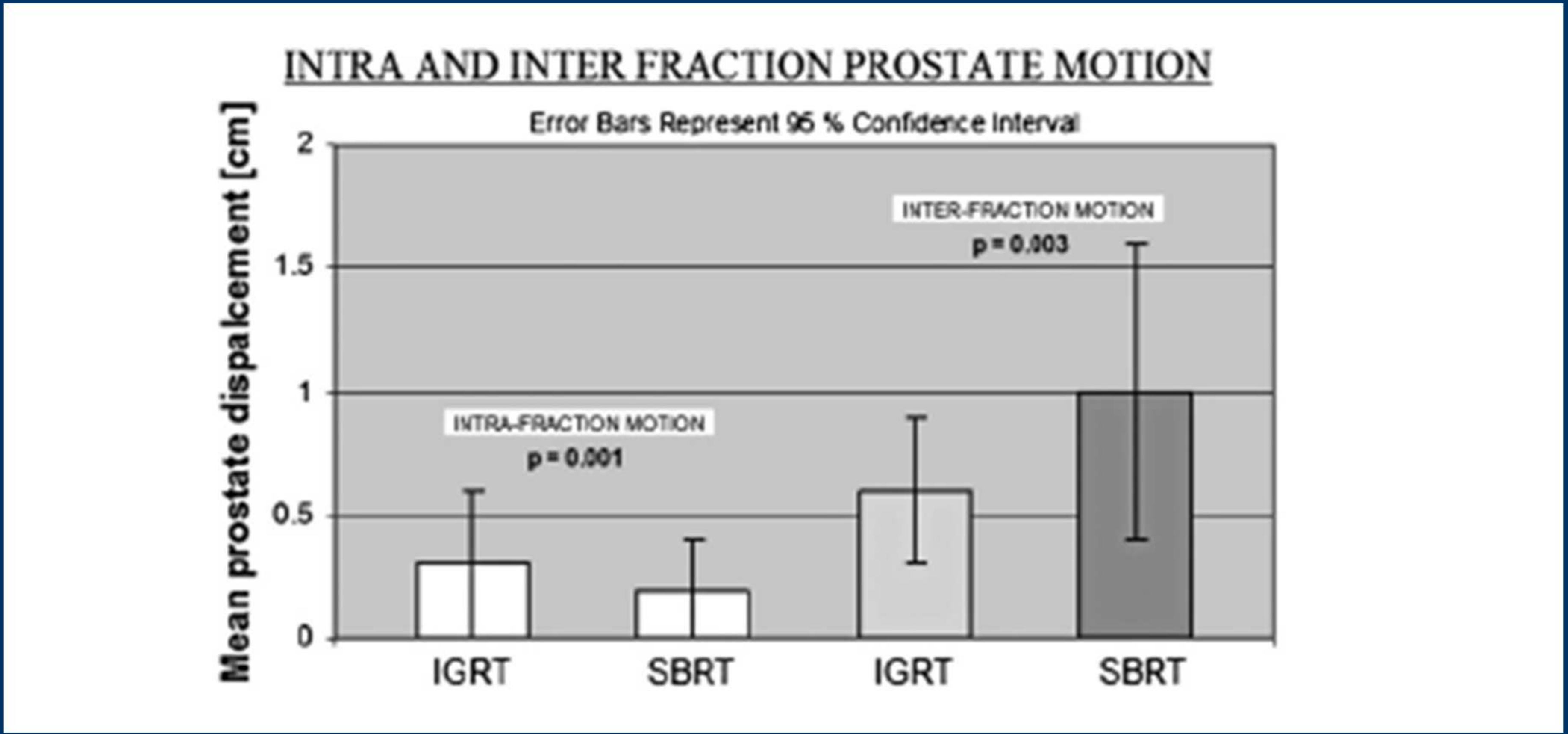
Rijkhorst et al. Int. J. Radiation Oncology Biol. Phys. 2007; 69:1608–1617.

AN AUTOMATIC CT-GUIDED ART TECHNIQUE - ONLINE MODIFICATION OF MLC LEAF POSITIONS



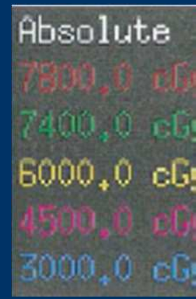
Court et al. Int. J. Radiation Oncology Biol. Phys. 2005; 62: 154–163,

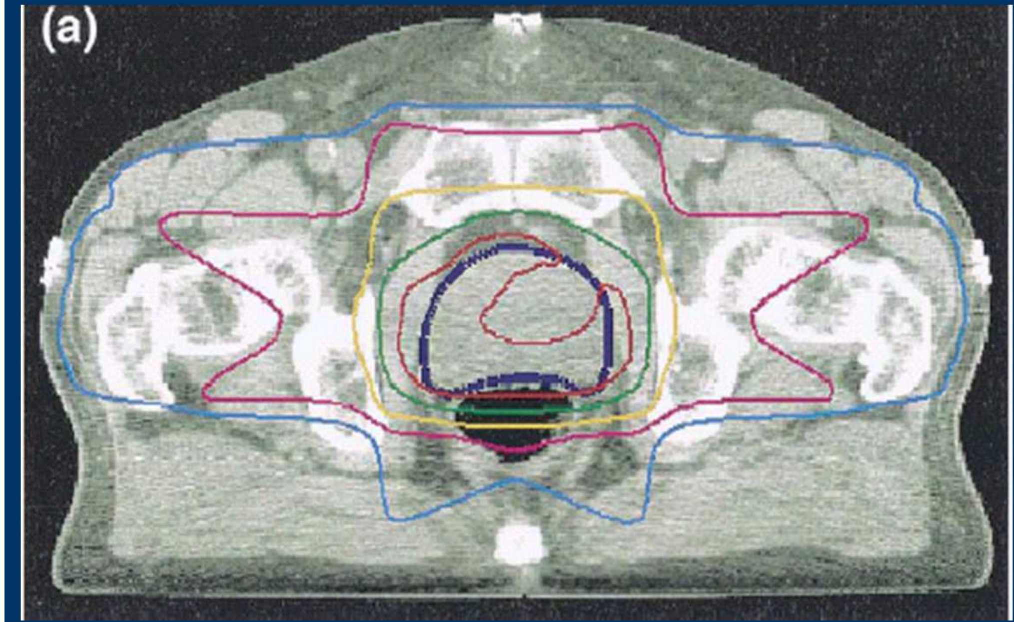
INTRA-FRACTION AND INTER-FRACTION MOTION ASSOCIATED WITH SBRT AND IGRT

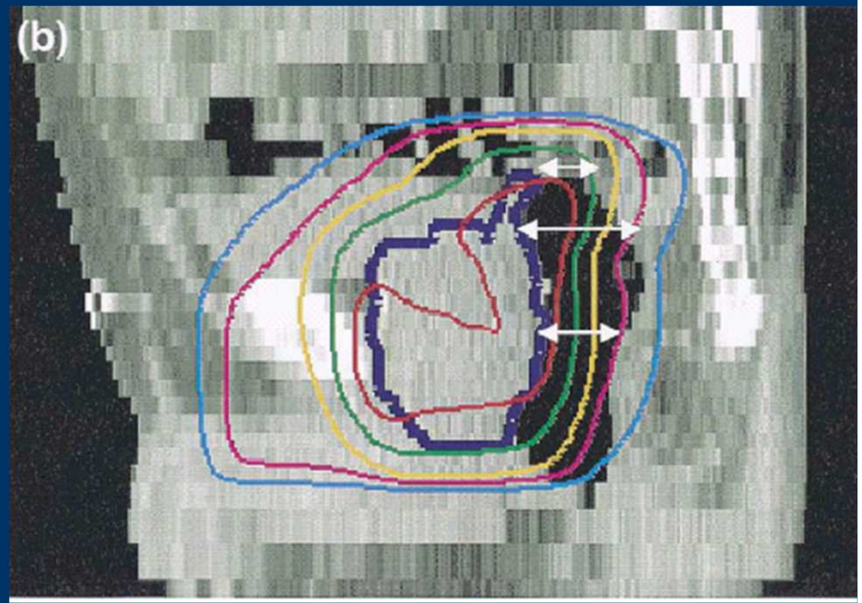


Boike et al, Int. J. Radiation Oncology Biol. Phys 2007; 69: S355

RECTAL DISTENSION &PSA CONTROL





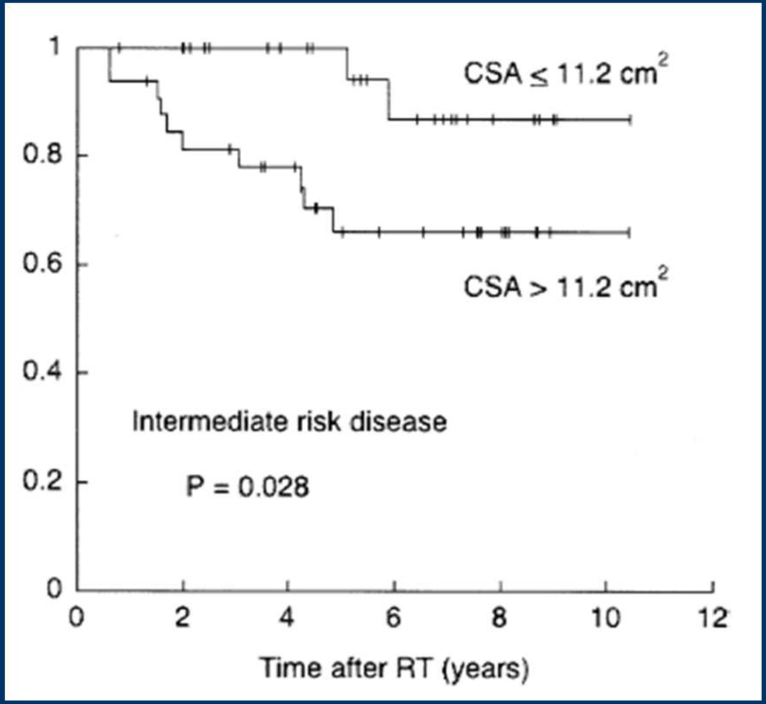


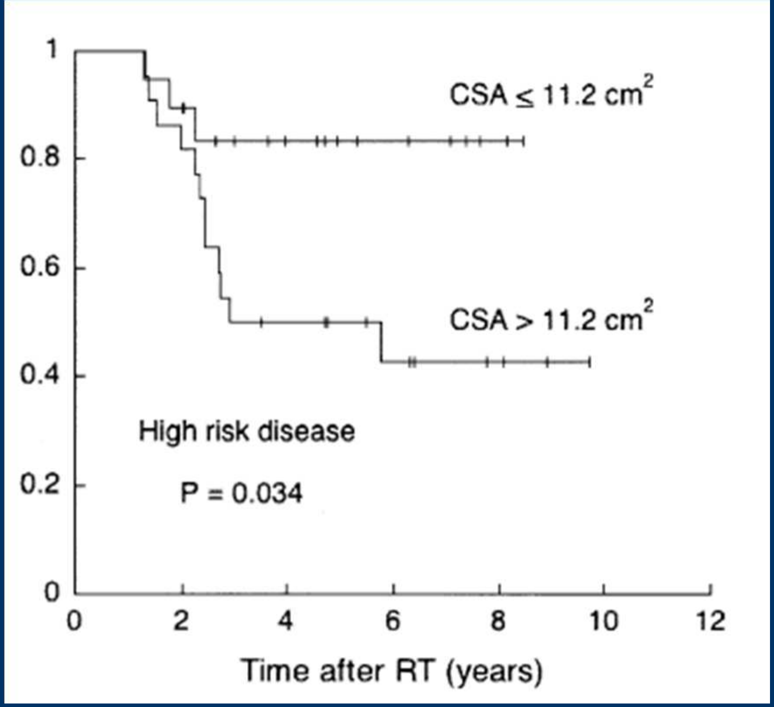
- **127 patients -3 D CRT - total dose of 78 Gy**

- **Rectal distension = average cross- sectional rectal area (CSA; defined as the rectal volume divided by length) and measuring three rectal diameters on the planning CT.**

de Crevoisier et al. Int J Radiat Oncol Biol Phys. 2005; 62: 965-73

RECTAL DISTENSION & PSA CONTROL





- **Rectal distension decreased the probability of biochemical control, local control, and rectal toxicity in patients without daily IGRT**

- **Therefore, an empty rectum is warranted at the time of simulation.**

- **Emphasize the need of empty rectum for IGRT to improve LC**

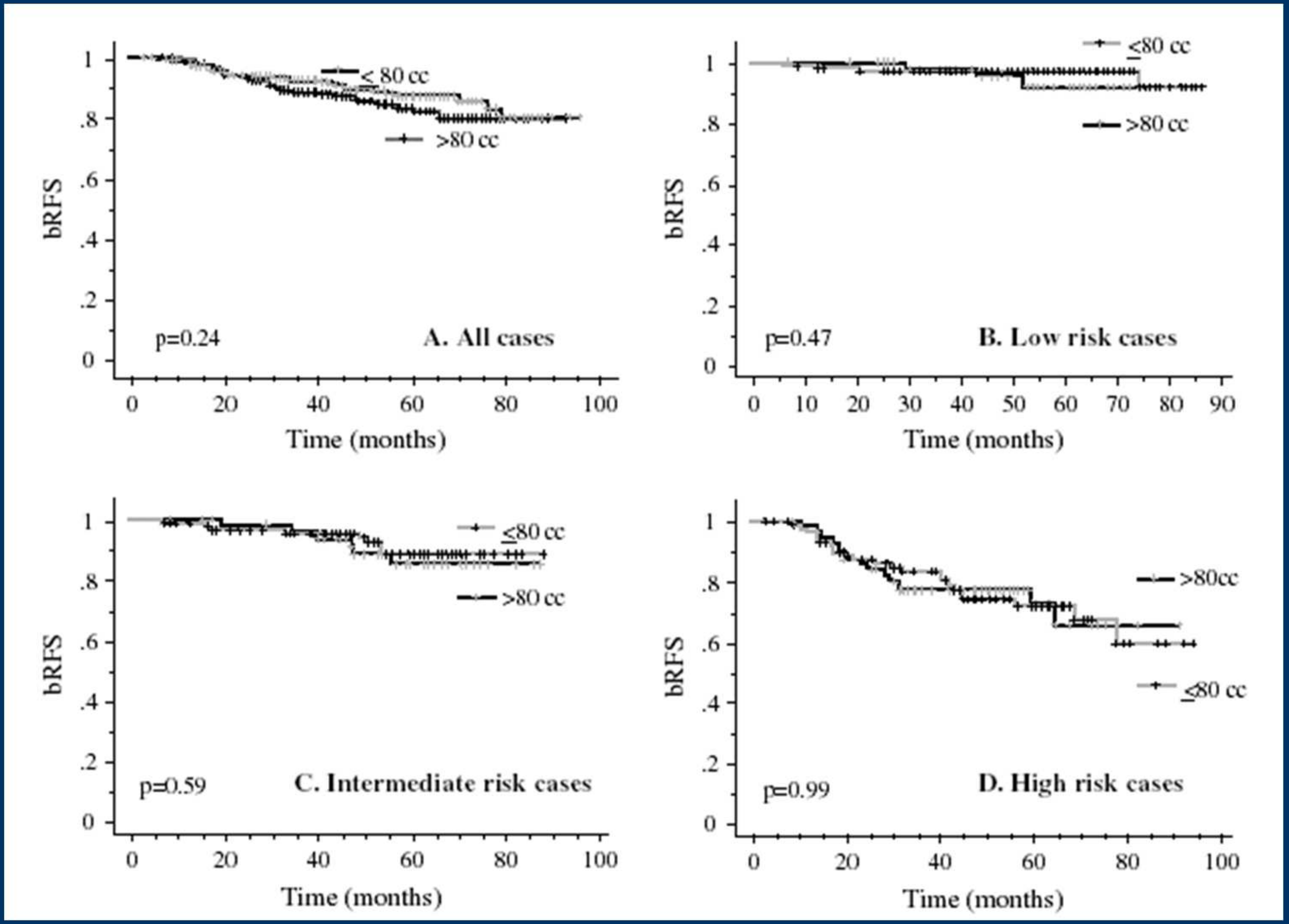
de Crevoisier et al. Int J Radiat Oncol Biol Phys. 2005; 62: 965-73

IMPACT OF IGRT ON OUTCOMES AFTER EBRT FOR LOCALIZED PROSTATE CANCER

- 488 pts trted with IGRT
- The radiation dose - 70 Gy at 2.5 Gy/fr
- Before each daily trt, alignment of the prostate was performed with BAT ultrasound system.

Kupelian et al, Int. J. Radiation Oncology Biol. Phys. 2008; 70: 1146–1150.

b RFS WITH IMAGE GUIDANCE

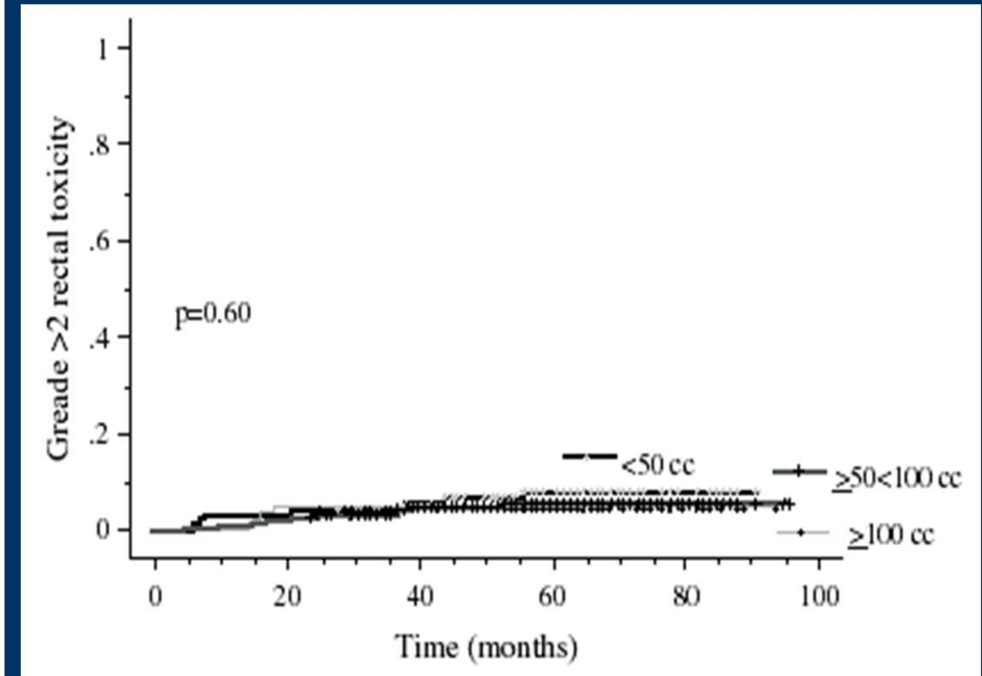


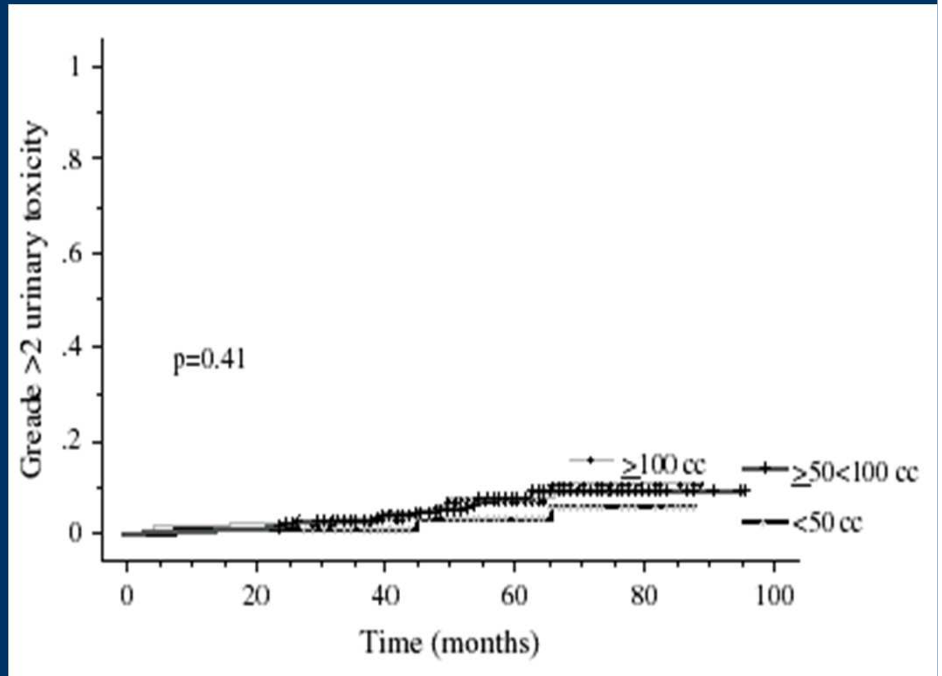
.

- 5-year b RFS rate for the rectal distention <50, 50 to <100, and >100 cm3 groups was 90%, 83%, and 85% (p =0.18).
- Rect dist was not an independent predictor of biochem failure (p = 0.80).

Kupelian et al, Int. J. Radiation Oncology Biol. Phys. 2008; 70: 1146–1150.

RECTAL & BLADDER TOXICITY WITH IMAGE GUIDANCE





- Rect dist was also not a predictor of rectal or urinary toxicity

Kupelian et al, Int. J. Radiation Oncology Biol. Phys. 2008; 70: 1146–1150.

PHASE II TRIAL OF HYPOFRACTIONATED IGRT FOR LOCALIZED PROSTATE CA

- Purpose: Feasibility and late toxicity of hypo fractionated IGRT for prostate cancer.

- T1c–2cNXM0. 60 Gy in 20fractions over 4 weeks with IGRT with intra prostatic fiducial markers. 92 pts

- Grade 3–4 toxicity in only 1 patient. Biochemical control at 14 months was 97%. The incidence of late toxicity was low.

- Hypo-fractionated IGRT is feasible and is associated with low rates of late bladder and rectal toxicity. Biochemical outcome is comparable.

Martin et al. Int. J. Radiation Oncology Biol. Phys. 2007; 69:1084–1089.

DOSIMETRIC EFFECTS OF THE PRONE AND SUPINE POSITIONS

• Soft-tissue alignment combined with 5 mm planning margins is appropriate in minimizing treatment planning and delivery uncertainties in both the supine and prone positions.

•Alignment based on bony structures showed improved results over the use of skin marks for both supine and prone setups.

•Under bony alignment, the dose coverage and PTV overlap index for prone setup were statistically better than for supine setup

Liu et al. Radiotherapy and Oncology 2008 (In press)

- IMAGE GUIDED BRACHYTHERAPY

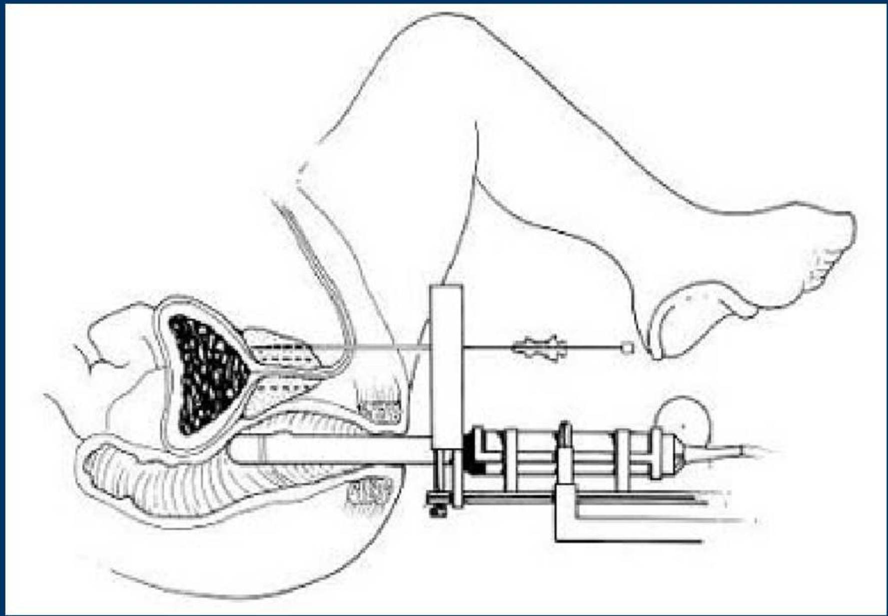
Imaging modalities used in brachytherapy

- Fluoroscopy
- Ultrasound / TRUS
- CT scan
- MRI

ADVANTAGES OF IMAGING IN BRACHYTHERAPY

- Real time guidance for placement
- Avoidance of normal structures
- Better accuracy
- Improved treatment planning

IMAGE GUIDED BRACHYTHERAPY




2005 10 26

IMBT

- Inverse Planning Simmulated Annealing (IPSA)

  Inverse Planning in Brachytherapy

CONCLUSIONS

- Radiotherapy has a very important role in the management of carcinoma prostate
- Advances like 3D CRT, IMRT,IGRT and HDR has made dose escalation feasible
- Image guidance helps to decrease geometric uncertainties
- IGRT important for dose escalation
- Long term results awaited

Thank You