MRI Guided GYN Brachytherapy: Clinical Considerations

AAPM
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Duke Radiation Oncology
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Disclosures

- none

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Learning Objectives

- Historical Context: Film based Brachytherapy
- Advantages of modern imaging for cervical cancer (CT, MRI)
- GEC-ESTRO recommendations for contouring on MRI
- Clinical results with image guided brachytherapy (IGBT)
- Logistics and challenges of implementing IGBT at our institution

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Intracavitary Brachytherapy: Cervical Cancer

- A solution to the problem of giving high dose to a highly mobile tumor in close proximity to bladder and rectum
- 3D conformal, IMRT and SBRT boosts are severely limited by intrafraction and interfraction movement
- Film based treatment has resulted local control rates of ~80%, with grade 3-4 late toxicity of ~15% (RTOG 9001)

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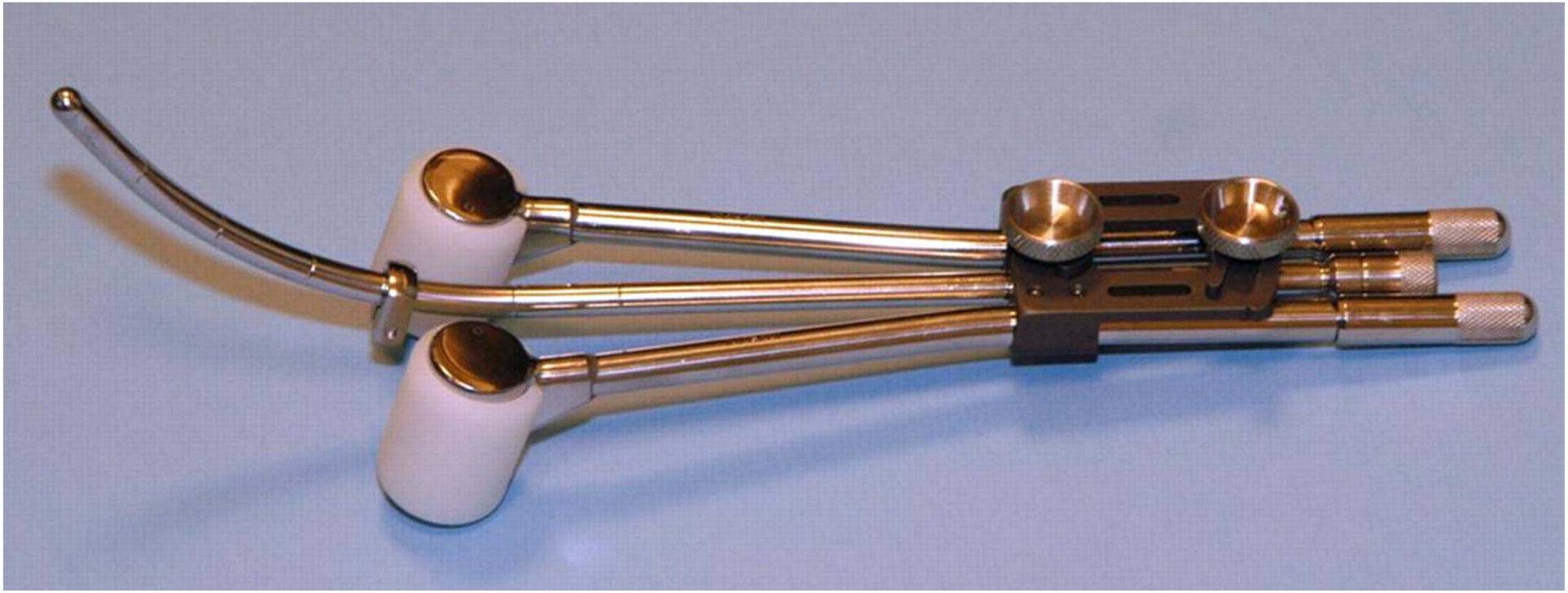
LDR T&O set



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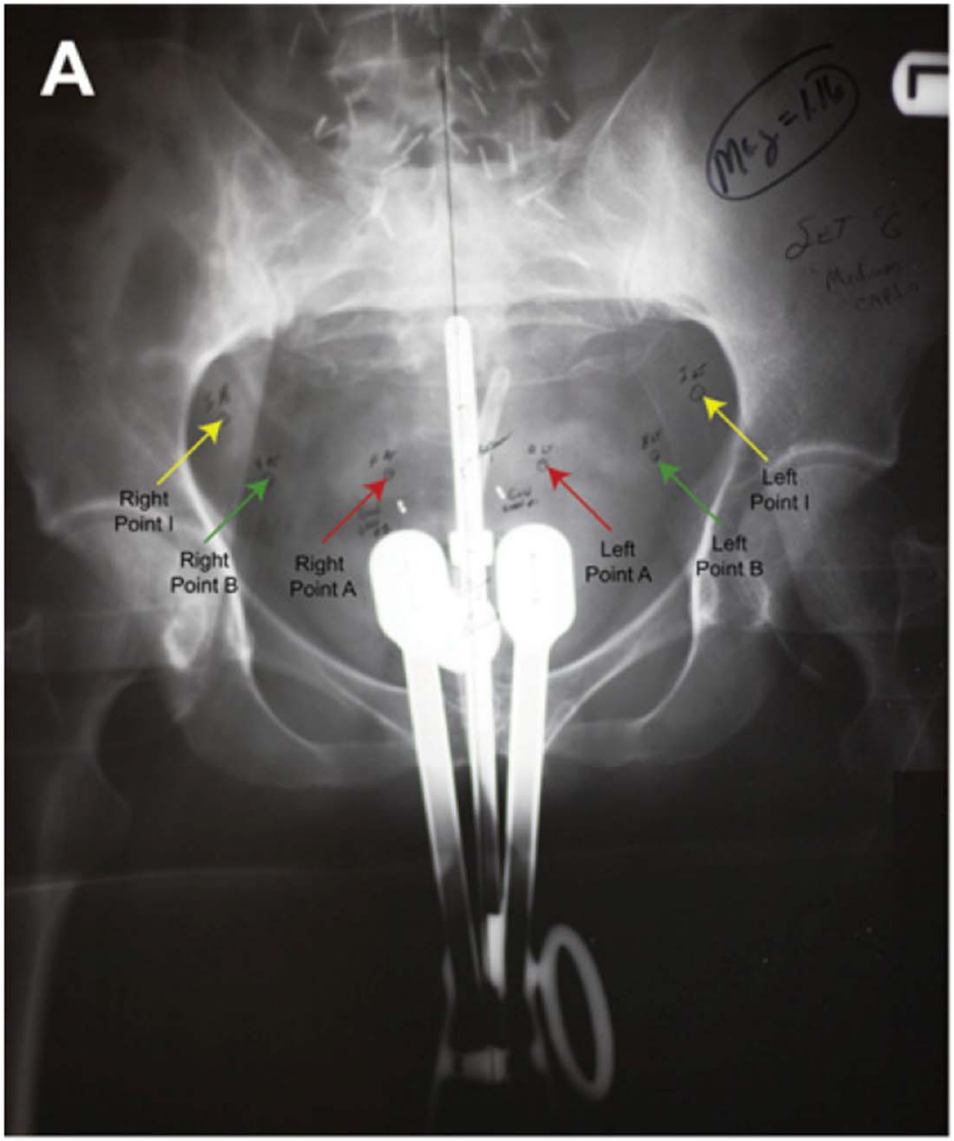
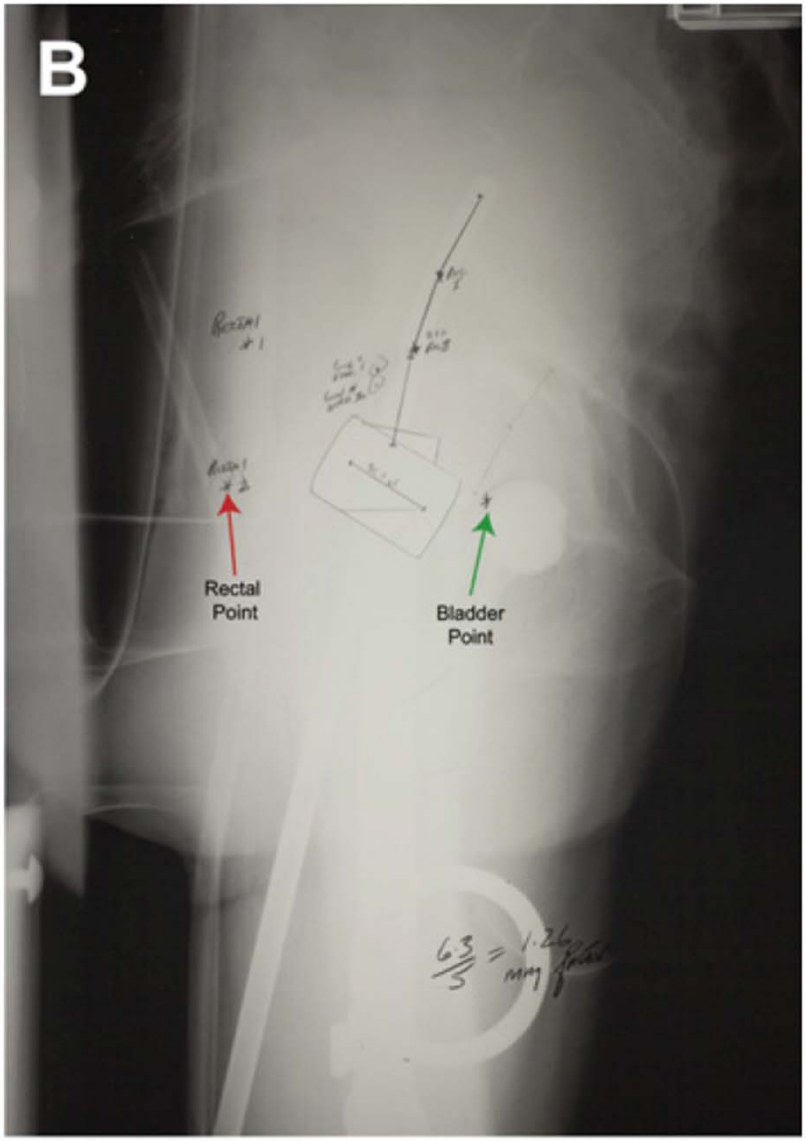
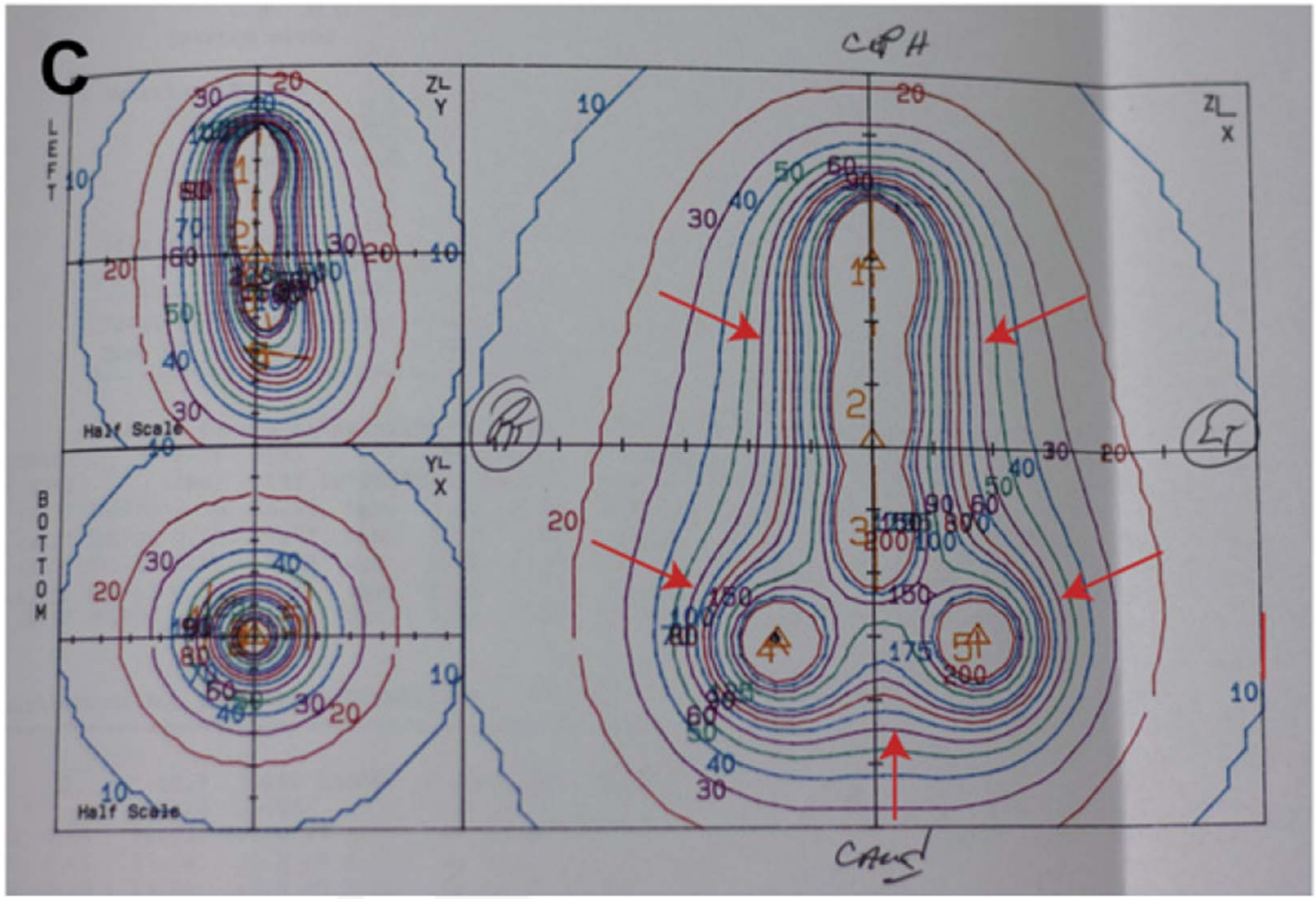
LDR planning





LDR planning



50-60cGY/hr. For 40Gy (85Gy with 45Gy WPRT) = 72-80hours

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Brachytherapy Doses
LDR

- Total doses should be summed with Prior External Beam
- Point A doses should be 75-90 Gy
- Point B doses should be 55-60 Gy
  - May boost sidewall with external beam for IIB disease to an additional 5-15 Gy
- Bladder point should be limited to 75Gy
- Rectal points should be limited to 70Gy

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Modern Imaging for Cervical Cancer: Part 1 CT

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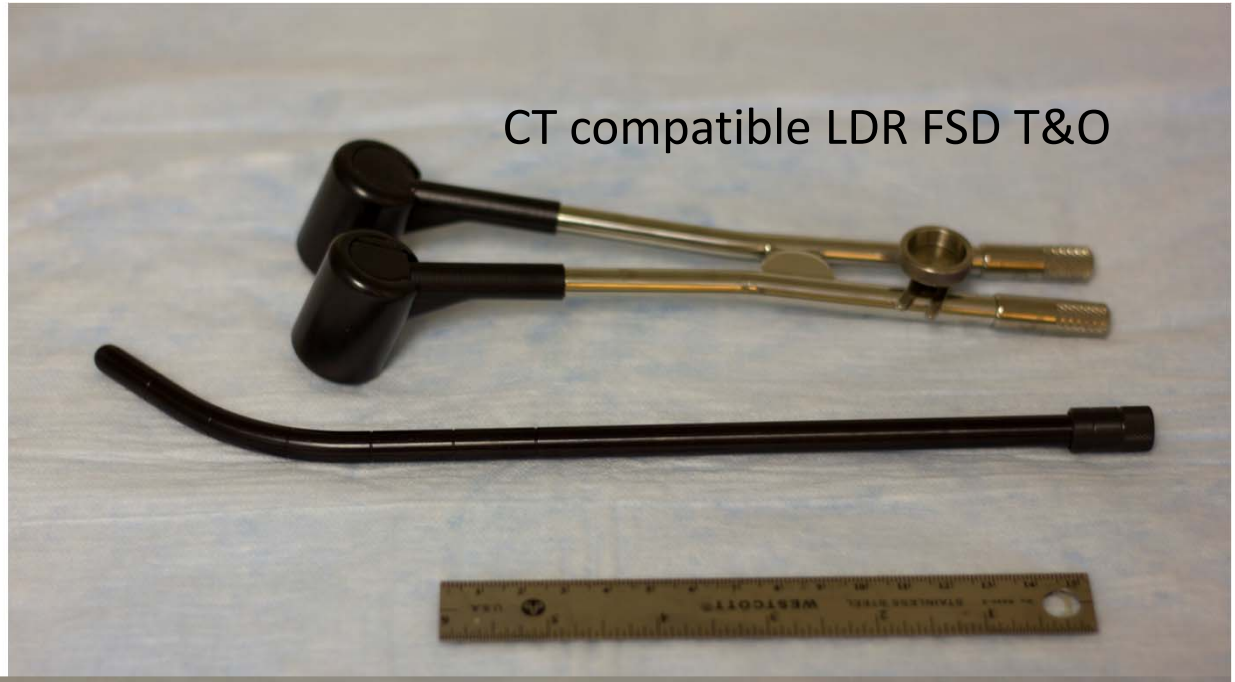
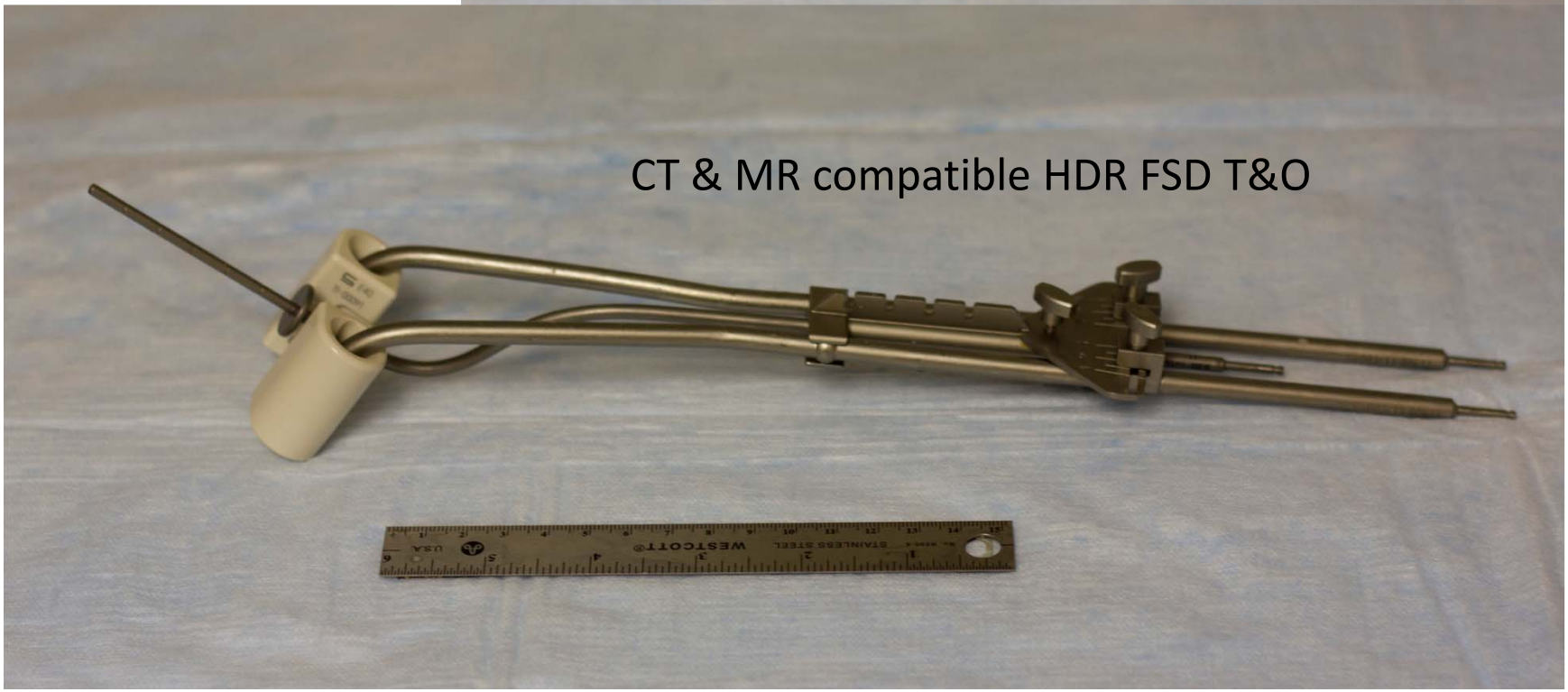
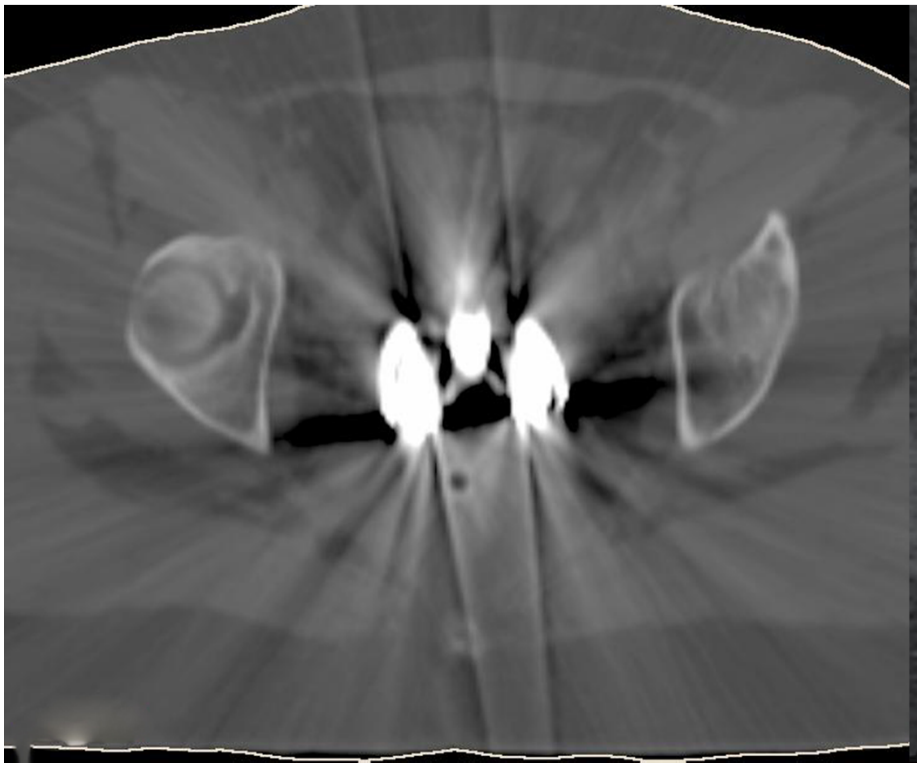
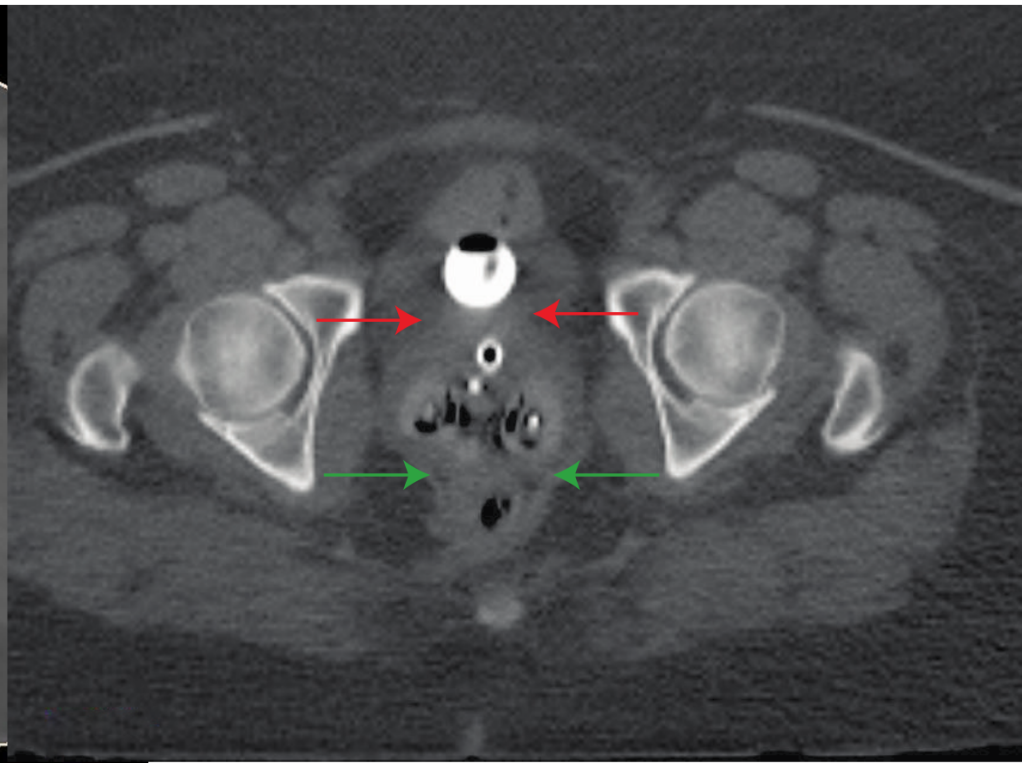

CT compatible LDR FSD T&O


CT & MR compatible HDR FSD T&O

CT compatible applicators



Conventional LDR FSD applicator



Weeks CT compatible Applicator

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CT-Based Planning (OAR)

- Weeks & Montana, developed CT compatible T&O set in 1997 at Duke
  - Systematic underestimation of max bladder and rectal doses with Film based plans
- MD Anderson series from 2005
  - rectal point a reasonable surrogate for rectal max
  - bladder point resulted in systematic underestimation of bladder max

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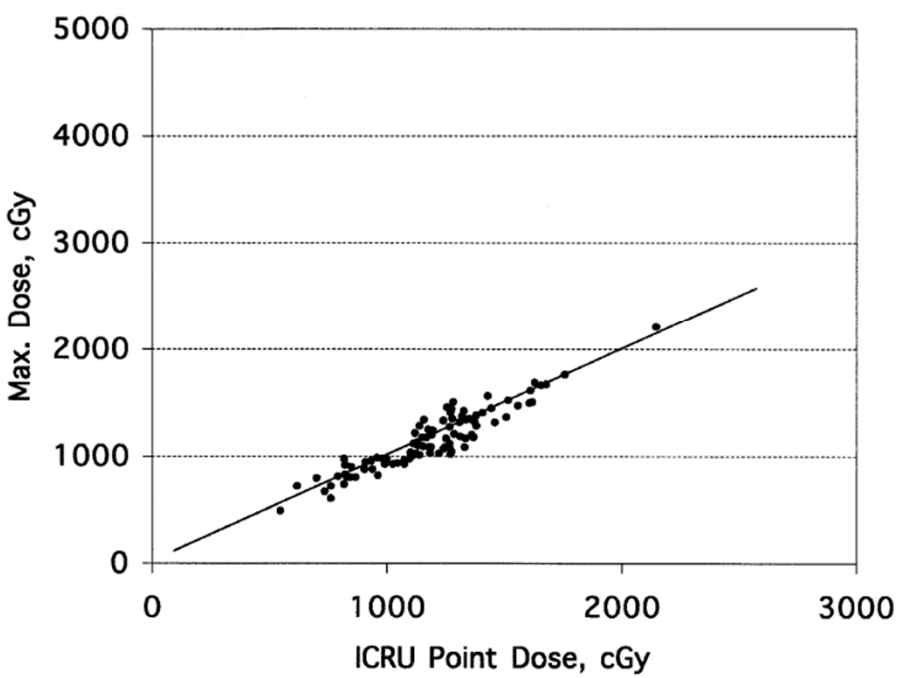
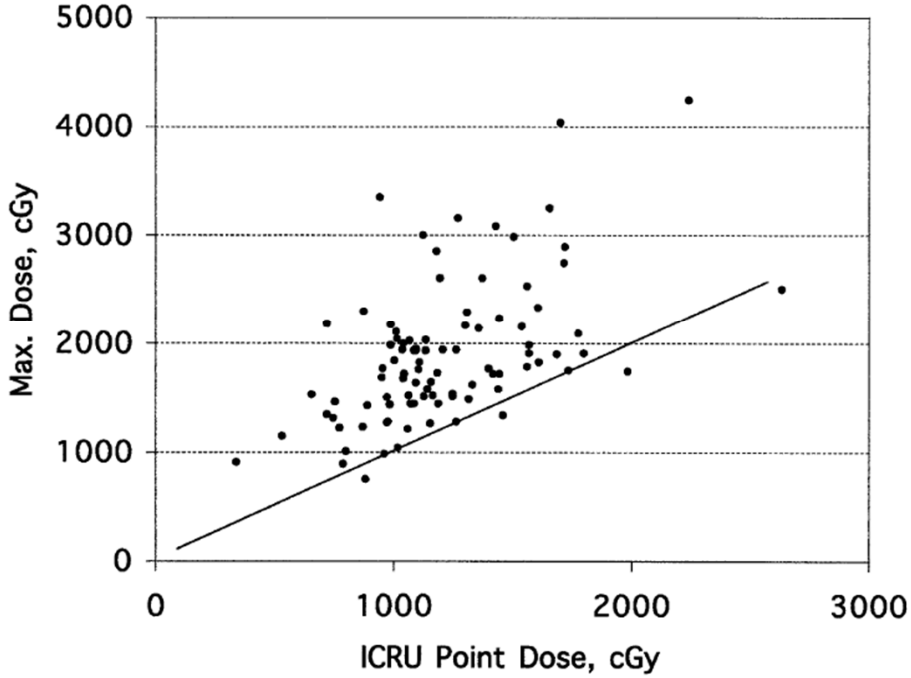
Pelloski, et al. IJROBP 2005;62:131

Film Points vs 3D Max Dose



Rectum



Bladder

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Pelloski, et al. IJROBP 2005;62:131

CT based Planning (Target)

- Michigan Series (Schoeppel, IJROBP 1994)
  - Film Based plans systematically underdose the CT-visible cervix
- Loyola Series (Gao, Brachytherapy 2010)
  - CT defined volume varied greatly between patients (12ml – 39ml)
  - With Film based plans, the cervical dose was 40% lower than prescription in those with high volumes.

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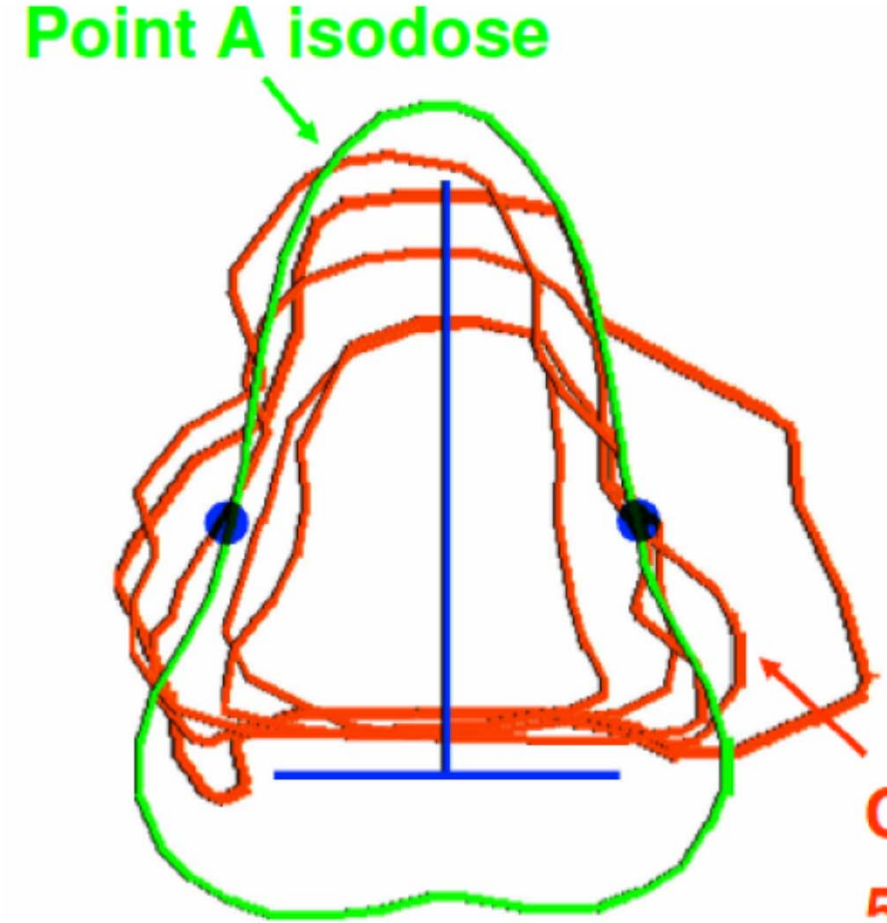

Minimum CTV dose relative to point A:

- 36%
- 49%
- 96%
- 103%
- 134%

CTV's assessed from MRI

5 pt's

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CT-Based Planning: Limitations

- CT is not to be ideal at determining extent of disease
- Preoperative CT studies show:
  - 50-65% accurate for extent within cervix
  - 75-80% accurate for determining extension outside of cervix

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Kim et al. J Comput Assist Tomogr 1993
Subak et al OB GYN 1995

Modern Imaging for Cervical Cancer: Part 2 MRI

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T2 weighted MRI as a Imaging Standard

- MRI superior in same preoperative studies compared to CT
  - 75-90% accurate for extent within cervix
  - 85-95% accurate for extension beyond cervix
- Viswanathan (IJROBP 2007) compared CT contours to MRI
  - Found systematic overestimation of cervix with CT
    - 20% median deviation between CT and MRI
    - CT overestimates in the lateral dimension

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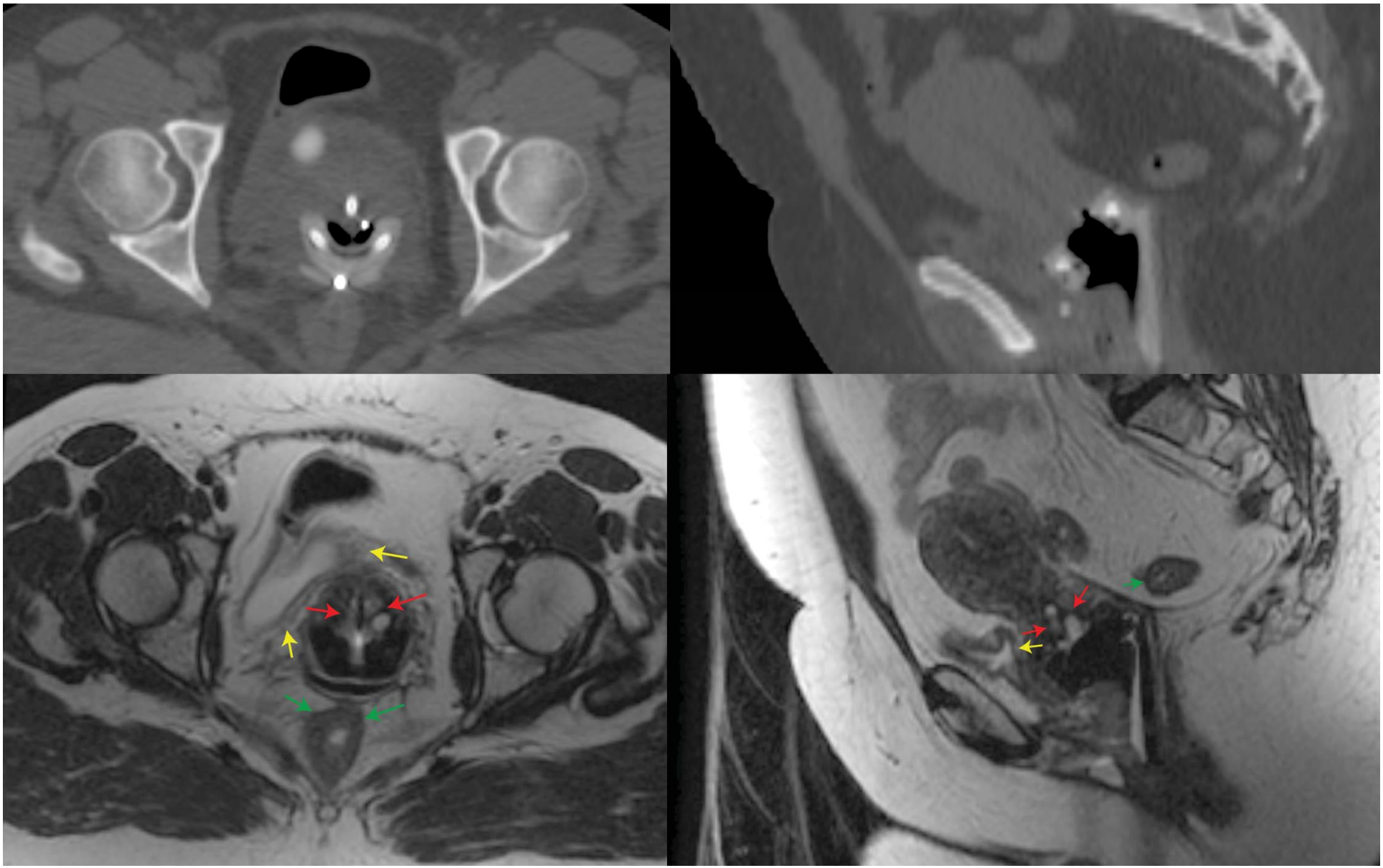
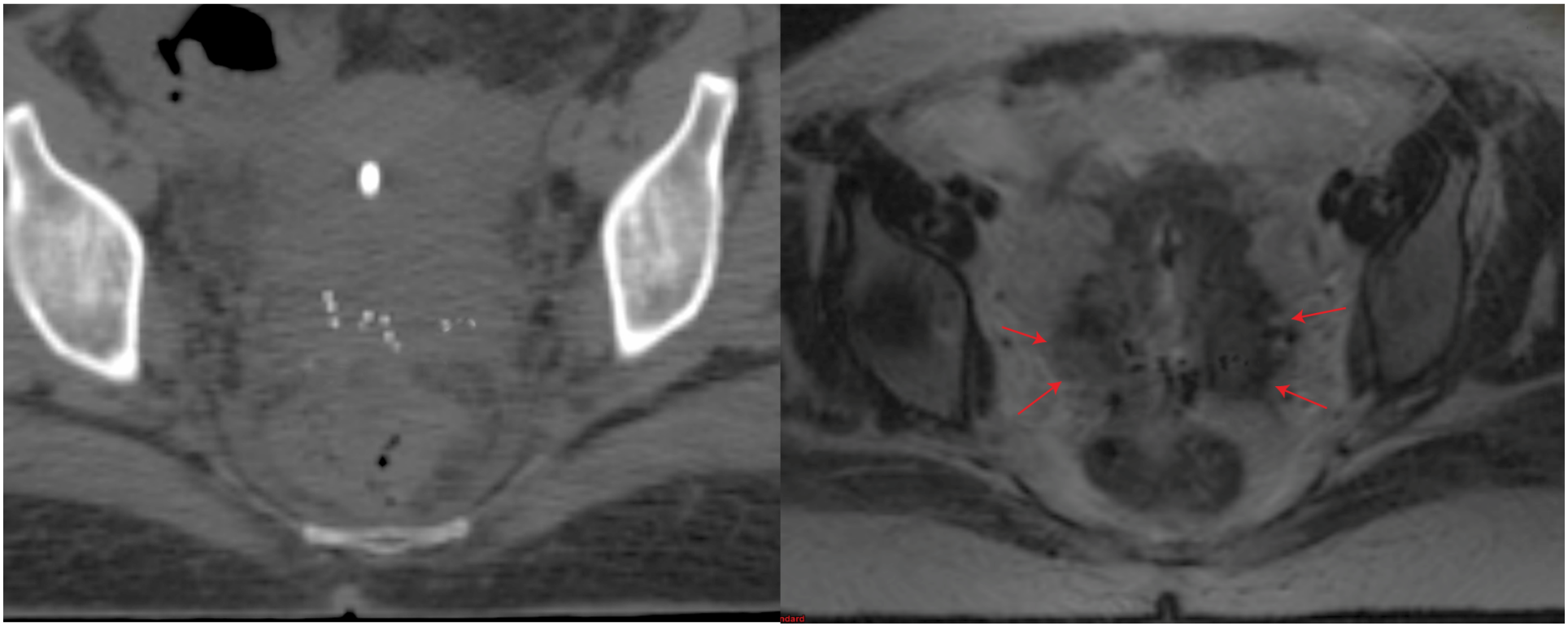
CT vs MRI



CT vs MRI



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GEC-ESTRO recommendations for MRI contouring

- GTV: all MRI visible tumor at time of brachytherapy
- HRCTV: GTV + cervix + “grey zones” of indeterminate signal (usually in parametrium)
- IRCTV: HRCTV + 10mm margin, restricted to 5mm anterior and posterior + initial extent of disease
- Normal tissue including bladder, rectum, sigmoid

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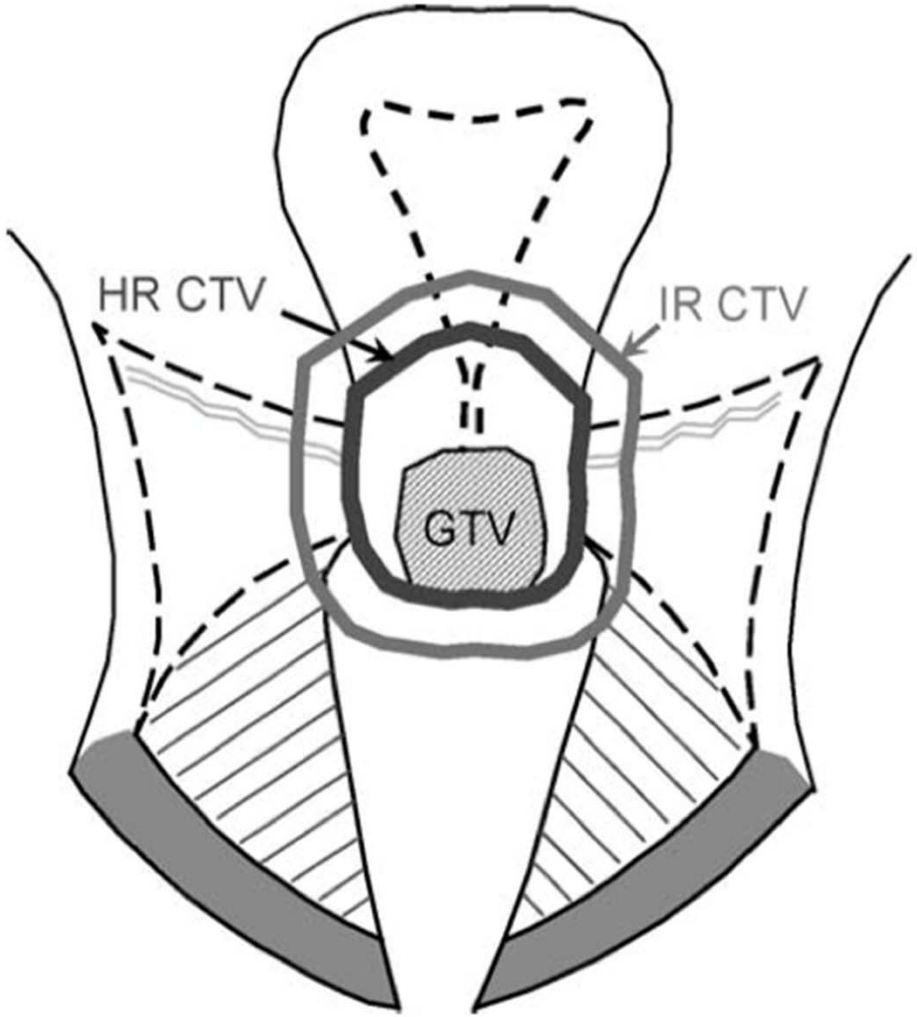
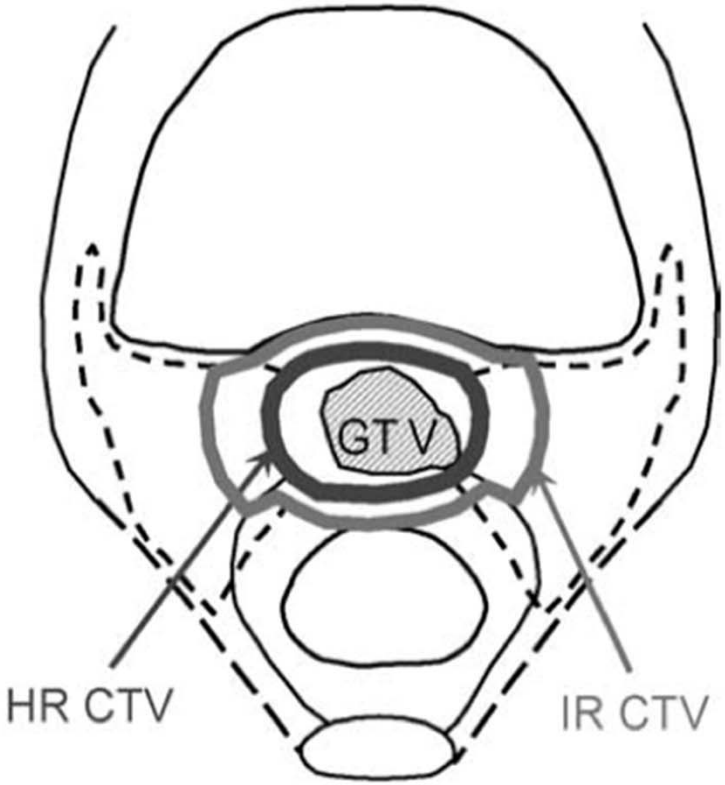
Haie-Meder et al. Rad Onc 2005
Potter et al. Rad Onc 2006

C. Haie-Meder et al. / Radiotherapy and Oncology 74 (2005) 235–245





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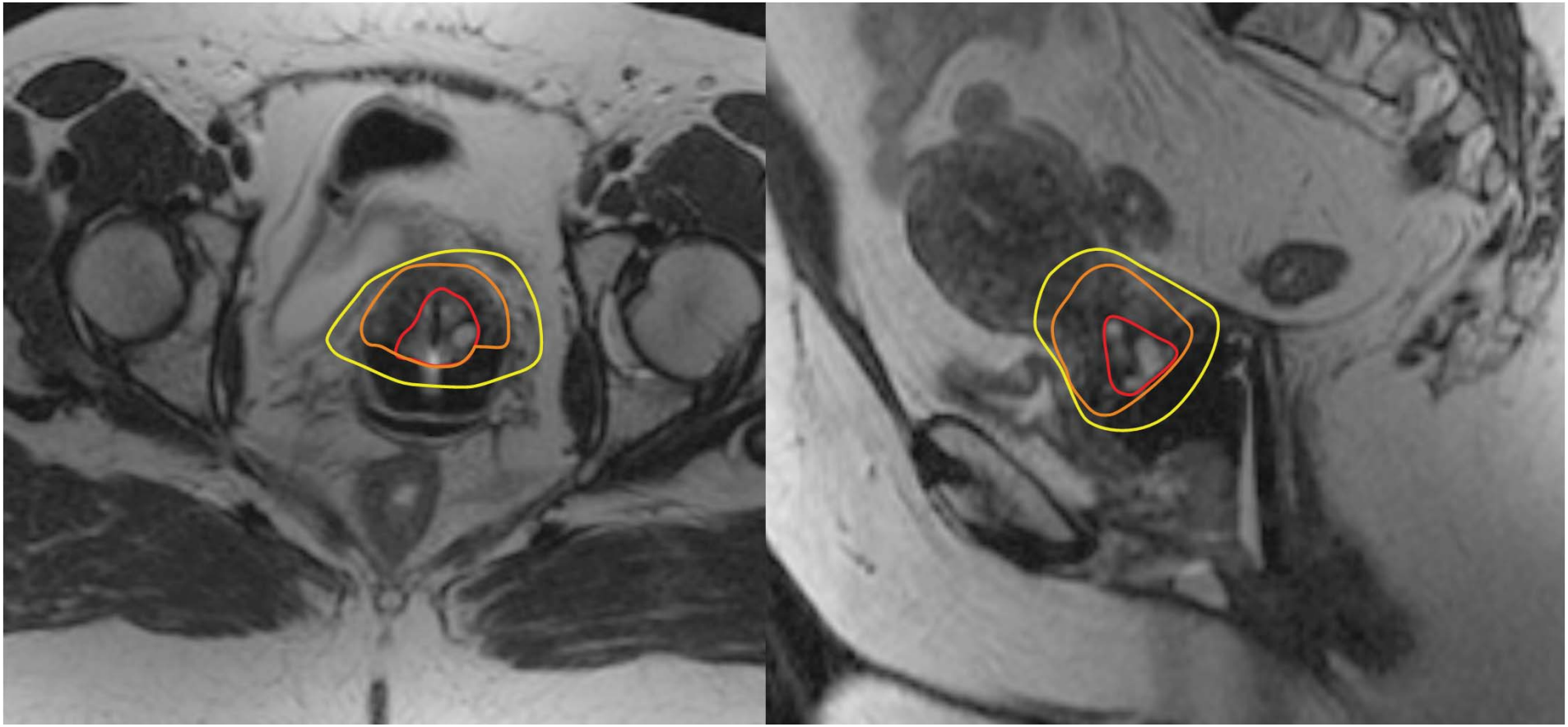

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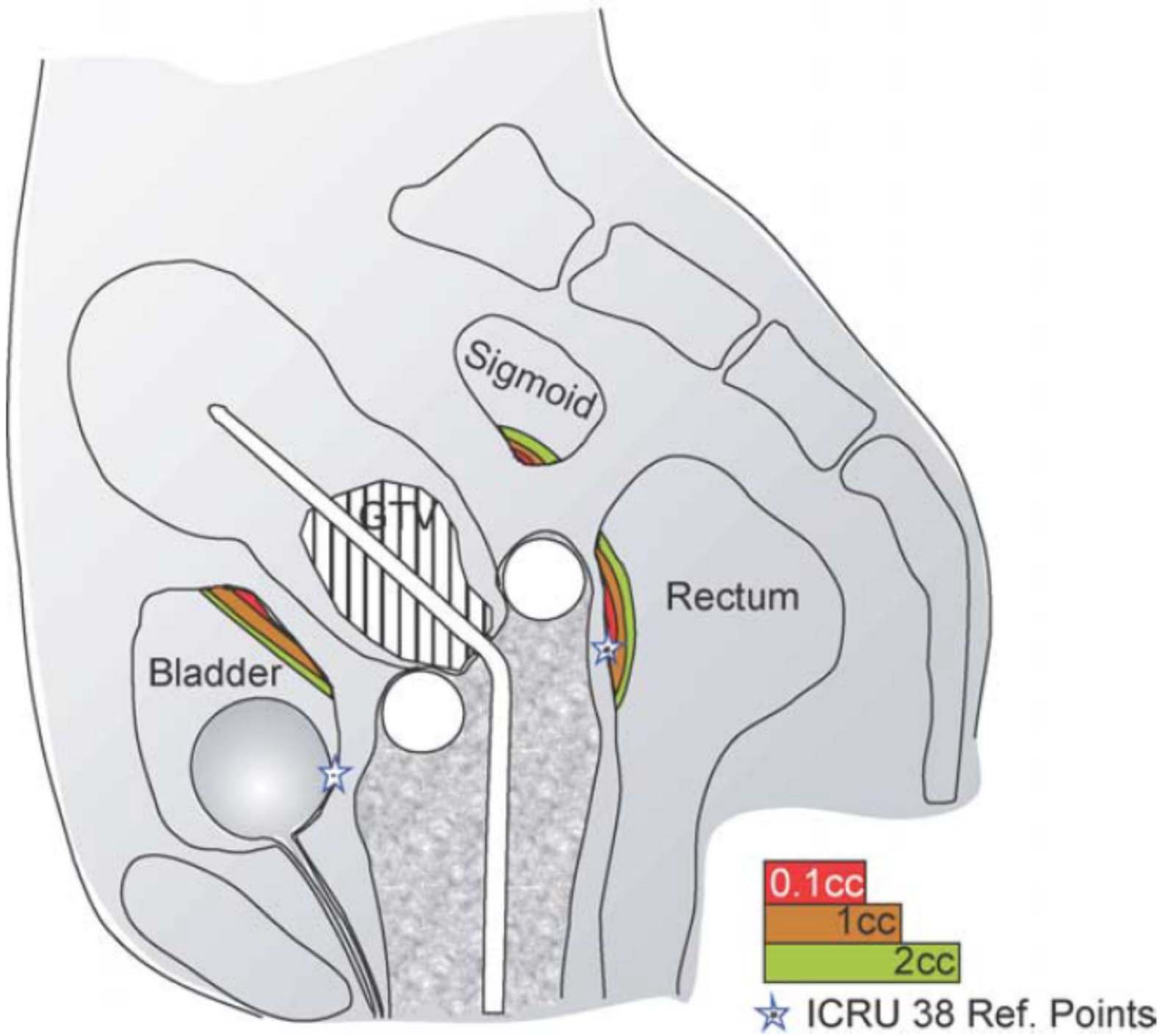

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Potter et al. Rad Onc 2006

Clinical Results: Vienna Group

- 141 women with IB-IVA cervical cancer treated with 45-50.4 Gy, concurrent cisplatin
- First 3 years, dose to HRCTV/IRCTV recorded but not used for optimization
- Last 3 years, dose optimized to cover HRCTV/IRCTV

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Dimopoulos et al. IJROBP 2009
Dimopoulos et al. Rad Onc 2009

Clinical Results: Vienna

- HRCTV D90
  - <87Gy resulted in local control of 80%
  - >87Gy resulted in local control of 96%
- HRCTV D100 (D98)
  - <66Gy resulted in local control of 83%
  - >66Gy resulted in local control of 93%
- IRCTV dose was not significantly associated with clinical outcome

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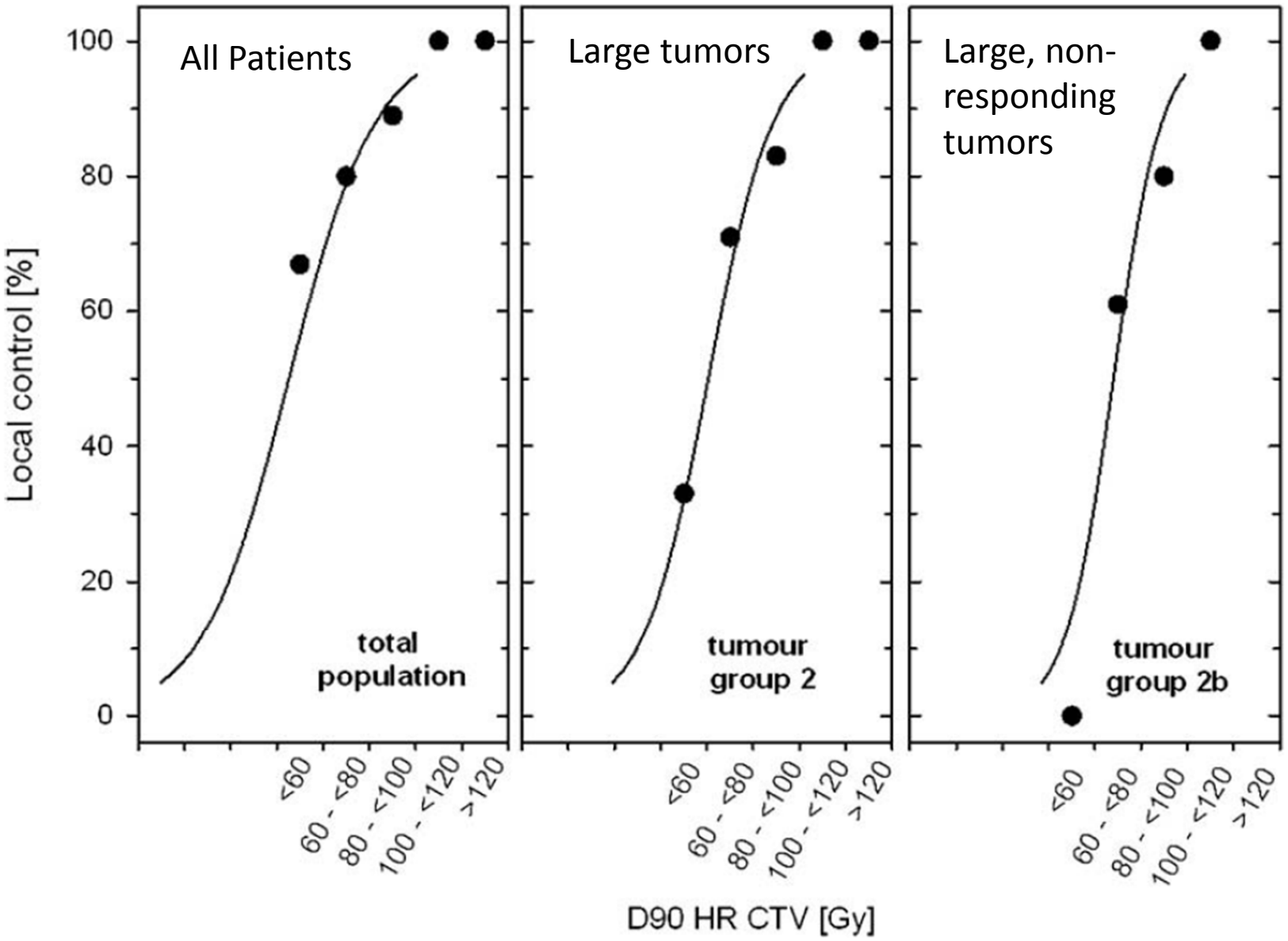

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Potter, et al Rad Onc 2009

Toxicity: Vienna

- Same group demonstrated association with late toxicity
- Rectum Grade 2-4 late toxicity:
  - D2cc 67GY = 5%
  - D2cc 78Gy = 10%
  - D2cc 90Gy = 20%
- Bladder Grade 2-4 late toxicity
  - D2cc 70Gy = 5%
  - D2cc 101Gy = 10%
  - D2cc 134Gy = 20%
- No small bowel or sigmoid association noted

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Georg IJROBP 2012

Volume	2D point analogue	3D dosimetric measures	Dosimetric Goal/Limit	Endpoint	Level of Evidence for Goal/Limit
HRCTV (tumor + cervix +parametrial extent at time of implant)	Point A (2cm superior to ovoids, 2cm lateral to tandem)	D90 D100	D90 > 75-85Gy D100 > 65Gy	Pelvic Control >90%	Strong
IRCTV (HRCTV +margin, +initial extent of disease)	Closest analogue is Point B (3cm lateral to point A) for IIB disease	D90	D90 > 60-75Gy	Pelvic Control (no firm data)	Weak
Bladder	Bladder point (most dependent point of foley balloon)	D2cc	D2cc <90Gy	G2-4 late toxicity <5-10%	Strong
Rectum	Rectal point (5mm posterior to vaginal packing)	D2cc	D2cc <75Gy	G2-4 late toxicity <5-10%	Strong
Sigmoid	None	D2cc	D2cc <75Gy	No firm data	Weak
Small Bowel	None	D2cc	D2cc <65Gy	No firm data	Weak

STIC trial: Film vs 3D

- 801 women (705 evaluable) treated with either film based or IGBT (mostly CT)
- Prospective but non-randomized
- Local control @ 2 years
  - 73.9% Film Based
  - 78.5% IGBT (p=0.003)
- Grade 3-4 toxicity
  - 22.7% Film based
  - 2.6% IGBT (p=0.002)

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Charra-Brunaud et al. Rad Onc 2012

A European study on MRI-guided brachytherapy in locally advanced cervical cancer

EMBRACE

(ENDORSED BY GEC ESTRO)

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EMBRACE: How often can HRCTV and OAR constraints be met?

- 134 cases were reviewed and non-optimized plans were generated (equal time in all activated dwell positions)
- Comparison was made between tandem only vs tandem and vaginal loading (non-optimized)

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Nkiwane, Brachytherapy 2013

How good are non-optimized plans?

	Percent of plans meeting HRCTV constraint					Percent of plans exceeding OAR tolerance		
	HRCTV D90 IB1	**HRCTV D90 IB2**	**HRCTV D90 IIA**	**HRCTV D90 IIB**	**HRCTV D90 IIIB**	**D2cc Bladder**	**D2cc Rectum**	**D2cc Sigmoid**
Tandem only	88%	67%	33%	44%	31%	36%	3%	30%
Tandem + ring or ovoids	88%	75%	50%	90%	75%	45%	22%	33%

Therefore: small tumors are often adequately treated by uniform loading – more extensive disease may need additional measures (optimization / paracervical needles)

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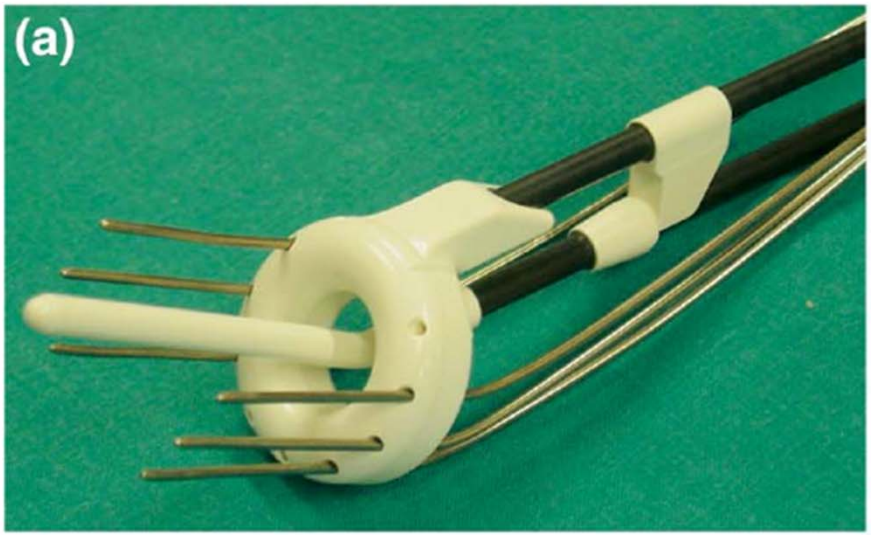
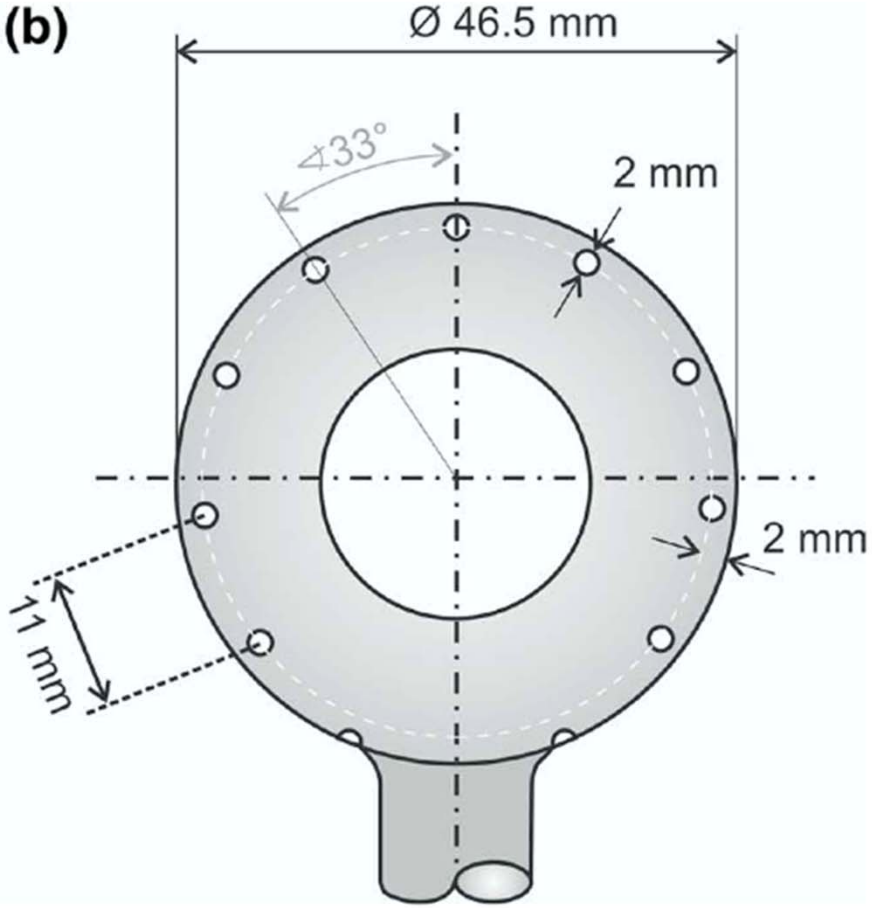
Nkiwane, Brachytherapy 2013

Vienna Applicator





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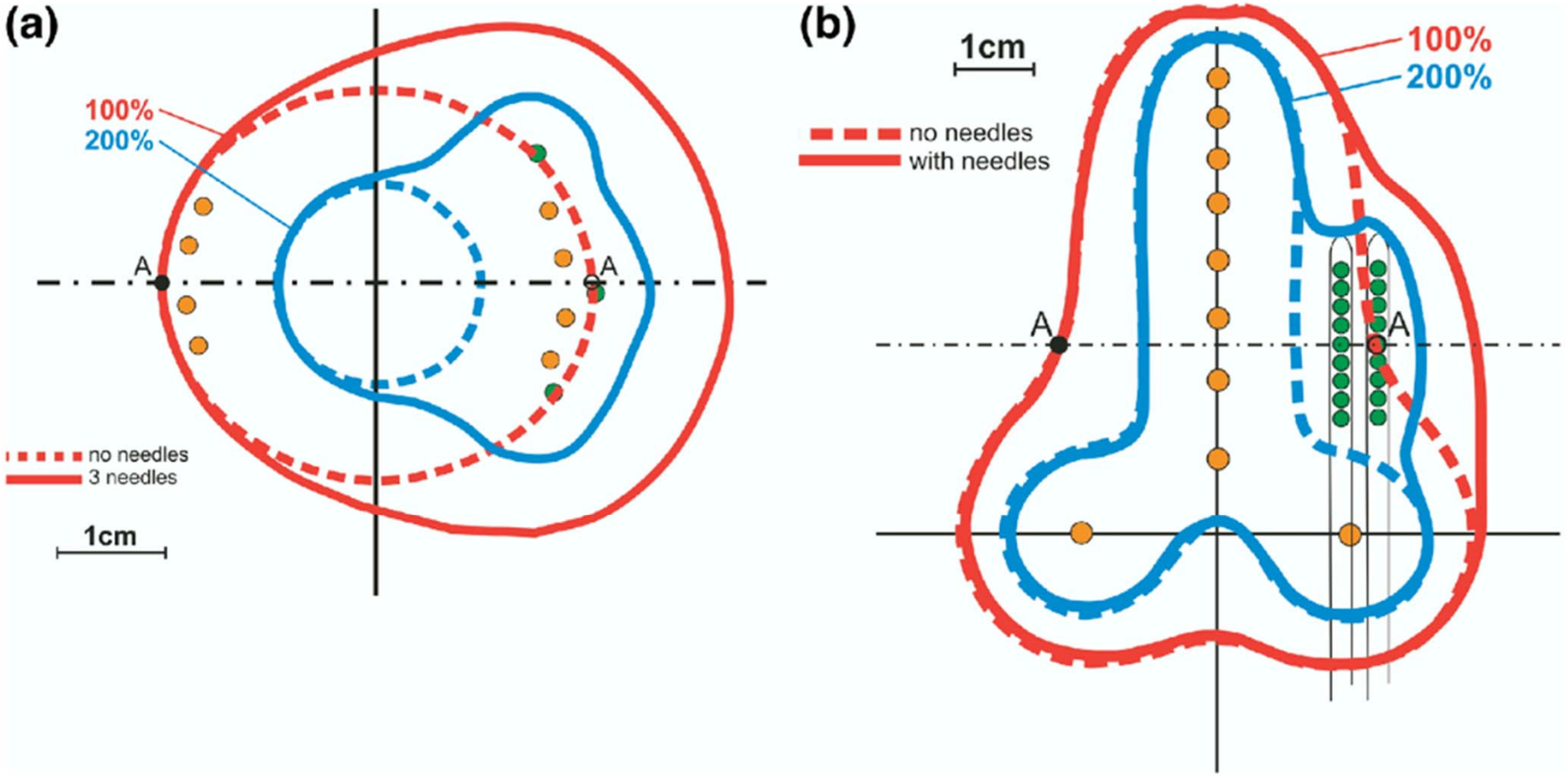
Krisitis et al. IJROBP 2006

Vienna Applicator



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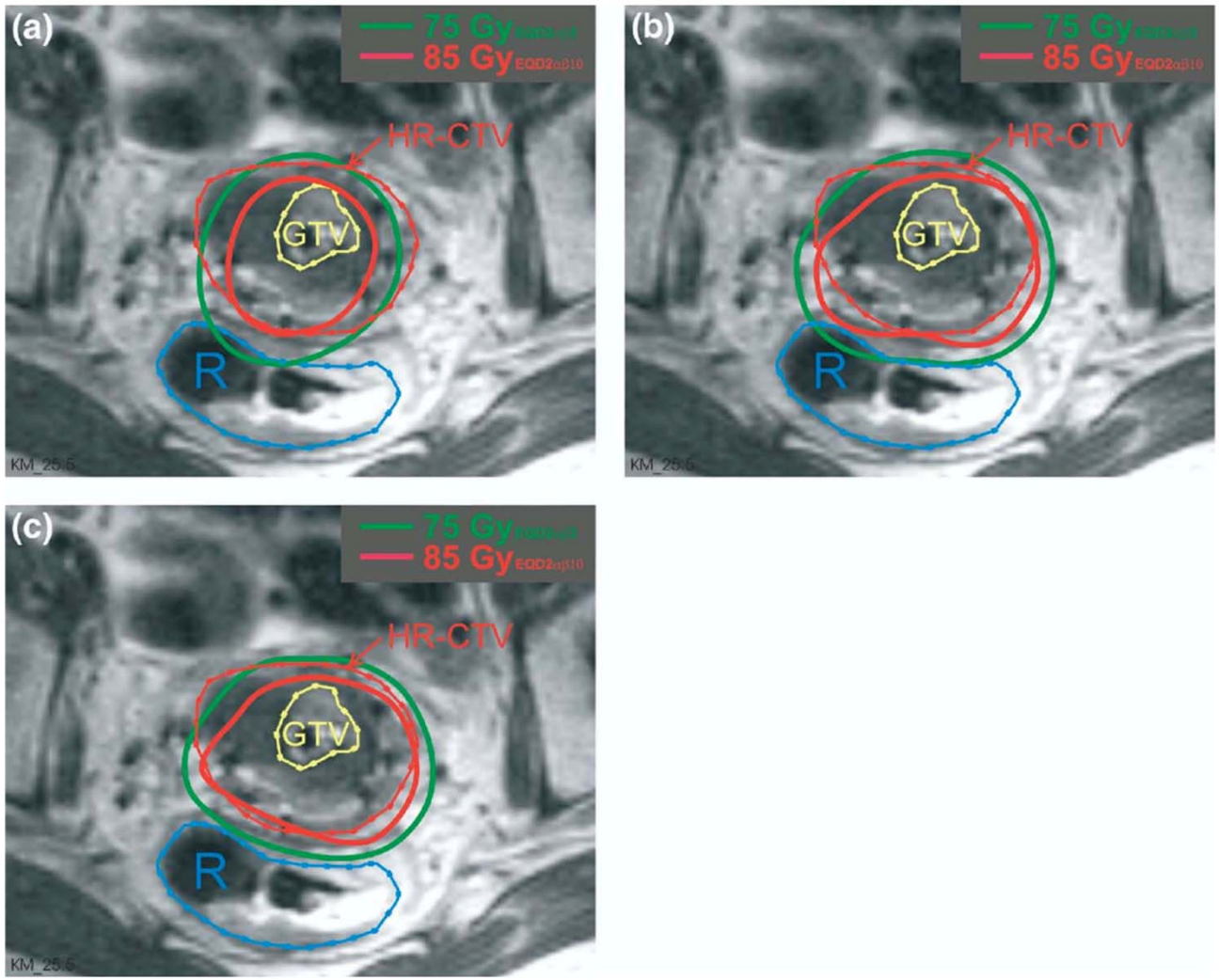
Vienna Applicator



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Krisitis et al. IJROBP 2006

Applicator Selection

- T&R will cover most small tumors
  - Posterior and anteriorly based tumors may benefit from loading the anterior and posterior ring
- T&O: lateral coverage for larger cervical disease
- Vienna: parametrial disease
- Tandem Cylinder/Miami: thin vaginal disease
- Syed template + Tandem: thick vaginal disease

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Conclusions from published data

- MRI is superior to CT and film based delineation of tumor
- Doses to MRI based volumes are associated with clinically relevant outcomes
- Doses to the contoured Bladder and Rectum are associated with late toxicity
- IGBT as a technique is associated with decreased toxicity with the same or improved control

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Emerging modalities

- DCE-MRI: may reveal areas of poor perfusion, which may be high risk regions
- DW-MRI: may reveal areas of high cellular density (restricted diffusion) which may be high risk areas
- PET-CT: prognostic utility is well established, but uncertain for utility with IGBT
- US: used clinically for decades, but uncertain as of yet how best to integrate this highly accessible modality in the frame work of IGBT

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Questions

- Is it exportable?
- Are the metrics currently reported the best?
- Is the method of dose optimization relevant?
- Are there other organs/volumes that should be contoured?
- What are the logistical challenges to making the switch from FBBT to IGBT?

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Our Experience

- Film Based through 2005 (LDR)
- CT based IGBT was used throughout 2006-2010 (LDR)
- 2011-present MRI based IGBT used (HDR)

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2005

- T&O placed in OR
- Orthogonal Films taken
- Points chosen (A, B, rectum, and bladder)
- Plan devised
- Patient loaded on floor
- 70-80 hours in hospital immobilized
- Implant unloaded, T&O removed

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2013

- Patient brought to clinic
- Anesthesia induced (level similar to that used during colonoscopy)
- Applicator selected and placed
- CT immediately obtained (r/o perforation)
- MRI obtained
- CT/MRI fused
- Physician contours fused images (HRCTV on MRI, OAR on CT with MRI assist)
- Treatment plan created
- QA performed
- Treatment delivered
- Applicator removed
- Discharge from clinic

x5

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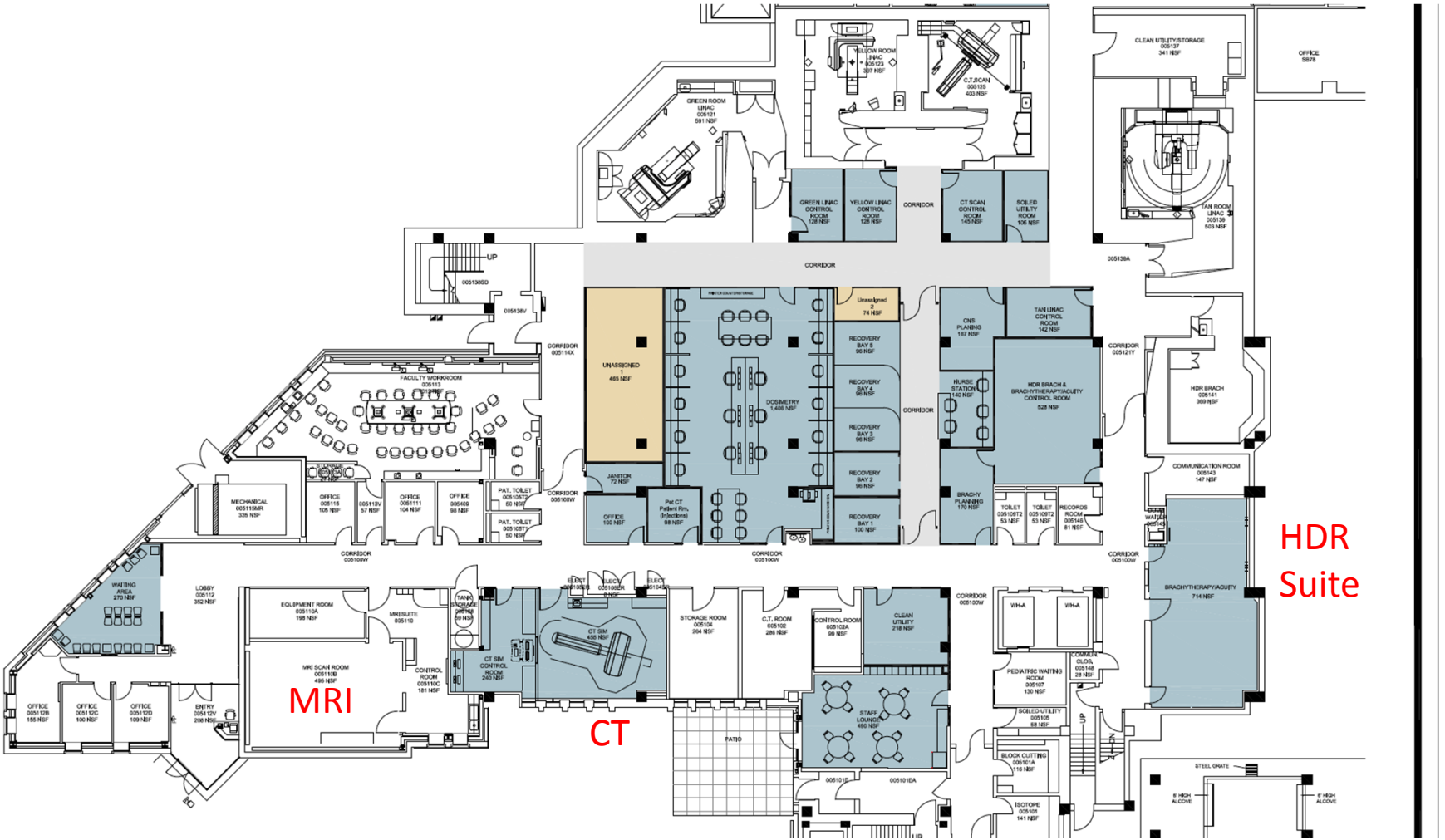
Physical Layout



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Team Members

- Radiation Oncology (1 attending, 1 resident)
- Anesthesiologist (1 attending +/- 1 CRNA)
- Physics (2 faculty, 1 resident)
- CT/MR operators (3+ therapists/techs)
- Nursing (1 RN + support at recovery)
- It is critical that this be a stable team, for both patient safety, and for efficient use of time

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Average Case

- 7:30 am Patient arrives – obtain IV access, premeds (RN)
- 8:00 am Patient to suite, anesthesia induced (MD)
- 8:15 am Applicator selected and placed (MD)
- 8:30 am Anesthesia recovery (RN)
- 8:45 am CT scan (Tech)
- 9:15 am MRI scan (Tech)
- 10:00 am MRI/CT fused (Physics)
- 10:30 am Physician contours (MD)
- 11:00 am Plan optimized (Physics/MD)
- 11:15 am Plan approved (MD)
- 11:30 am Plan/Afterloader QA (Physics)
- 12:00 pm Patient treated (MD/Physics)
- 12:15 pm Applicator Removed (MD)
- 1:00 pm Patient discharged (RN)

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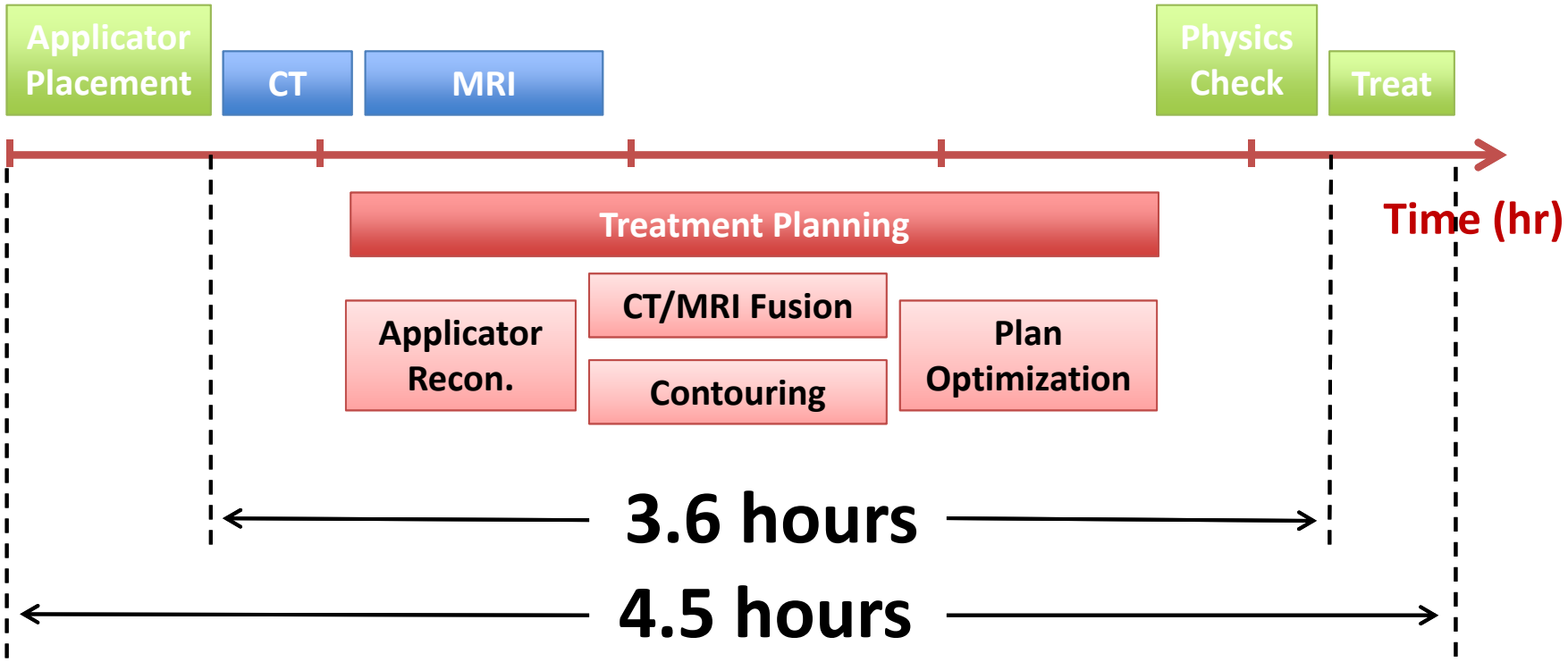
Time Requirement



The median time from start of imaging to treatment delivery was 3.6 hours (3.3 – 3.9 hours).

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Why plan each time?

- Eliminating the MRI on subsequent fractions would improve throughput and lessen burden on team

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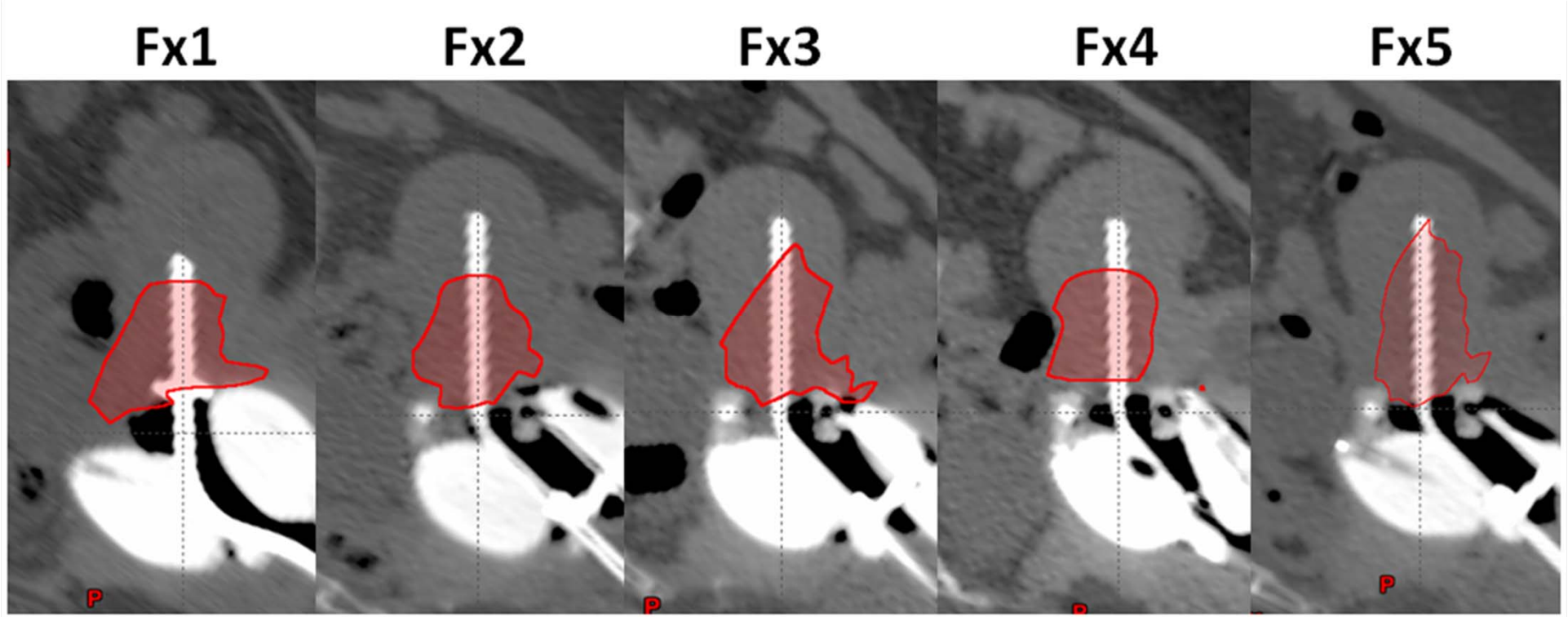
Intrafraction Variations



- Applicator change
- HRCTV/IRCTV variations
- OARs variations

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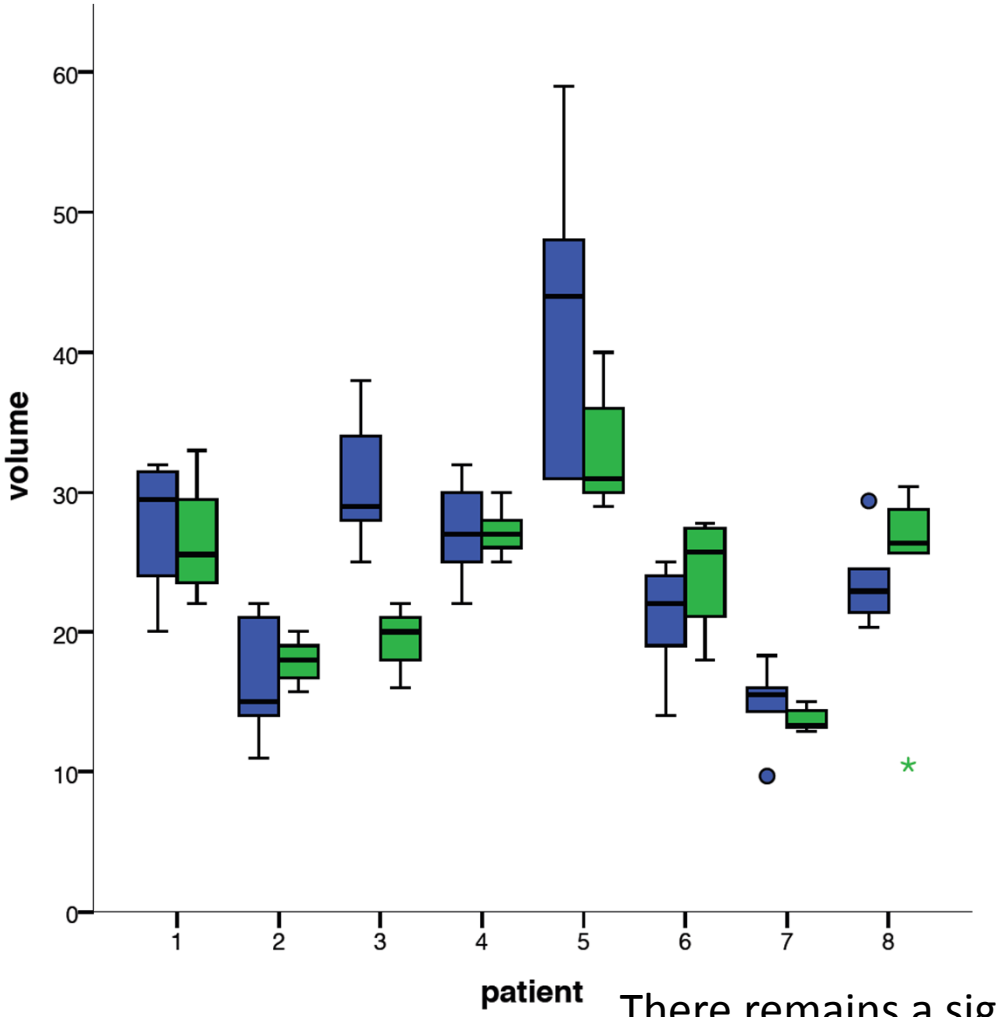
Changes in HRCTV contours



Blue box = range of HRCTV volumes as contoured at time of treatment

Green box = range of HRCTV volumes when recontoured in single sitting (retrospective)

There remains a significant variation in contouring, which is reduced but not eliminated by a more consistent approach.

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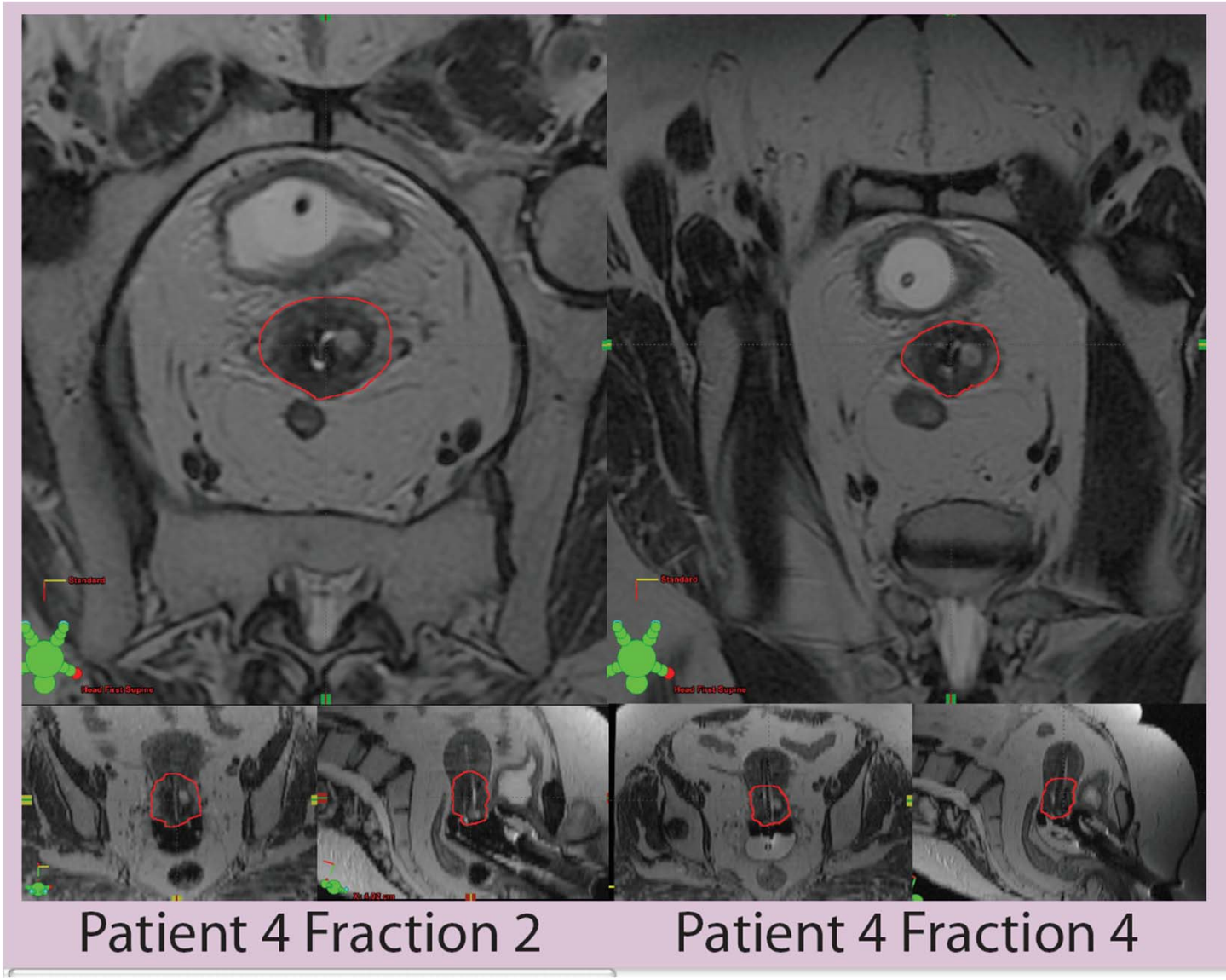
Patient with Good Accord



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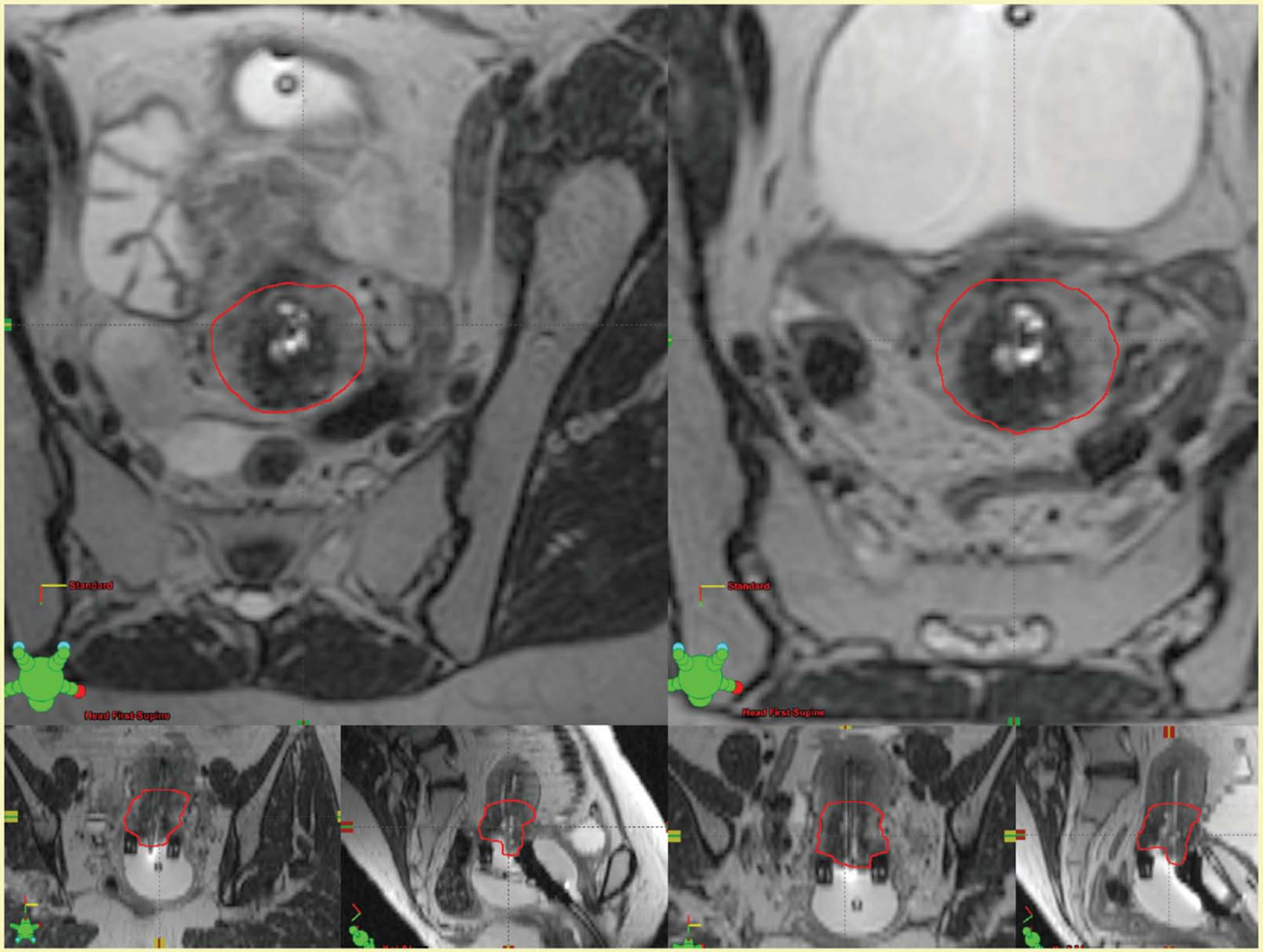
Patient with Minor Variation



Patient 1 Fraction 3 Patient 1 Fraction 5

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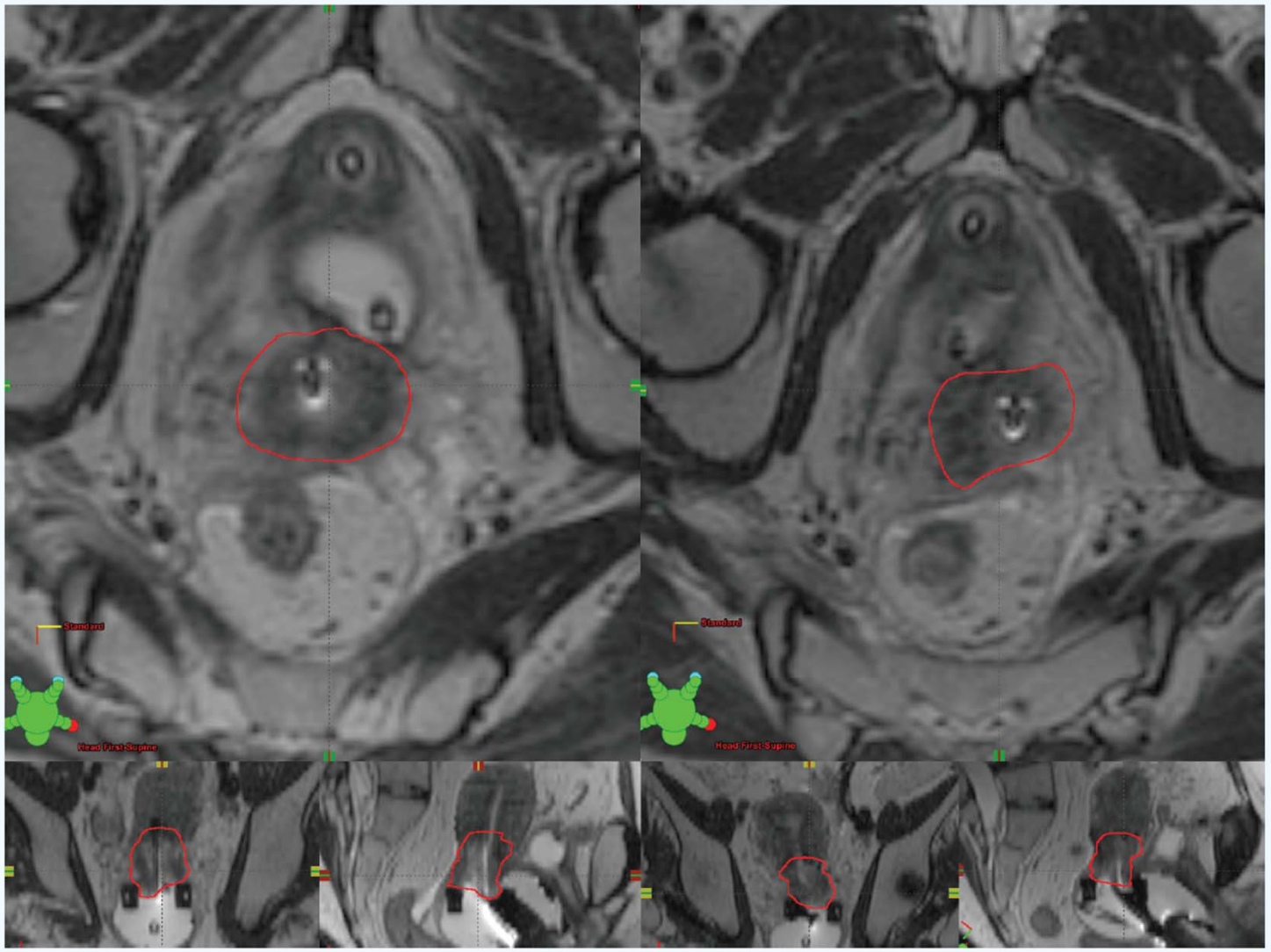
Patient with Large Variation



Patient 6 Fraction 2 Patient 6 Fraction 3

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Pitfalls/Cautions

- Team needs excellent and open communication
- Schedule needs tight coordination
- MDs and Physics need to perform their work safely and efficiently
- Image fusion and applicator reconstruction need to be done with care
- Dose optimization should be approached stepwise from a more standard film based plan
- Particular attention should be paid to QA prior to treatment by all members of team

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The Duke Brachytherapy Team

- Oana Craciunescu PhD
- Jing Cai PhD
- Beverley Steffey MS
- Sheridan Meltsner PhD
- Kimberley Maingat RN
- Danielle Raya RN
- + many more therapists, rad techs, and support staff

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