Rectal balloons reduce rectal dose in proton radiotherapy for prostate cancer

Ryan Grover MD,
David Bush MD,
Richard P. Levy MD Ph.D,
Jerry Slater MD

Loma Linda University Medical Center
Radiation Medicine

What we know:

- Higher doses of radiation therapy improve disease control in prostate cancer
- Rectal balloons immobilize the prostate and displace normal tissue.
- Rectal balloons are well-tolerated.
- Rectal balloons improve dosimetry when used with x-rays
- Rectal balloons improve dosimetry when used with protons.

What we know:

- **Higher doses of radiation therapy improve disease control in prostate cancer**
- Rectal balloons immobilize the prostate and displace normal tissue.
- Rectal balloons are well-tolerated.
- Rectal balloons improve dosimetry when used with x-rays
- Rectal balloons improve dosimetry when used with protons.

PROG 95-09

Comparison of Conventional-Dose vs High-Dose Conformal Radiation Therapy in Clinically Localized Adenocarcinoma of the Prostate

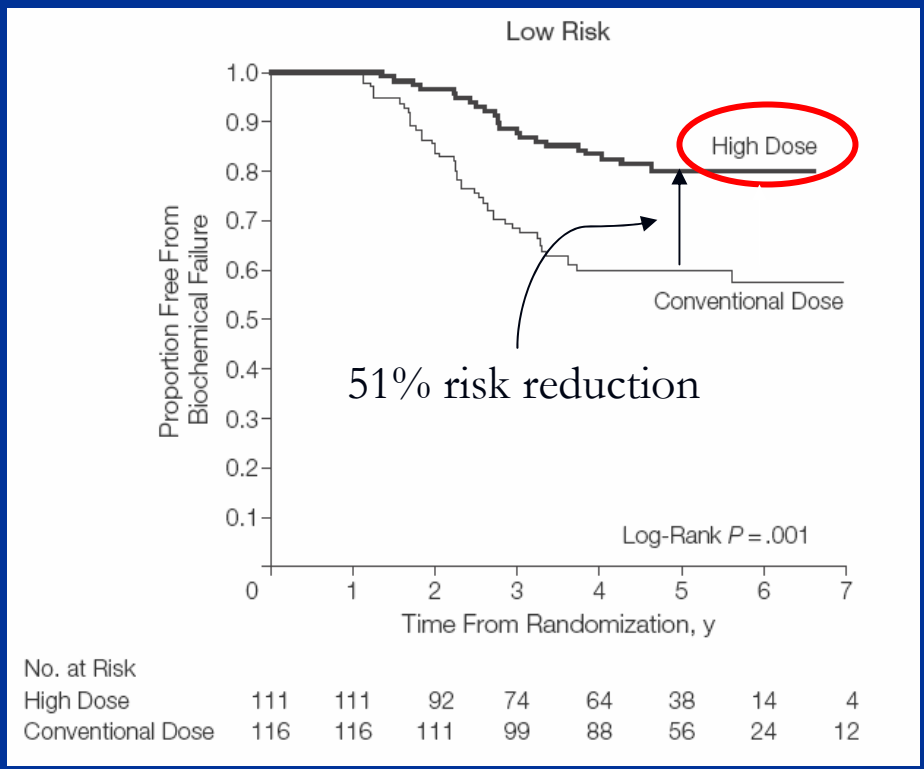
A Randomized Controlled Trial

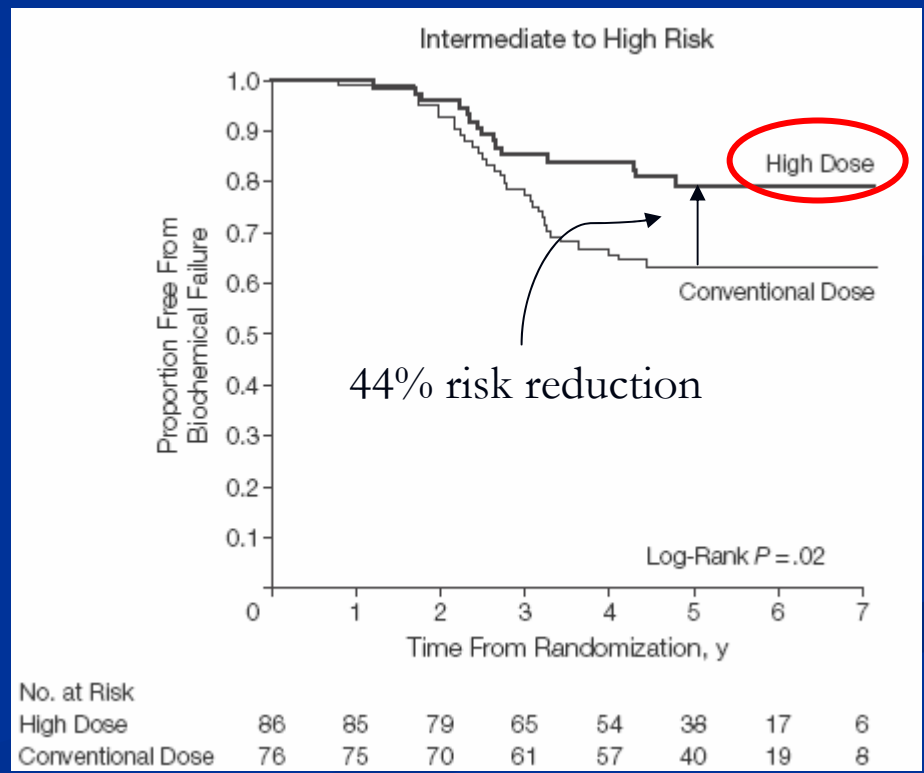
Anthony L. Zietman, MD
Michelle L. DeSilvio, PhD
Jerry D. Slater, MD
Carl J. Rossi, Jr, MD
Daniel W. Miller, PhD
Judith A. Adams, MS
William U. Shipley, MD

Context Clinically localized prostate cancer is very prevalent among US men, but recurrence after treatment with conventional radiation therapy is common.

Objective To evaluate the hypothesis that increasing the radiation dose delivered to men with clinically localized prostate cancer improves disease outcome.

Design, Setting, and Patients Randomized controlled trial of 393 patients with stage T1b through T2b prostate cancer and prostate-specific antigen (PSA) levels less than 15 ng/mL randomized between January 1996 and December 1999 and treated at 2 US academic institutions. Median age was 67 years and median PSA level was 6.3 ng/mL. Median follow-up was 5.5 (range, 1.2-8.2) years.





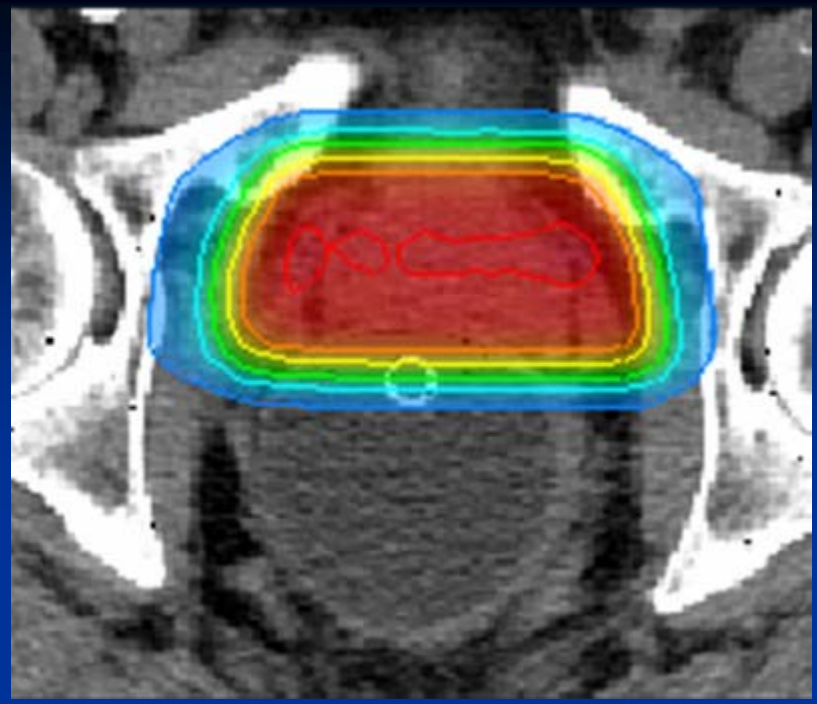
Zietman, A.L., et al. *Comparison of conventional-dose vs high-dose conformal radiation therapy in clinically localized adenocarcinoma of the prostate: a randomized controlled trial* . JAMA 2005 Sep 14;294(10):1233-9

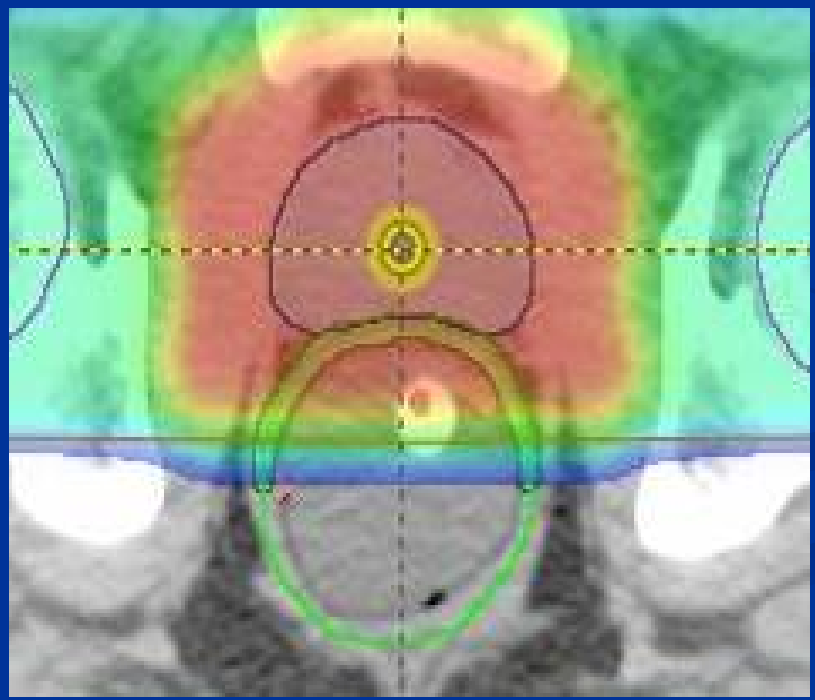
Dose escalation

- Limits of dose-escalation are not yet known
- Efforts continue to escalate the biological-equivalent-dose (BED)
- Normal tissue protection is increasingly important

What we know:

- ✓ Higher doses of radiation therapy improve disease control in prostate cancer
- **Rectal balloons immobilize the prostate and displace normal tissue.**
- Rectal balloons are well-tolerated.
- Rectal balloons improve dosimetry when used with x-rays
- Rectal balloons improve dosimetry when used with protons.





Rectal balloon benefits

- Rectal balloon has been used at Loma Linda University Medical Center for 20 years
  - over 7450 patients treated with protons for prostate cancer since the Loma Linda Proton Center's opening 15 years ago.

- Why?
  - Immobilize the prostate
  - Displace normal tissue

Int. J. Radiation Oncology Biol. Phys., Vol. 66, No. 3, pp. 876–882, 2006

0360-3016/06/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2006.06.011

PHYSICS CONTRIBUTION

DAILY VARIATIONS IN DELIVERED DOSES IN PATIENTS TREATED WITH RADIOTHERAPY FOR LOCALIZED PROSTATE CANCER

PATRICK A. KUPELIAN, M.D.,* KATJA M. LANGEN, PH.D.,* OMAR A. ZEIDAN, PH.D.,* SANFORD L. MEEKS, PH.D.,* TWYLA R. WILLOUGHBY, M.S.,* THOMAS H. WAGNER, PH.D.,* SAM JESWANI, PH.D.,† KENNETH J. RUCHALA, PH.D.,† JASON HAIMERL, PH.D.,† AND GUSTAVO H. OLIVERA, PH.D.†‡

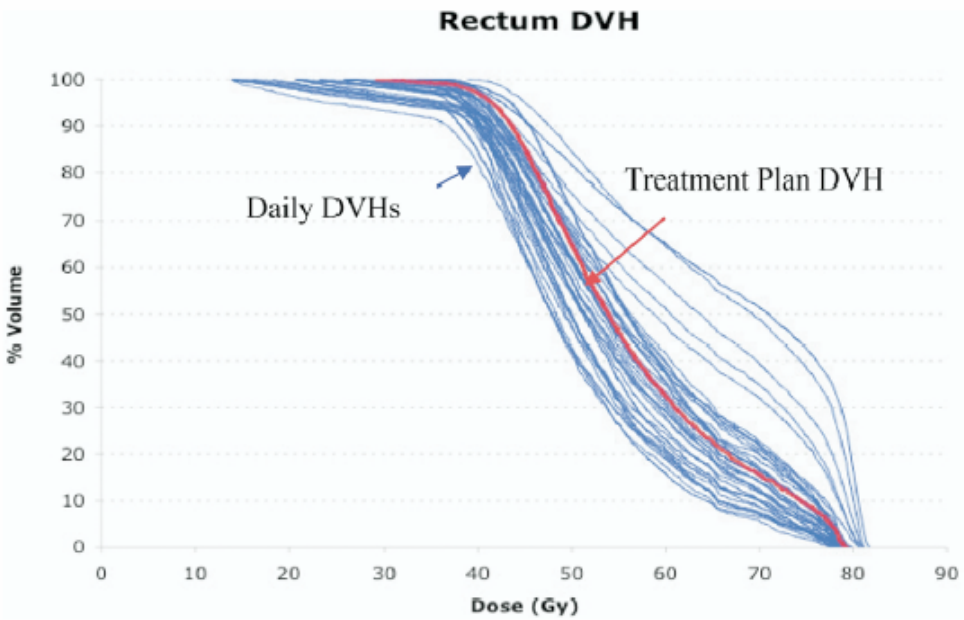


Fig. 4. Rectal dose–volume histogram (DVH) for all 39 treatment fractions in 1 patient. Red line represents the planning computed tomography DVH; thinner blue lines represent daily DVHs.

Kupelian PA et. al., *Daily variations in delivered doses in patients treated with radiotherapy for localized prostate cancer.* IJROBP 2006 Nov 1;66(3):876-82

Int. J. Radiation Oncology Biol. Phys., Vol. 44, No. 3, pp. 525–533, 1999

0360-3016/99/$–see front matter

ELSEVIER

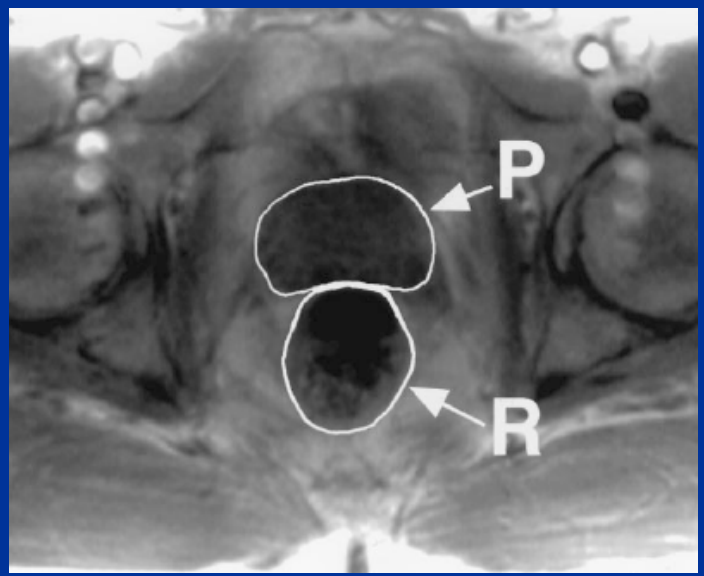
PII S0360-3016(99)00040-1

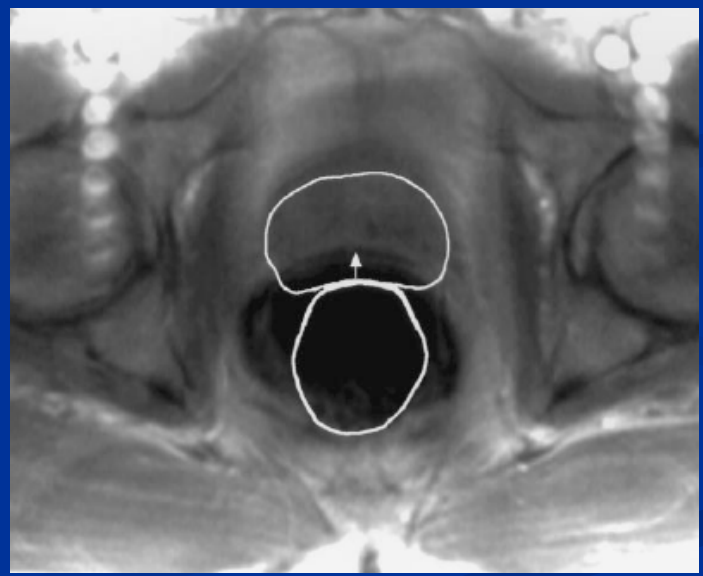
CLINICAL INVESTIGATION **Prostate**

EVALUATING THE EFFECT OF RECTAL DISTENSION AND RECTAL MOVEMENT ON PROSTATE GLAND POSITION USING CINE MRI

ANWAR R. PADHANI,* M.R.C.P., F.R.C.R., VINCENT S. KHOO, F.R.A.C.R.,†
JOHN SUCKLING, B.SC., M.SC., PH.D., MINST.P.,*‡ JANET E. HUSBAND, F.R.C.P., F.R.C.R.,*
MARTIN O. LEACH, PH.D., F.INST.P., F.I.P.E.M.B.,*
AND DAVID P. DEARNALEY, M.A., M.D., F.R.C.P., F.R.C.R.†

- Cine-MR over 7 minutes: up to 1.2 cm movement





Padhani et. al., *Evaluating the effect of rectal distension and rectal movement on prostate gland position using cine MRI.* IJORBP 1999 Jun 1;44(3):525-33.

Int. J. Radiation Oncology Biol. Phys., Vol. 51, No. 5, pp. 1431–1436, 2001

0360-3016/01/$–see front matter

ELSEVIER

PII S0360-3016(01)02663-3

PHYSICS CONTRIBUTION

A PRACTICAL METHOD TO ACHIEVE PROSTATE GLAND IMMOBILIZATION AND TARGET VERIFICATION FOR DAILY TREATMENT

ANTHONY V. D'AMICO, M.D., PH.D.,* JUDI MANOLA, PH.D.,† MARIAN LOFFREDO, R.N., O.C.N.,* LYNN LOPES, R.N.,* KRISTOPHER NISSEN, B.S., R.T.T.,* DESMOND A. O'FARRELL, C.M.D.,* LEAH GORDON, B.A.,* CLARE M. TEMPANY, M.D.,‡ AND ROBERT A. CORMACK, PH.D.*

Departments of *Radiation Oncology, †Biostatistics, and ‡Radiology, Brigham and Women's Hospital and Dana Farber Cancer Institute, Boston, MA

- Maximum displacement in any direction:
  - From 4 mm without balloon to ≤ 1mm with balloon

D'Amico, A.V., et al., *A practical method to achieve prostate gland immobilization and target verification for daily treatment.* Int J Radiat Oncol Biol Phys, 2001. **51**(5): p. 1431-6.

What we know:

- ✓ Higher doses of radiation therapy improve disease control in prostate cancer
- ✓ Rectal balloons immobilize the prostate and displace normal tissue.
- **Rectal balloons are well-tolerated.**
- Rectal balloons improve dosimetry when used with x-rays
- Rectal balloons improve dosimetry when used with protons.

Int. J. Radiation Oncology Biol. Phys., Vol. 64, No. 5, pp. 1367–1370, 2006

0360-3016/06/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2005.11.001

CLINICAL INVESTIGATION **Prostate**

PATIENT TOLERANCE OF RECTAL BALLOONS IN CONFORMAL RADIATION TREATMENT OF PROSTATE CANCER

BRIAN B. RONSON, M.D., LES T. YONEMOTO, M.D., CARL J. ROSSI, M.D.,
JAMES M. SLATER, M.D., F.A.C.R., AND JERRY D. SLATER, M.D.

- Evaluation of 3561 charts spanning 11 years:
  - 97.6% tolerated the balloon for the entire treatment
  - 99.5% vs. 95.7% for protons-alone vs. combo

Ronson BR, et al., *Patient tolerance of rectal balloons in conformal radiation treatment of prostate cancer.* Int J Radiat Oncol Biol Phys, 2006. **64**(5): p. 1367-70

What we know:

- ✓ Higher doses of radiation therapy improve disease control in prostate cancer
- ✓ Rectal balloons immobilize the prostate and displace normal tissue.
- ✓ Rectal balloons are well-tolerated.
- ❑ **Rectal balloons improve dosimetry when used with x-rays**
- ❑ Rectal balloons improve dosimetry when used with protons.

ELSEVIER

Radiotherapy and Oncology 67 (2003) 285–294

RADIOTHERAPY & ONCOLOGY

www.elsevier.com/locate/radonline

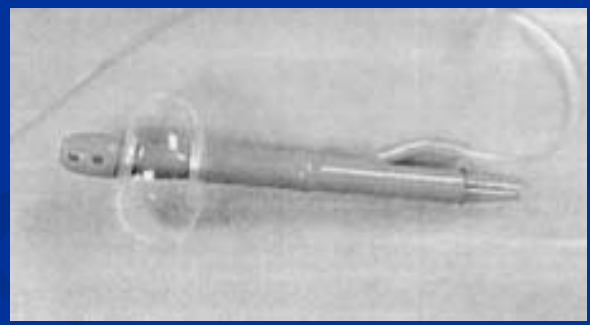
Rectal dose sparing with a balloon catheter and ultrasound localization in conformal radiation therapy for prostate cancer

Rakesh R. Patel[a], Nigel Orton[a], Wolfgang A. Tomé[a], Rick Chappell[b], Mark A. Ritter[a,*]

[a]*Department of Radiation Oncology, University of Wisconsin, 600 Highland Avenue K4/B100, Madison, WI 53792, USA*
[b]*Department of Biostatistics and Informatics, University of Wisconsin, 600 Highland Avenue K4/B100, Madison, WI 53792, USA*

Received 5 December 2001; received in revised form 27 January 2003; accepted 20 February 2003

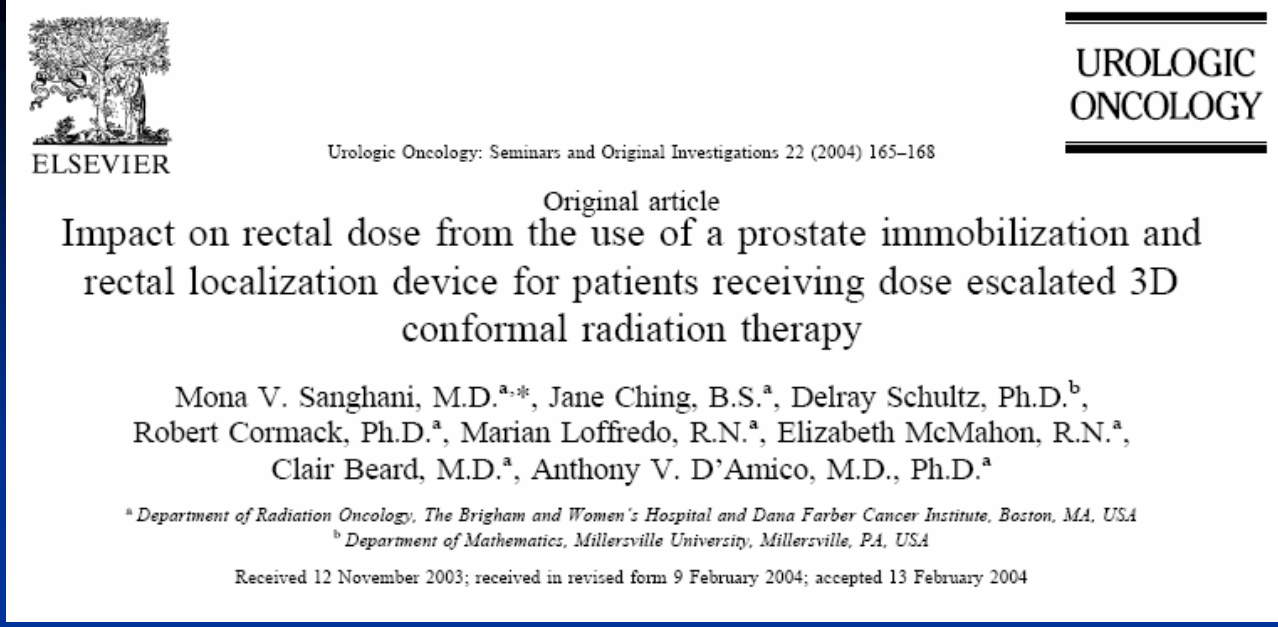
- 5 pts:
  - 76 Gy/38F IMRT to prostate +/- SV



vs. 3DCRT, +/- 60cc air balloon.

→ "Rectal sparing ratio" ~0.6 for V60, V65 and V70

Patel, R.R., et al., *Rectal dose sparing with a balloon catheter and ultrasound localization in conformal radiation therapy for prostate cancer.* Radiother Oncol, 2003. **67**(3): p. 285-94.



ELSEVIER

Urologic Oncology: Seminars and Original Investigations 22 (2004) 165–168

UROLOGIC ONCOLOGY

Original article

Impact on rectal dose from the use of a prostate immobilization and rectal localization device for patients receiving dose escalated 3D conformal radiation therapy

Mona V. Sanghani, M.D.[a,*], Jane Ching, B.S.[a], Delray Schultz, Ph.D.[b], Robert Cormack, Ph.D.[a], Marian Loffredo, R.N.[a], Elizabeth McMahon, R.N.[a], Clair Beard, M.D.[a], Anthony V. D'Amico, M.D., Ph.D.[a]

[a] *Department of Radiation Oncology, The Brigham and Women's Hospital and Dana Farber Cancer Institute, Boston, MA, USA*
[b] *Department of Mathematics, Millersville University, Millersville, PA, USA*

Received 12 November 2003; received in revised form 9 February 2004; accepted 13 February 2004

- 28 pts:
  - sim +/- balloon.
  - Tx planned for balloon use in 0, 15 or 40 treatments:
  - V70s of 25%, 7.5%, and 3.6% (*p=0.0001*)

Sanghani M.V., et al, *Impact on rectal dose from the use of a prostate immobilization and rectal localization device for patients receiving dose escalated 3D conformal radiation therapy*. Urologic Oncol, 2004. 22: p. 165-8.

What we know:

- ✓ Higher doses of radiation therapy improve disease control in prostate cancer
- ✓ Rectal balloons immobilize the prostate and displace normal tissue.
- ✓ Rectal balloons are well-tolerated.
- ✓ Rectal balloons improve dosimetry when used with x-rays
- ❑ **Rectal balloons improve dosimetry when used with protons.**

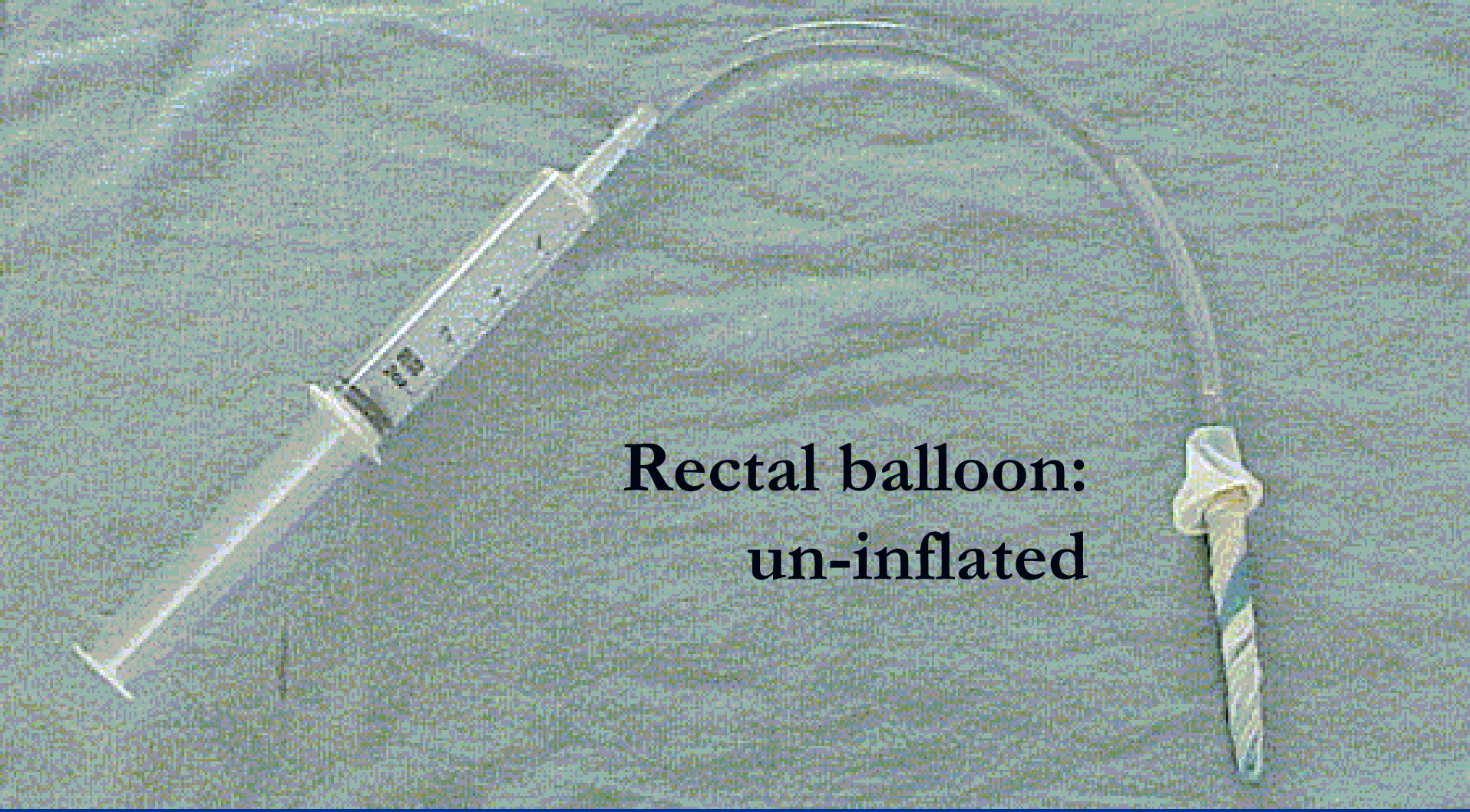
LLUMC analysis:

- Study of the effects of rectal balloons on rectal dosimetry:
  - 29 patients enrolled in this IRB-approved protocol
  - Eligible patients included those with histologically-proven, adenocarcinoma of the prostate stages T1A-T3B (N0M0).

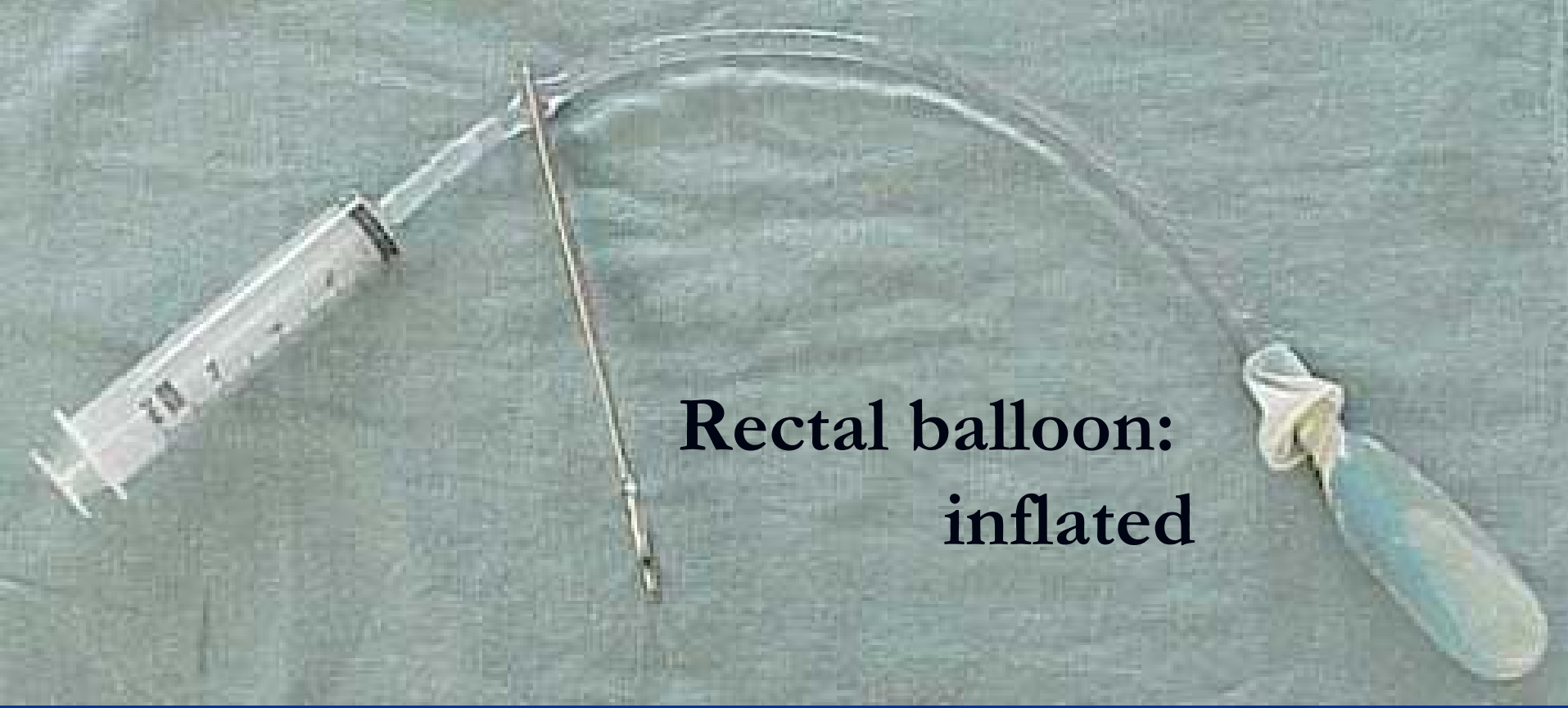
LLUMC analysis:

- Patients received a CT scan in a body-immobilization pod in the usual and customary fashion, but first **without** a rectal balloon

- Patients were **re-scanned** in the same position after a rectal balloon was placed.



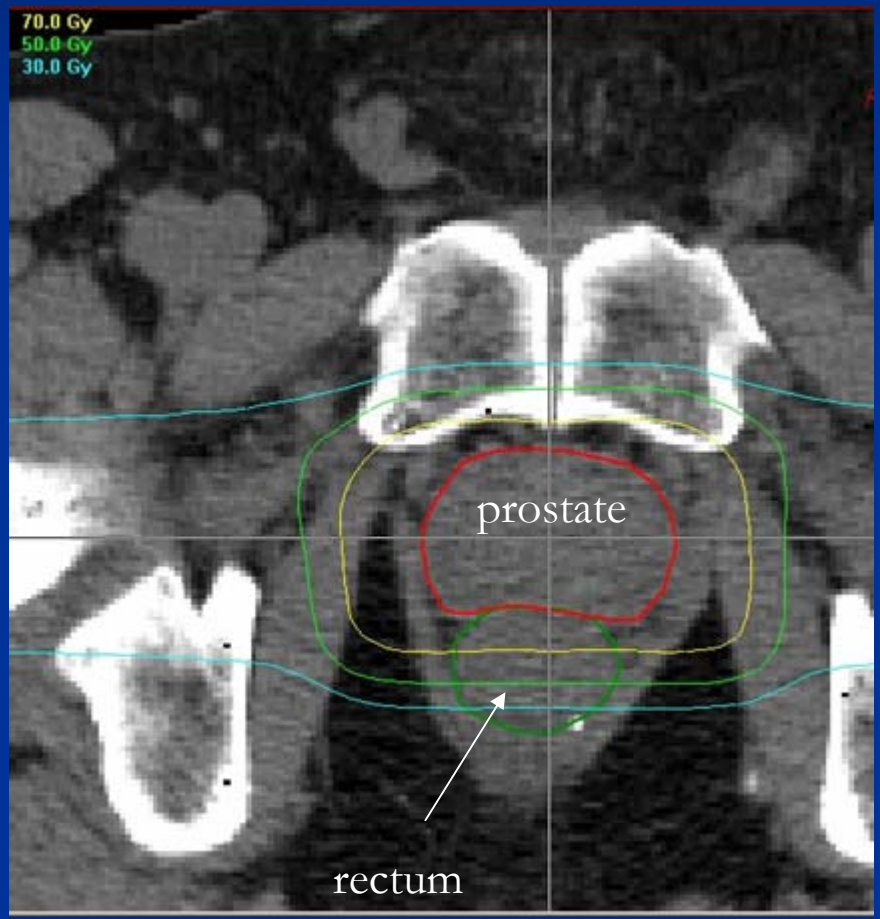
- Latex ultrasound transducer cover secured over an infant barium enema tip
- Attached to a plastic tubing and syringe



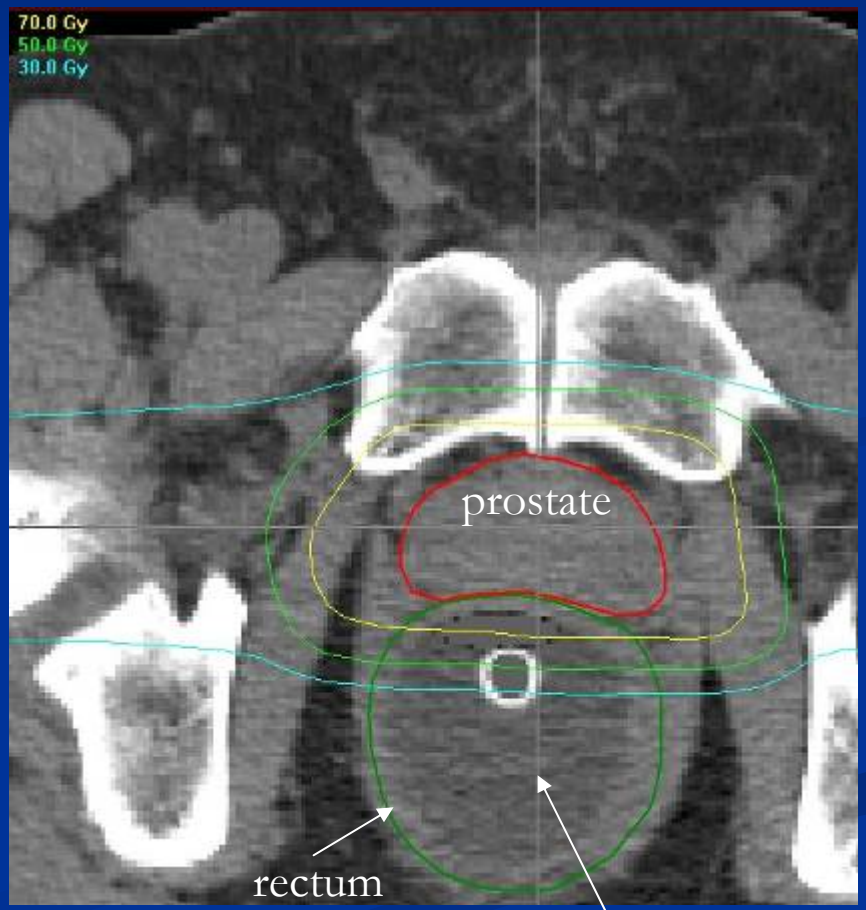
Rectal balloon: inflated

- Prior to treatment planning CT and each treatment, the balloon is inserted into the rectum and inflated with 120 mL of water

LLUMC analysis:

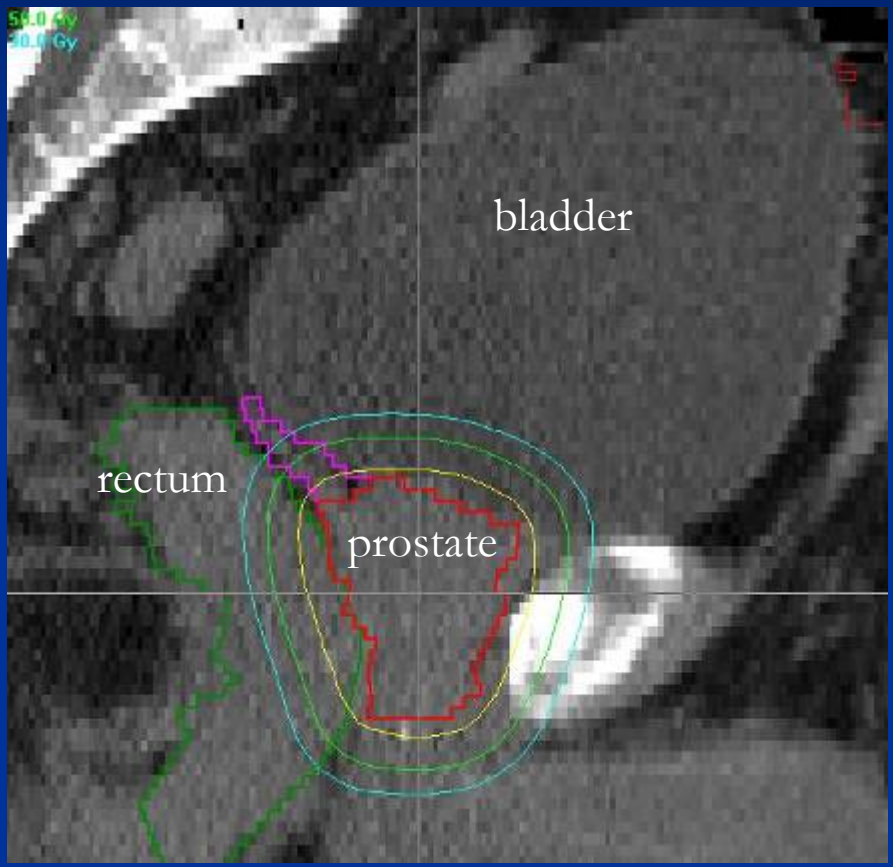


Balloon absent

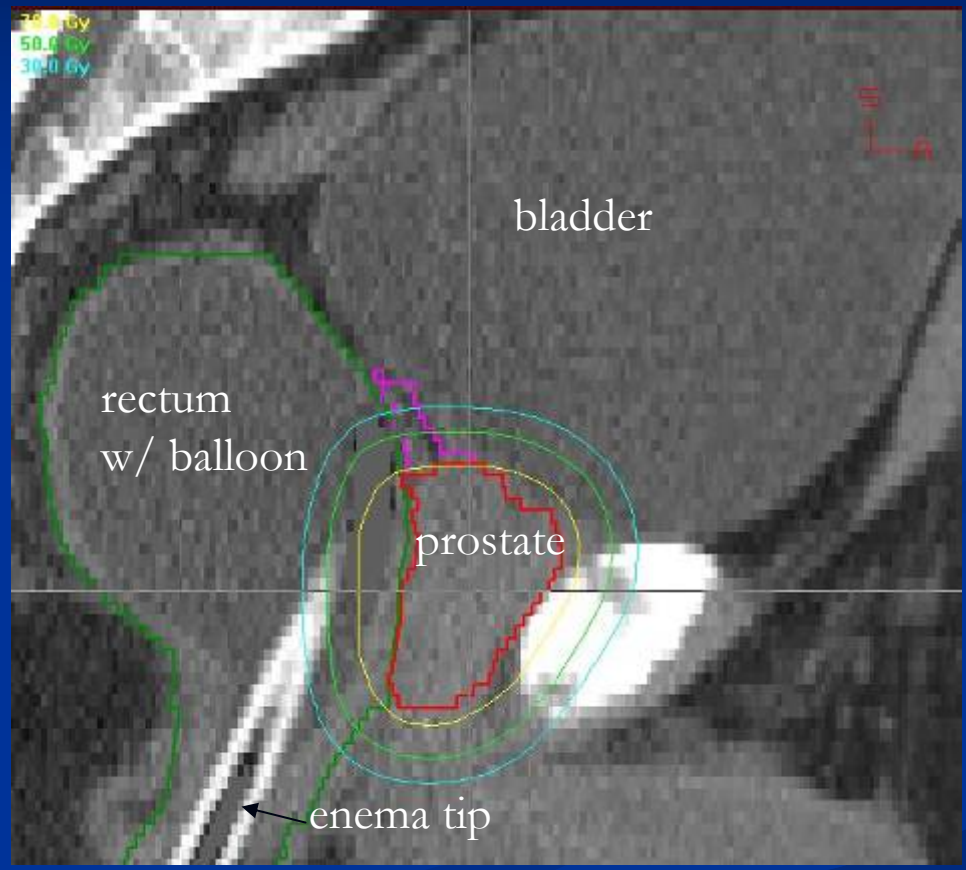


Balloon present

LLUMC analysis:



Balloon absent



Balloon present

LLUMC analysis: part I

- Structures were outlined:
  - Whole rectum (recto-sigmoid junction to bottom of ischial tuberosities)
  - GTV: prostate gland
  - CTV: prostate + SV
- Treatment plans were designed using OptiRad:
  - CTV = 50.4 CGE @ 1.8 CGE/F/d
  - + GTV = 28.8 CGE @ 1.8 CGE/F/d
  - Total = 79.2 CGE @ 1.8 CGE/F/d
- Comparisons were made using **paired** Student's *t*-test

Study endpoints:

- Pollack et. al. and Storey et. al.:
  - Increased late rectal toxicity if >70 Gy to >25% of rectal volume
  - Recommended **V70 < 25%**
- Huang et. al:
  - Retrospective DVH analysis (3DCRT)
  - Variables exponentially related to Gr 2 toxicity:
    - **Max dose to**: **rectum**, CTV, rectum/Rx, 10cm^3 rectum
    - V60 (>40.6%), **V70** (>26.2%), V75.6 (>15.8%), **V78** (>5.1%)

Pollack, A., et al., *Prostate cancer radiation dose response: results of the M. D. Anderson phase III randomized trial.* Int J Radiat Oncol Biol Phys, 2002. **53**(5): p. 1097-105.

Storey, M.R., et al., *Complications from radiotherapy dose escalation in prostate cancer: preliminary results of a randomized trial.* Int J Radiat Oncol Biol Phys, 2000. 48(3): p. 635-42

Huang, E.H., et al., *Late rectal toxicity: dose-volume effects of conformal radiotherapy for prostate cancer.* Int J Radiat Oncol Biol Phys, 2002. **54**(5): p. 1314-21

LLUMC analysis: part I

- Rectal volume:

	mean (cc)	*95% C.I.*	*std dev*
no balloon:	**99.5**	(78.4 - 121)	53.2
balloon:	**225**	(203 - 247)	55.6

mean difference = 125 (116 - 135)

(***p*=0.000**)* $t = 27.2$ (d.o.f.= 26)

*Using Paired Student's *t*-test

LLUMC analysis: part I

- Rectal V70:

	mean(%)	*95% C.I.*	*std dev*
no balloon:	**8.71**	(7.6-9.8)	2.8
balloon:	**6.53**	(5.8-7.3)	1.9

mean difference = 2.19 (1.1-3.2)

(***p*=0.000**)* $t = 4.32$ (d.o.f.= 26)

*Using Paired Student's *t*-test

LLUMC analysis: part I

- Rectal V78:

	mean(%)	*95% C.I.*	*std dev*
no balloon:	**2.8**	(1.7-3.9)	2.8
balloon:	**1.6**	(1.2-2.0)	1.0

mean difference = 1.2 (0.1-2.3)

(***p*=0.033**)* **t** = 2.25 (d.o.f.= 26)

*Using Paired Student's *t*-test

LLUMC analysis: part I

- Rectal max dose:

	mean(%)	*95% C.I.*	*std dev*
no balloon:	**79.7**	(79.2 - 80.2)	1.3
balloon:	**79.4**	(79.2 - 79.6)	0.54
mean difference = 0.28		(-0.28 - 0.84)	1.4
(*p*=0.315)*	$t = 1.02$ (d.o.f.= 26)		

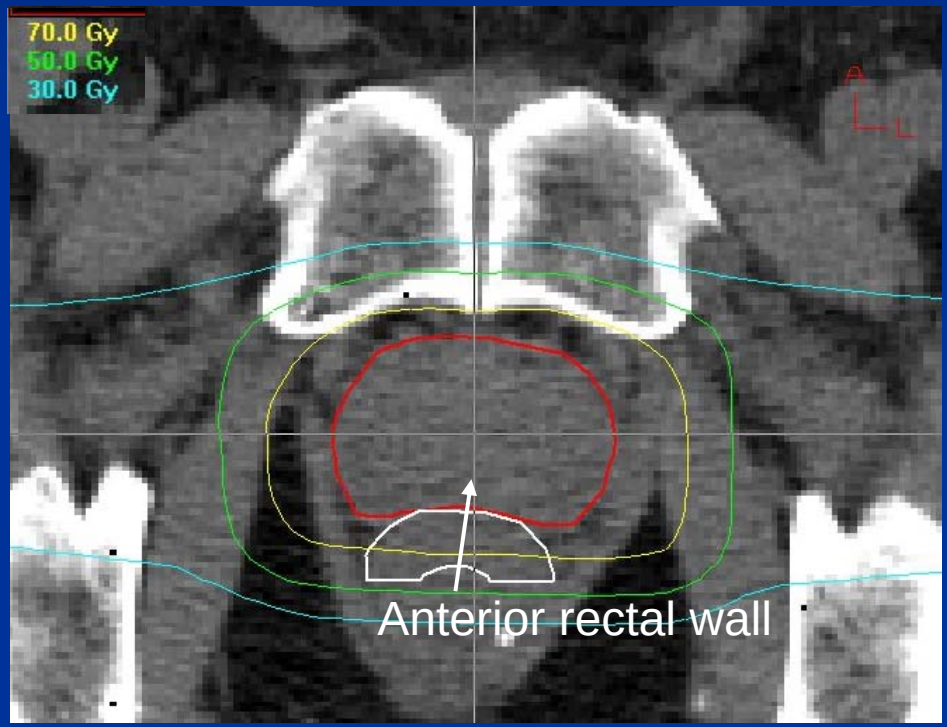
*Using Paired Student's *t*-test

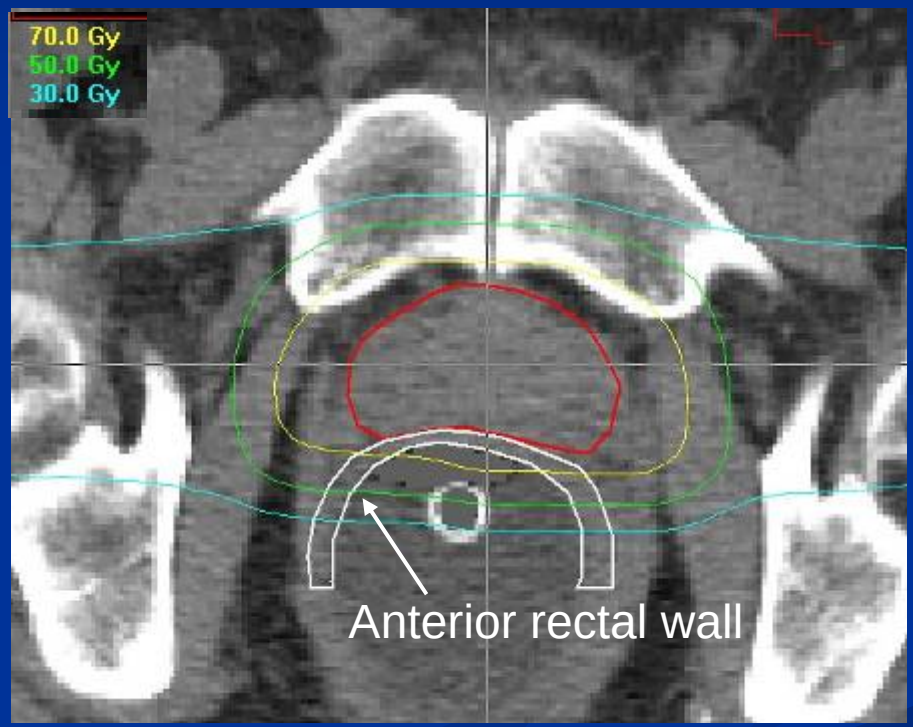
LLUMC analysis: part I

	No balloon	Balloon	mean Δ	*p*
Rectal volume	99.5	225	**125**	0.000
V70 (goal: <0.25)	8.71	6.53	**2.19**	0.000
V78 (goal: <0.05)	2.8	1.6	**1.18**	0.033
Max rectal dose	79.7	79.4	0.278	0.315

Total rectum, n=27, combo (CTV/GTV) plan

LLUMC analysis: part II

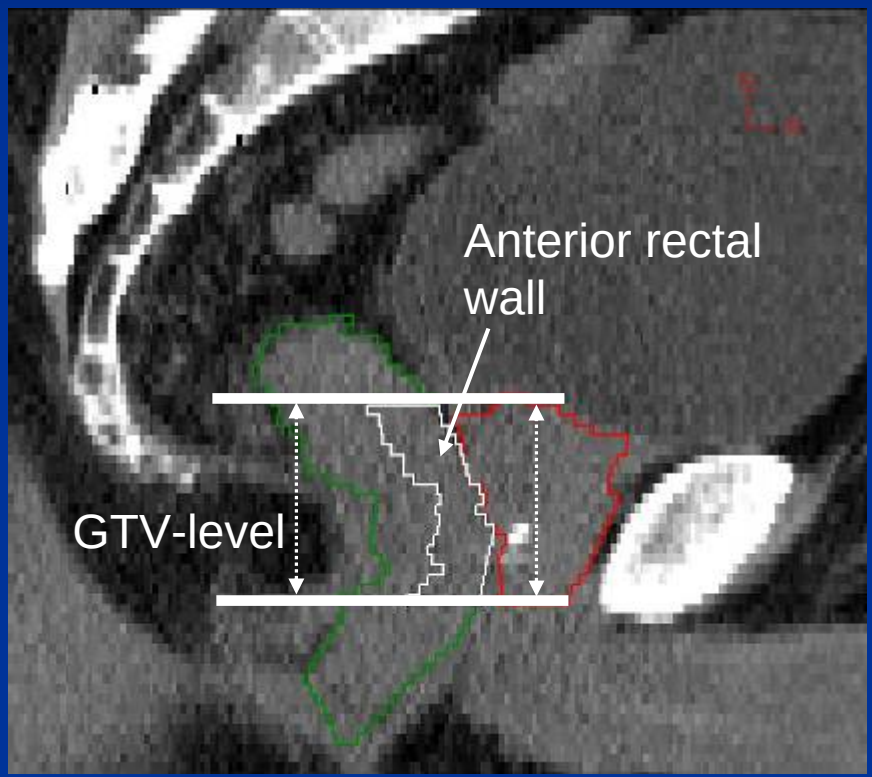


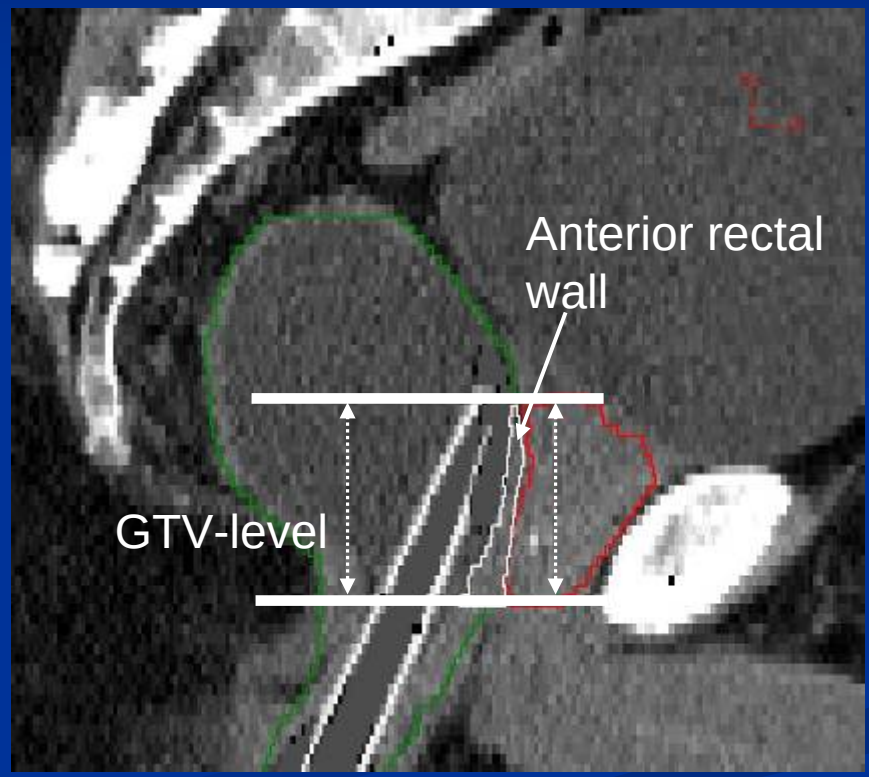


LLUMC analysis: part II

- Prostate gland only and adjacent anterior rectal wall (GTV-level anterior rectal wall) were contoured
- Treatment plans were designed using OptiRad:
  - GTV = 79.2 CGE @ 1.8 CGE/F/d
- Comparisons were made using **paired** Student's *t*-test

LLUMC analysis: part II





LLUMC analysis: part II

- Anterior wall (cc) > 70 CGE:

	mean(%)	*95% C.I.*	*std dev*
no balloon:	**3.72**	(3.11 - 4.33)	1.54
balloon:	**3.14**	(2.74 - 3.53)	1.00
mean difference = 0.58		(0.55 - 1.11)	1.33
(*p*=0.032)*	$t = 2.27$ (d.o.f.= 26)		

*Using Paired Student's *t*-test

LLUMC analysis: part II

- Anterior wall (cc) > 78 CGE:

	mean(%)	*95% C.I.*	*std dev*
no balloon:	**0.63**	(0.30 - 0.95)	0.83
balloon:	**0.79**	(0.46 - 1.11)	0.82
mean difference = -0.16		(-0.49 - 0.16)	0.82
	(*p*=0.32)*	t = -1.02 (d.o.f.= 26)	

*Using Paired Student's *t*-test

LLUMC analysis: part II

	No Balloon	Balloon	Mean Δ	*p*	relative improvement
V70 (goal: <0.25)	8.71	6.53	**2.19**	0.000	~25%
V78 (goal: <0.05)	2.8	1.6	**1.18**	0.033	~42%

Total rectum , n=27, combo (GTV/CTV) plan

cc Ant wall>70 CGE	3.72	3.14	**0.58**	0.032	~16%
cc Ant wall>78 CGE	0.63	0.79	**-0.16**	0.32	NS

GTV-level anterior rectal wall , n=27, GTV-only plan

Conclusions

- Rectal balloons effectively immobilize the prostate gland.
- V70 and V78 of whole rectum are reduced with use of the rectal balloon.
- Absolute volume of anterior rectal wall tissue receiving ≥ 70 CGE, but not 78 CGE, is reduced with use of the rectal balloon.

Thank you

Int. J. Radiation Oncology Biol. Phys., Vol. 50, No. 1, pp. 265–278, 2001

0360-3016/01/$–see front matter

ELSEVIER

PII S0360-3016(01)01453-5

CRITICAL REVIEW

ORGAN MOTION AND ITS MANAGEMENT

K. M. LANGEN, PH.D., AND D. T. L. JONES, PH.D.

National Accelerator Centre, Medical Radiation Group, Faure, South Africa

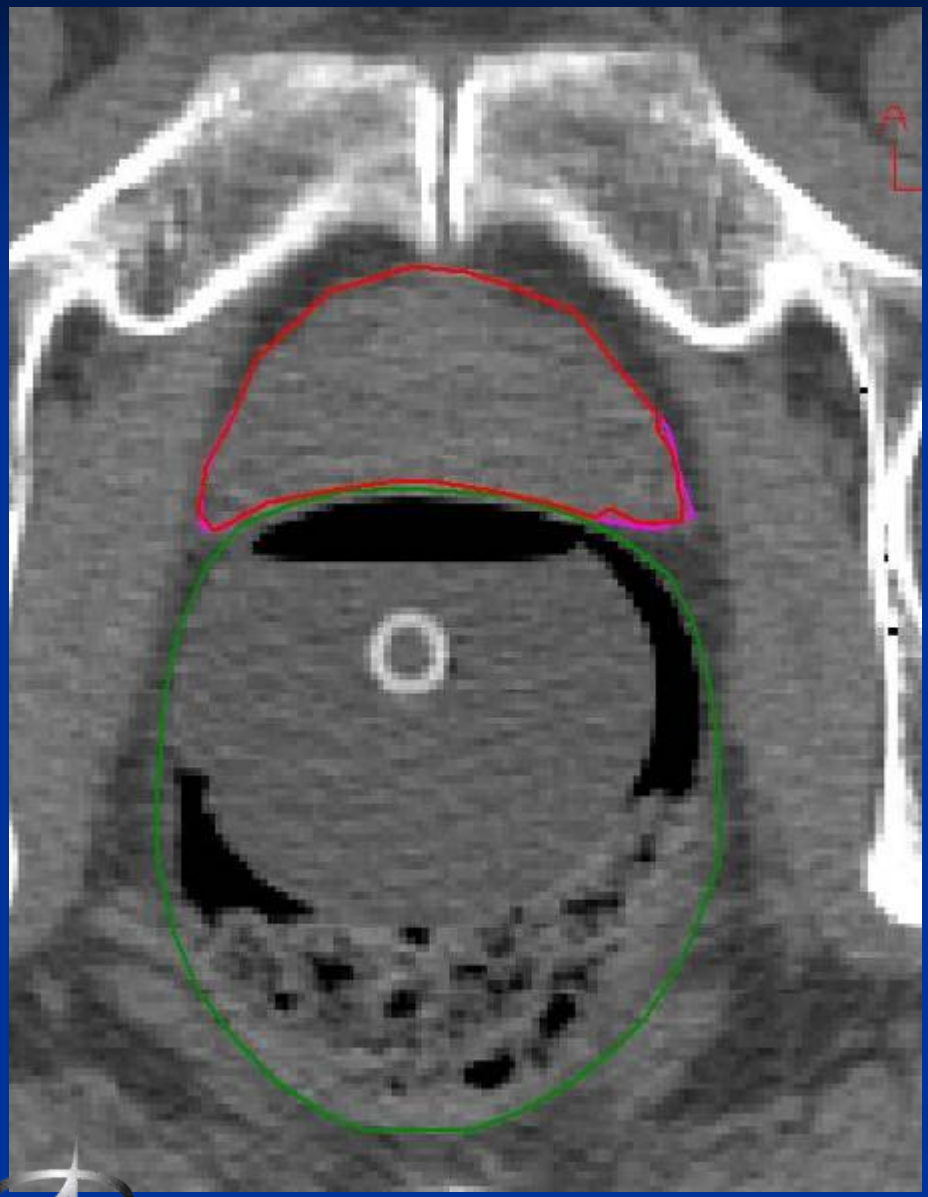
Table 1. Summary of prostate motion studies

Study first author (ref)	No. of patients	Comments	Displacement (mm)	Max. (mm)
Ten Haken (8)	50	+30–50 cm^3 of contrast in R	62% > 5	20
Schild (9)	18	60 → 180 cm^3 of contrast in R	17% > 5	17
	11	60 → 180 cm^3 of contrast in B	9% > 5	8
Balter (10)	10	ROM, full B, weekly portals, relative to a reference portal image	Max. exp. (p = 0.05) AP: 4.5 Lat: 1.7 SI: 3.7	 7.5 2 5
van Herk (11)	11	3–4 CT, biweekly, full B, displacement between 2 CT	AP: sd = 2.7 Lat: sd = 0.9 SI: sd = 1.7	
Roeske (12)	10	Weekly CT, full B, relative to init. CT	AP: mean = −0.4, SD = 3.9 Lat: mean = −0.6, SD = 0.7 SI: mean = −0.2, SD = 3.2	5.3 (mean) 6.3 (mean)
Crook (13)	55	Gold seeds, full B, init. and 2nd film before boost	Post: mean = 5.6, SD = 4.1 Inf: mean = 5.9, SD = 4.5	
Beard (14)	30	2 CT, 4 weeks apart, empty B	AP: 40% > 5 Inf: 7% > 5	Post: 13 Inf: 8

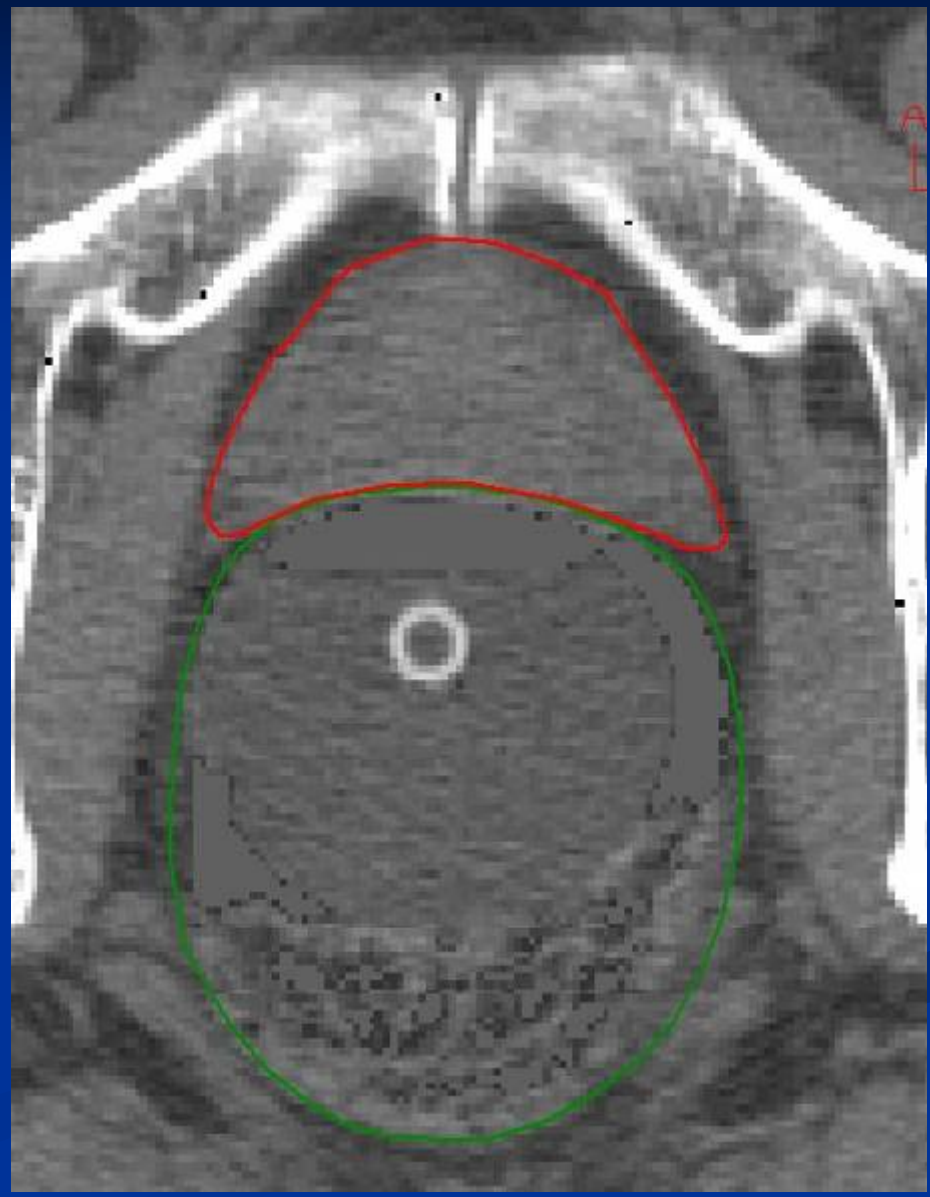
Study first author (ref)	No. of patients	Comments	Displacement (mm)	Max. (mm)
Althof (15)	9	^{125}I seed implants, 6 sets of X-rays, relative to first X-rays	AP: SD = 1.5 Lat: SD = 0.8 SI: SD = 1.7	7 3 4
Rudat (16)	28	Weekly CT, empty B and R, relative to mean position	AP: SD = 3.7 Lat: SD = 1.9	13 7
Melian (17)	13	4 CT scans, prone, relative to init. CT	AP: mean = −0.7, SD = 4.0 Lat: mean = 0.3, SD = 1.2 SI: mean = 0.4, SD = 3.1	
Roach (18)	10	Biweekly CT scans, full B, relative to first CT	Ant: 23%, post: 27% > 5 Lat: 0% > 5 Sup: 20%, inf: 3% > 5	14 4.5 8
Vigneault (19)	11	ROM, EPI over course of treatment relative to init. EPI	AP: mean = 0.5, SD = 3.5 Lat: mean = 0.3, SD = 1.9 SI: mean = 0.7, SD = 3.6	10.8 8.8 9.9
Tinger (20)	8	Weekly CT, full B, relative to init. CT	AP: mean = 0.5, SD = 2.6 Lat: mean = 0.0, SD = 0.9 SI: mean = 1.5, SD = 3.9	
Antolak (21)	17	4 CT, biweekly, full B, relative to init. CT	AP: SD = 3.6 Lat: SD = 0.7 SI: SD = 3.6	
Dawson (22)	6	Weekly CT, empty B, relative to init. CT		AP: 7.1 SI: 9.3
Stroom (23)	15	TPCT + 3 CT scans, supine	AP: SD = 2.8 SI: SD = 2.8	
Stroom (23)	15	TPCT + 3 CT scans, prone	AP: SD = 2.1 SI: SD = 1.7	
Zelefsky (25)	50	TPCT + 3 CT scans, empty B, prone, relative to TPCT	AP: mean = −1.2, SD = 2.9 Lat: mean = −0.6, SD = 0.8 SI: mean = −0.5, SD = 3.3	

Abbreviations: R = rectum; B = bladder; ROM = radio-opaque marker; Max. exp. = maximum expected; lat = lateral; SD = standard deviation; init. = initial, post = posterior; inf = inferior; ant = anterior; sup = superior; EPI = electronic portal imaging; TPCT = treatment planning CT.

LLUMC analysis:

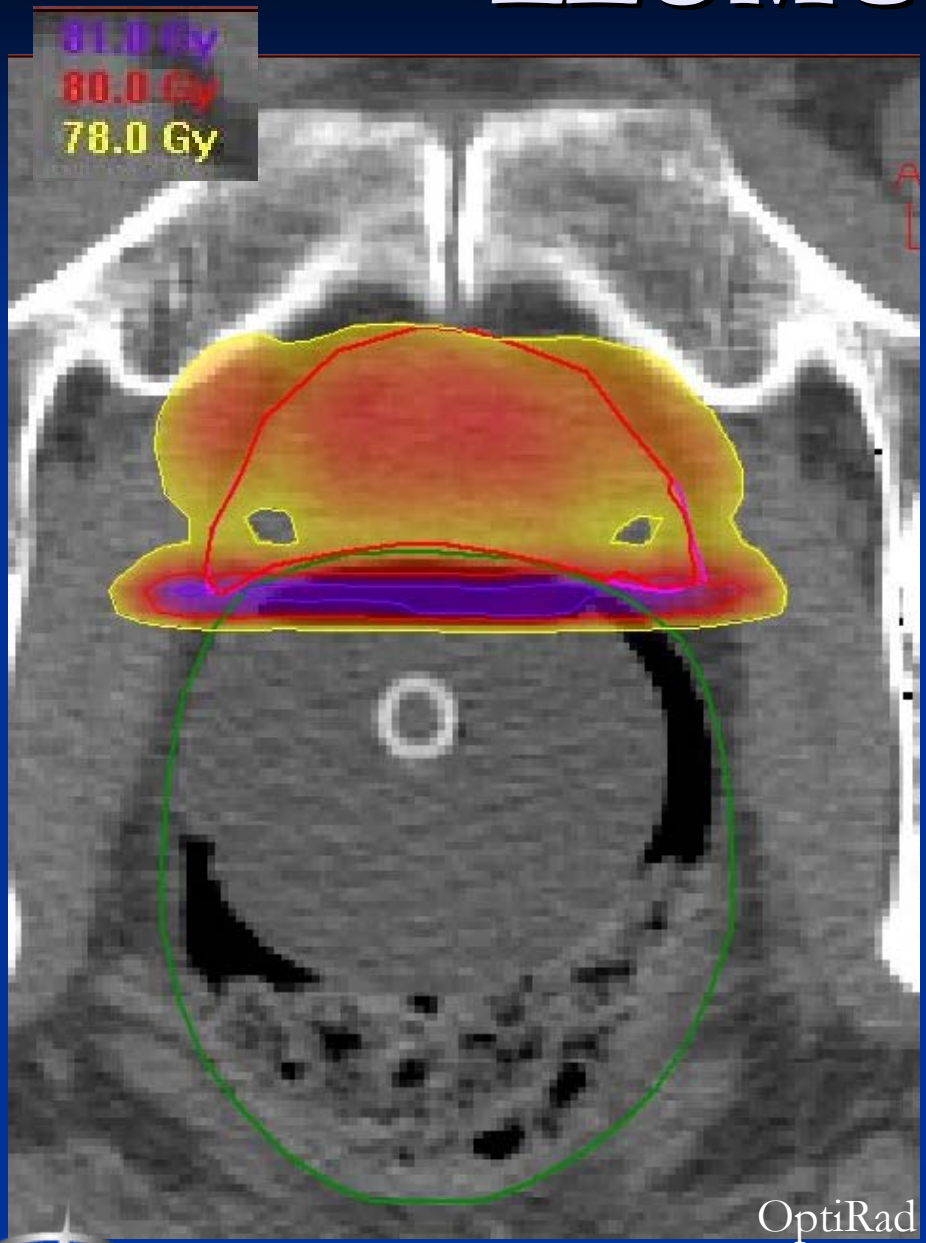


No density correction



Density correction

LLUMC analysis:



No density correction

Density correction

LLUMC analysis:

	No density correction	With density correction	mean Δ	*p*
V78	2.8	1.6	**1.22**	**0.000**
Max rectal dose	80.7	79.4	**1.28**	**0.000**

Total rectum, n=27, combo (CTV/GTV) plan, (+/-) balloon density correction