Target Delineation for Radiotherapy of Prostate Cancer

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Keys to Successful Treatment

- **Goal: high dose to prostate, spare surrounding normal tissue (ie, precision)**
- **Treatment Planning**
- **Treatment Delivery**
- **Buzz words: 3D Conformal, IMRT, IGRT**

Progression of Technology

Don't forget the past!!

1970-80s –

- **Treatment designed using Xrays and lead blocks**
- **Poor soft tissue delineation**
- **RT doses in range of 60Gy**

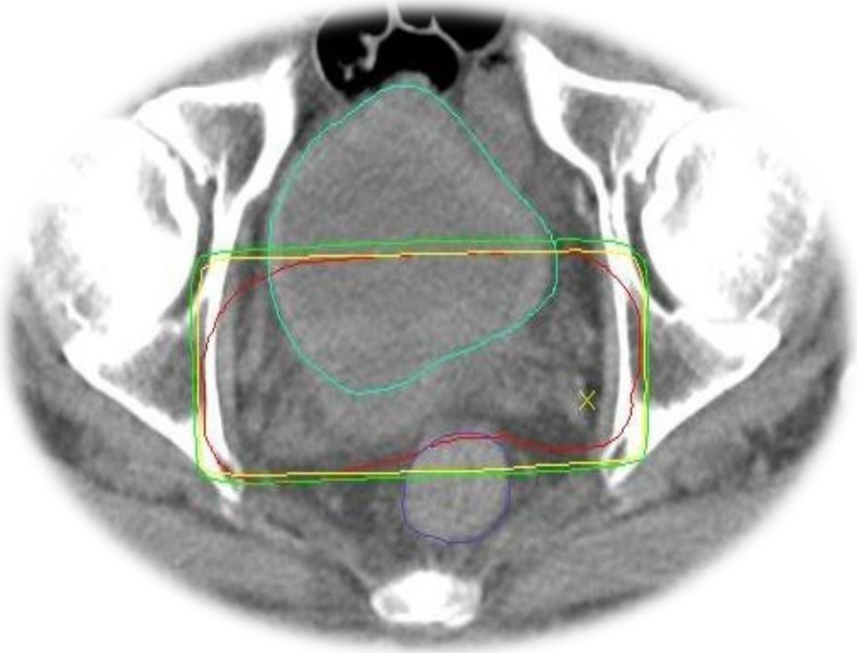
1980-90s –

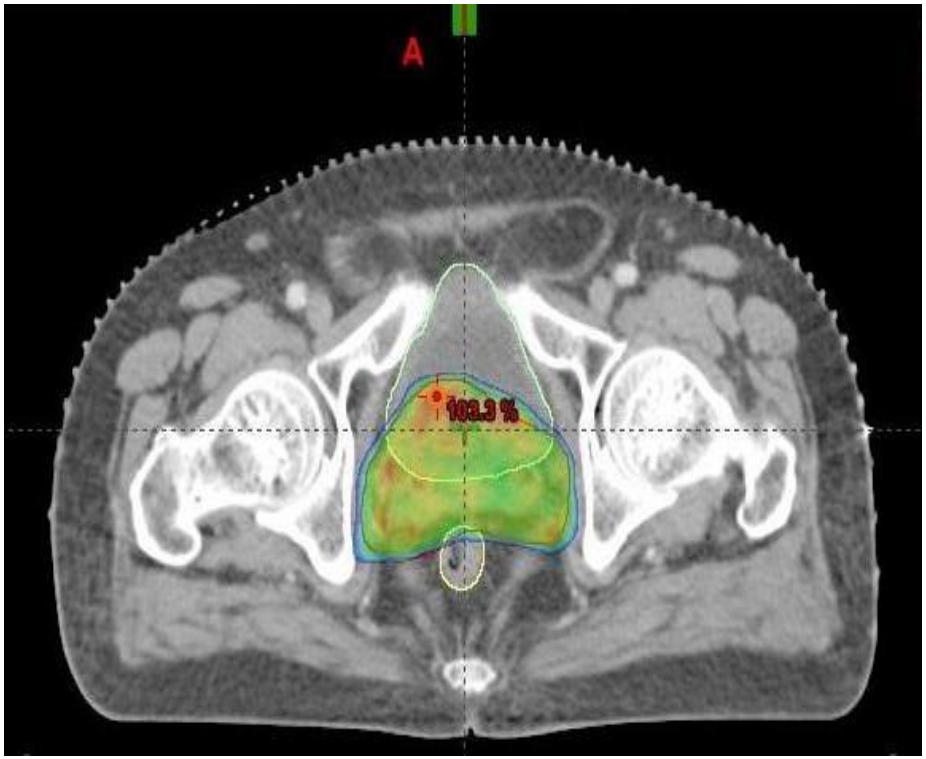
- **CT based treatment planning**
- **Outlining prostate, SV, rectum, bladder, femoral head**
- **RT doses around 70Gy**

21st Century – IMRT

- **New way of delivering photons**
- **Allowed increase of dose in 76-81Gy range**

Why IMRT??





3DCRT

IMRT

Why IMRT??

Safety – IMRT allows us to….

- **Decrease bowel toxicity and sexual dysfunction** *(Namiki 2006)*
- **Decrease bowel toxicity** *(Sanguineti 2006)*
- **Reduce bowel treated to high dose in WPRT** *(Ashman 2005)*
- **Spare penile structures and potentially reduce sexual dysfunction** *(Kao 2004)*

Efficacy –

- **Dose escalation leads to better PSA relapse free survival**

Zietman et al, JAMA 2005, Peeters et al, JCO 2006

What have we learned?

IMRT can deliver higher doses in prostate cancer safely

Higher dose demonstrates better control rates

IMRT in Prostate Cancer

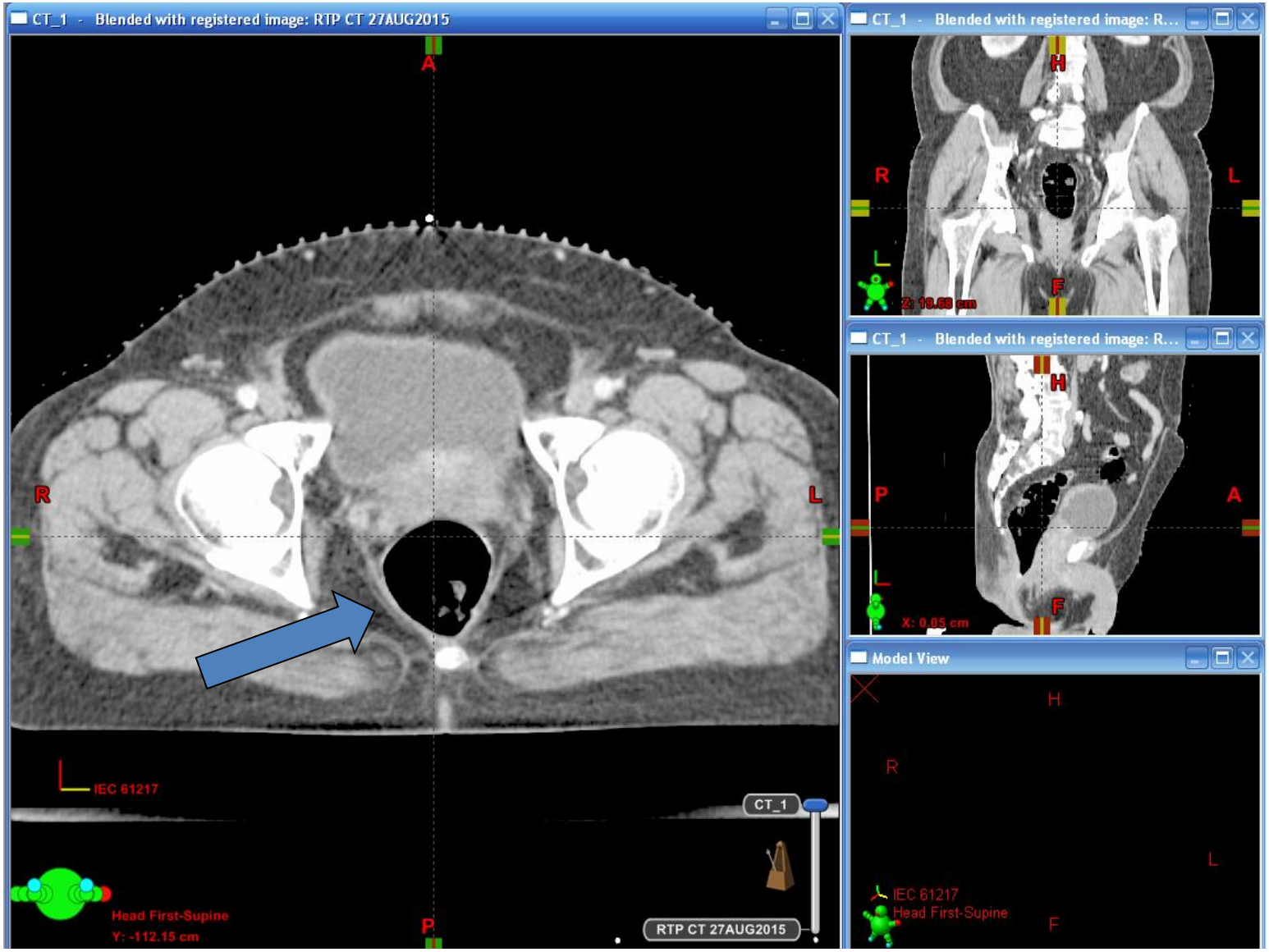
Things to consider..

- **Planning**
- **Verification**
- **Delivery**
- **Clinical Aspects**
- **Radiobiological Aspects**

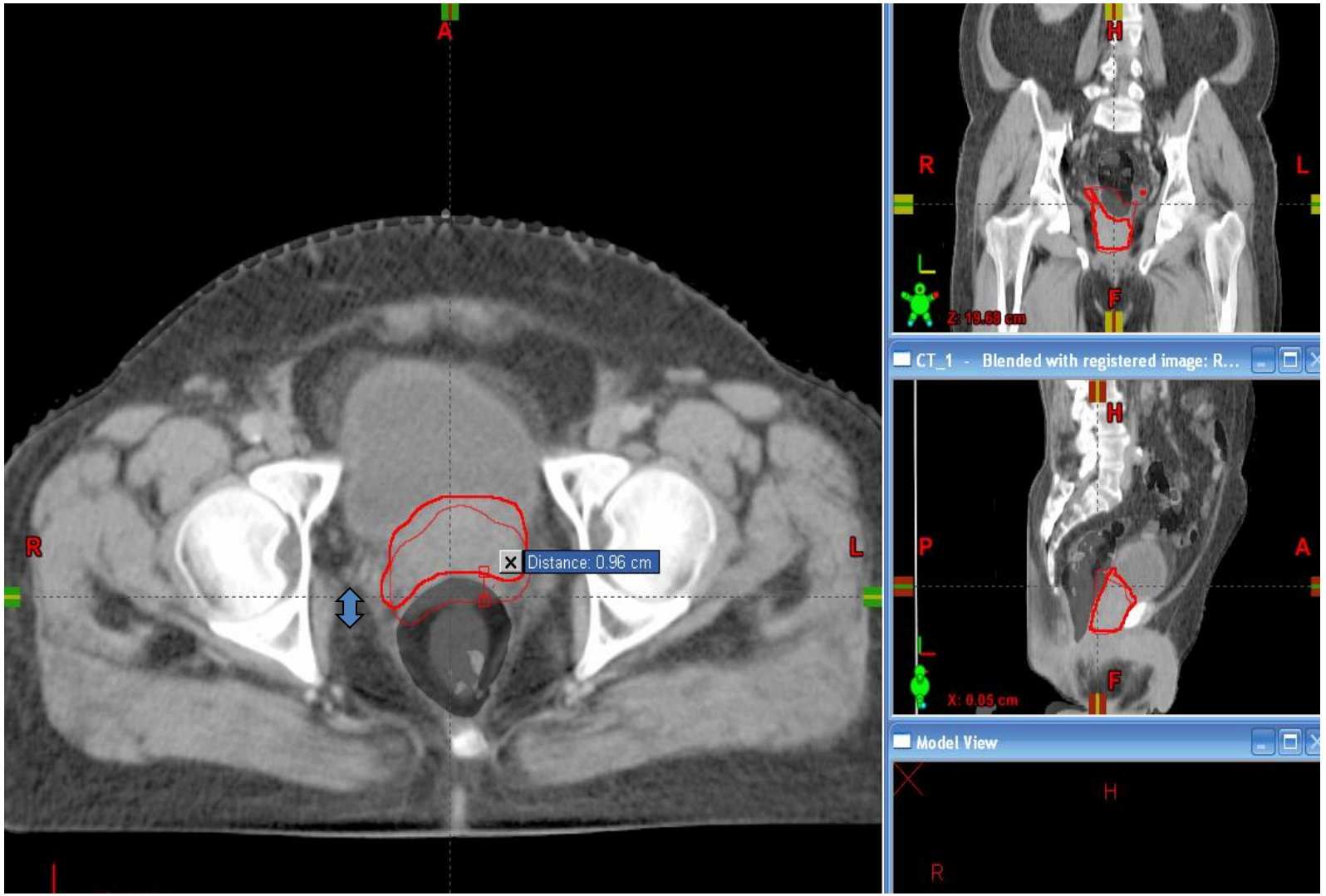
Patient Set-up:

Most vital but often the most neglected part of beam direction..

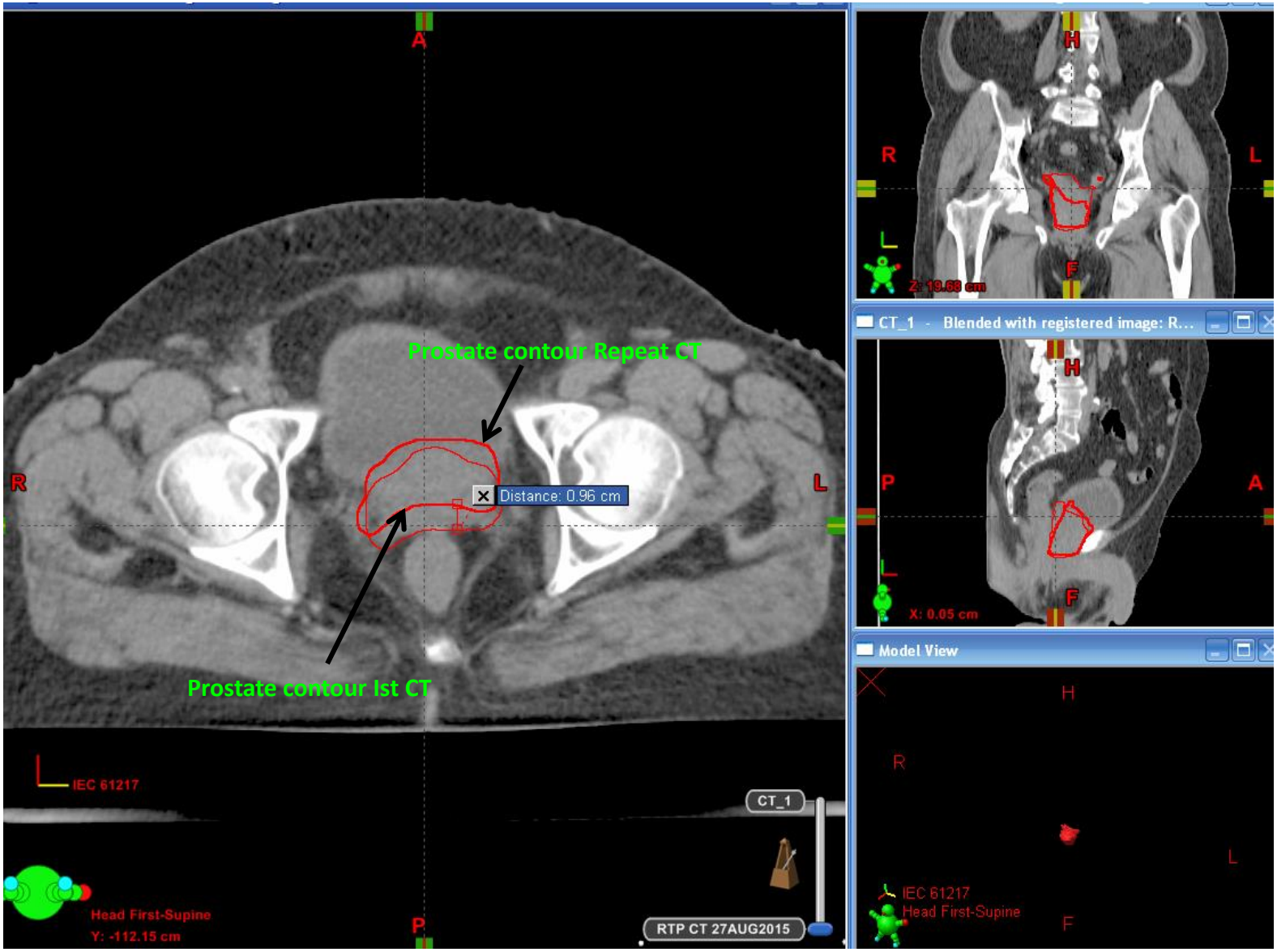
- **Supine position, hands on chest**
- **Laxatives a night before CT simulation (rectum as empty as possible)**
- **Void urine and drink 250-500ml water, starting 30mins before CT sim (reproducibility)**
- **CT –**
  3mm slice thickness
  From L4/5 to 3cm below ischial tuberosity
  No rectal contrast
- **CEMRI Prostate -**

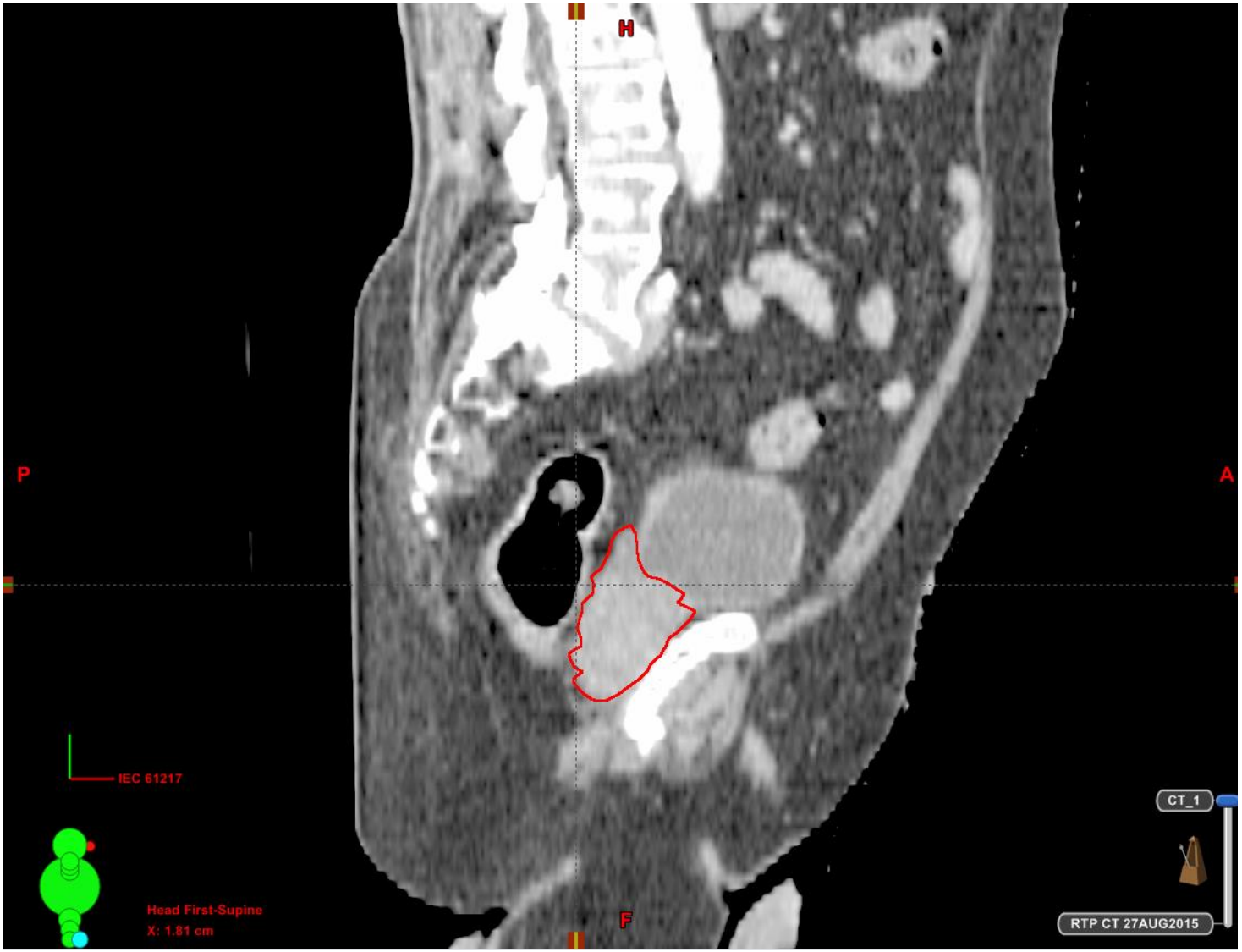


Distended Rectum at Simulation

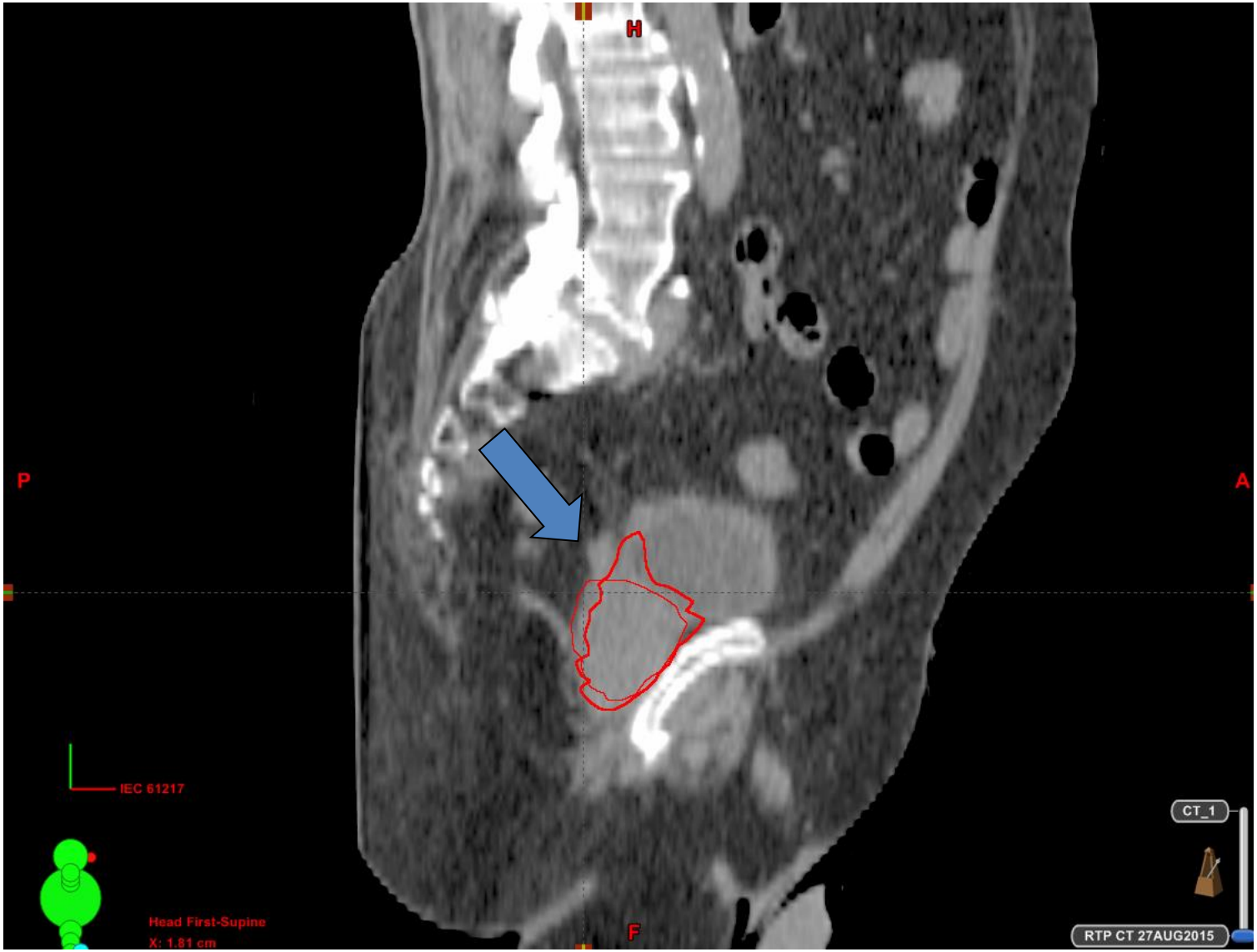


Superimposed Scans post Rectal Emptying


A
R
L
P
Prostate contour Repeat CT
Distance: 0.96 cm
Prostate contour Ist CT
IEC 61217
Head First-Supine
Y: -112.15 cm
CT_1
RTP CT 27AUG2015
H
F
Z: 19.68 cm
CT_1 - Blended with registered image: R...
X: 0.05 cm
Model View
IEC 61217
Head First-Supine



Sagittal view, Distended Rectum



Seminal Vesicles off contour

Structure delineation in Prostate Radiotherapy

The Tricks..

- **Identifying prostate apex and its relevance**
- **Anterior Fibromuscular Stroma (AFS) at mid prostate level**
- **Contouring errors at prostate base**
- **SV as target – When and How much??**

Delineation of Prostate Apex

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 63, No. 2, pp. 479–491, 2005

0360-3016/05/$–see front matter

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CLINICAL INVESTIGATION **Prostate**

FUNCTIONAL ANATOMY OF THE PROSTATE: IMPLICATIONS FOR TREATMENT PLANNING

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McLaughlin PW, IJROBP 2005, 63(2): 479-91

Erection functional anatomy: IPA, NVB, and CC

The IPA originates from the internal iliac and passes through the pudendal canal. It supplies three main arteries of the penis: the bulbo-urethral artery, the cavernous or deep artery, and the dorsal artery. These branch as the IPA passes through the GUD (25–27). The deep artery of the penis

Corpus cavernosum

The erection expansile tissue is the corpus cavernosum. The base of the CC is surrounded by the ischiocavernosus muscle and relaxation of this muscle in concert with IPA dilation results in rapid filling of the CC. Because of the unique venous anatomy, the filling of the CC compresses the veins, limiting efflux. Erectile dysfunction can result from arterial insufficiency (e.g., IPA-occlusive disease is the most common cause of impotence), venous leak, or nerve dysfunction. The CC is visible on CT lateral to the penile bulb, but is more clearly defined by T2 MRI, where the

Clinical implications of erectile functional anatomy

In this review, sexual function has been divided into erectile function and ejaculatory function. Disruption of the complex vascular physiology through small and large vessel damage is thought to be the principal cause of erectile dysfunction after radiation (63). Both the IPA and the CC are separable from the prostate, in some patients by more than 2 cm, and careful definition of the prostate apex may allow complete sparing of the CC and IPA in some patients (64). However, controversy remains about the mechanism of erectile dysfunction and the potential role of nerve damage in addition to vascular damage.

The penile bulb is adjacent to the erectile structures and has been correlated with erectile dysfunction (65, 66). This

involved in erectile function. The positive studies correlating penile bulb dose and erectile dysfunction may be attributed to the proximity of the penile bulb to the CC/IPA connection. Thus the penile bulb dose may be a surrogate for the CC/IPA dose (67, 68).

Although vascular effects have been considered the most common cause of erectile dysfunction after radiation therapy, the penile bulb correlation studies may also reflect dose to the terminal cavernosal nerve (65, 66). The terminal branch of the NVB, the cavernosal nerve, courses through the GUD next to the urethra and terminates in the CC very close to the base of the penile bulb. This leaves open the question of whether nerve disruption at or near the terminal branch of the cavernosal nerve (penile bulb region) is, in part, responsible for erectile dysfunction after radiation therapy. Although sparing of the NVB adjacent to the prostate is not technically feasible or advisable with current setup error, sparing of dose to the terminal branches of the cavernosal nerves is possible when the prostate apex is accurately defined. Dose limitation to the penile bulb and corpus

McLaughlin PW, IJROBP 2005, 63(2): 479-91

Axial T2 MRI

Level: Penile Bulb

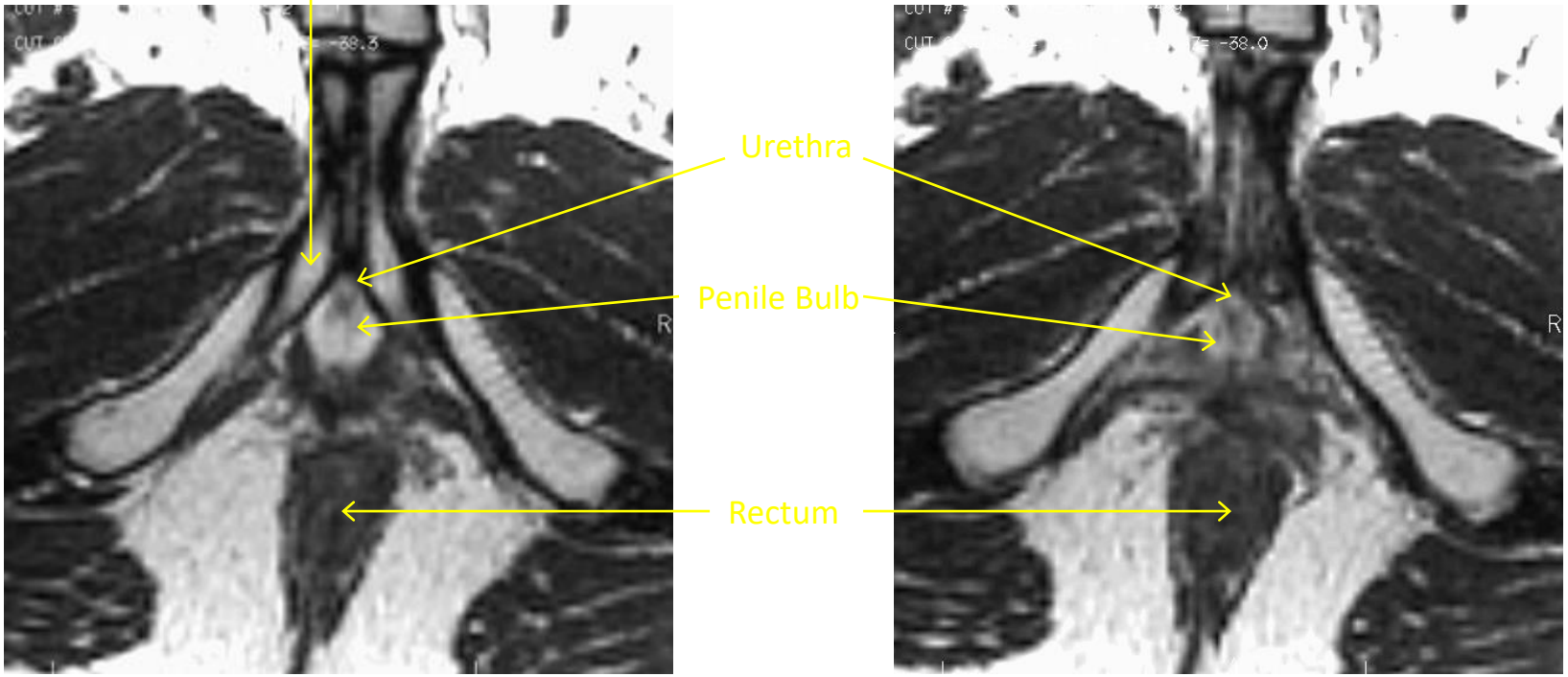


Image 1

Image 2

Axial T2 MRI

Level: Penile Bulb/ GUD transition

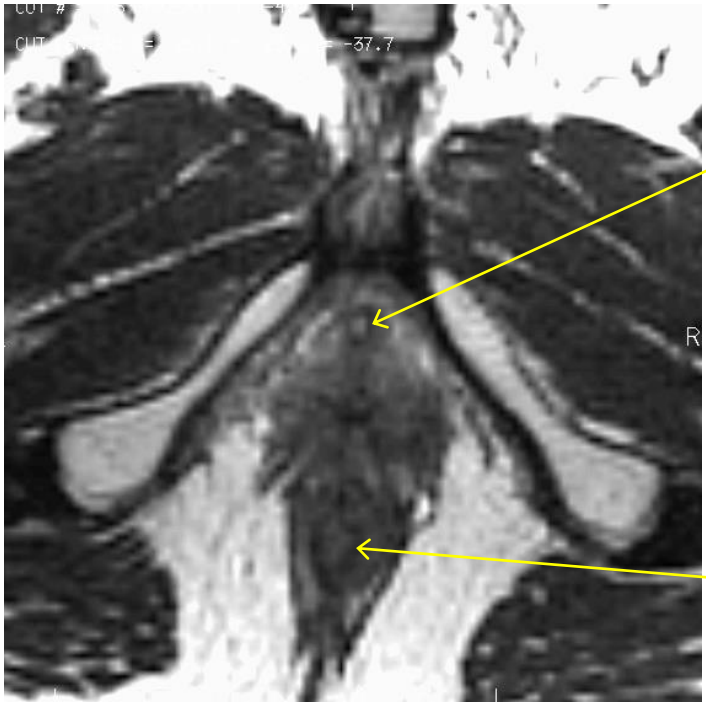


Image 3

Urethra

Rectum

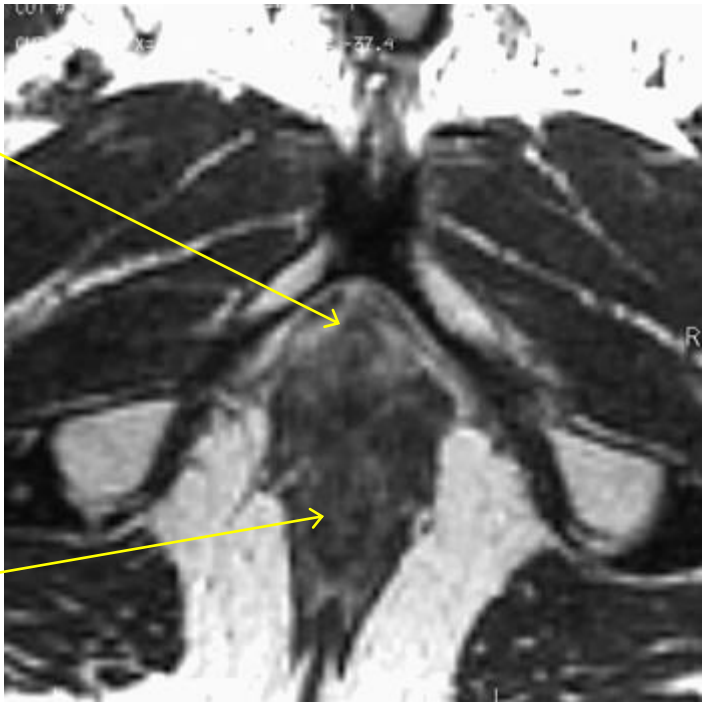


Image 4

Note the penile bulb ends and the GU Diaphragm (GUD) begins.

Axial T2 MRI

Level: GUD

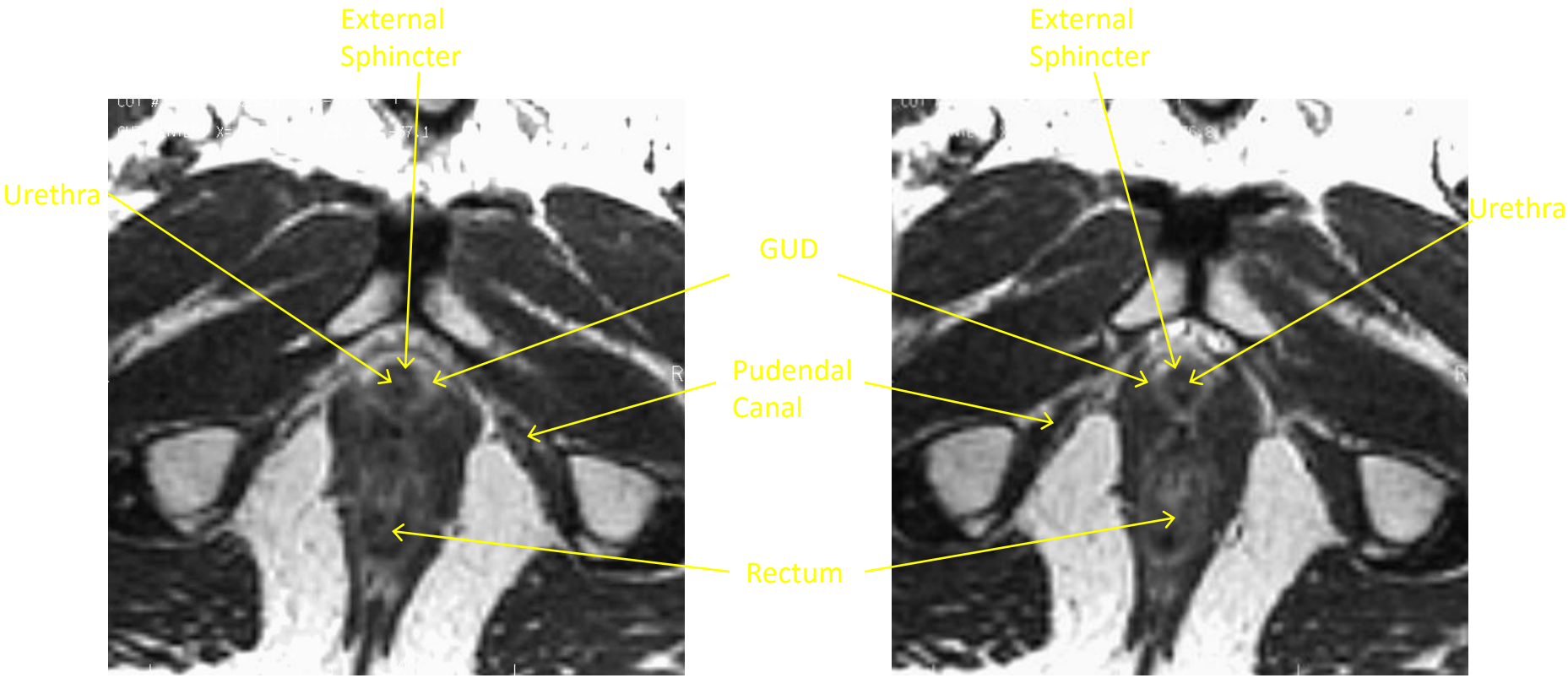


Image 5

Image 6

Note the thickness of the External Sphincter muscle. The circular shape of the GUD suggests prostate but this is still 1 cm below the prostate. Also note the Pudendal Canal is clear near the GUD level.

Axial T2 MRI

Level : GUD

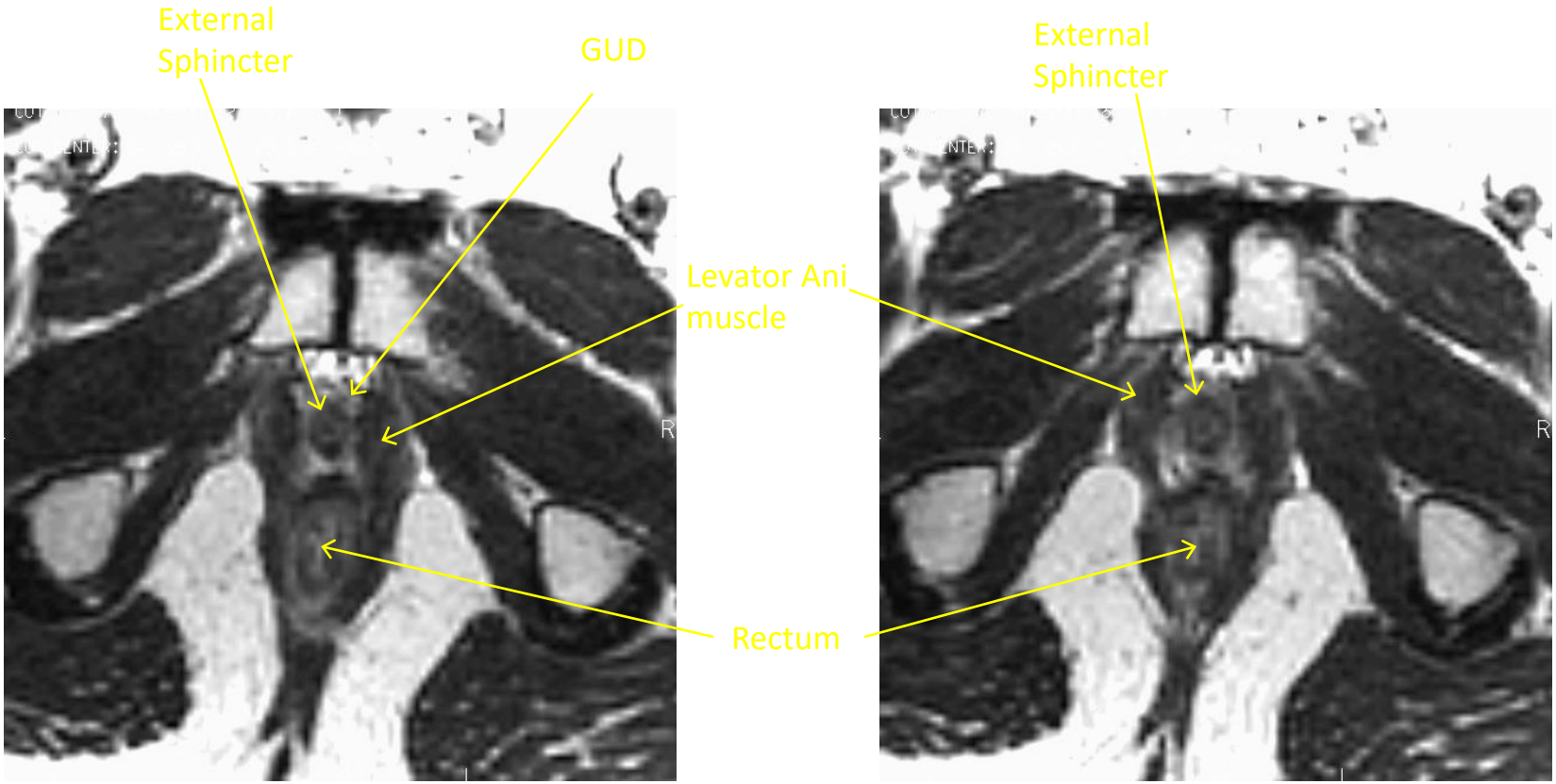


Image 7

Image 8

Note the convex shape of the Levator Ani at the upper GUD (Image 7). On image 8 the concave shape of the Levator Ani marks the transition to the prostate apex.

Axial T2 MRI

Level: Prostate Apex

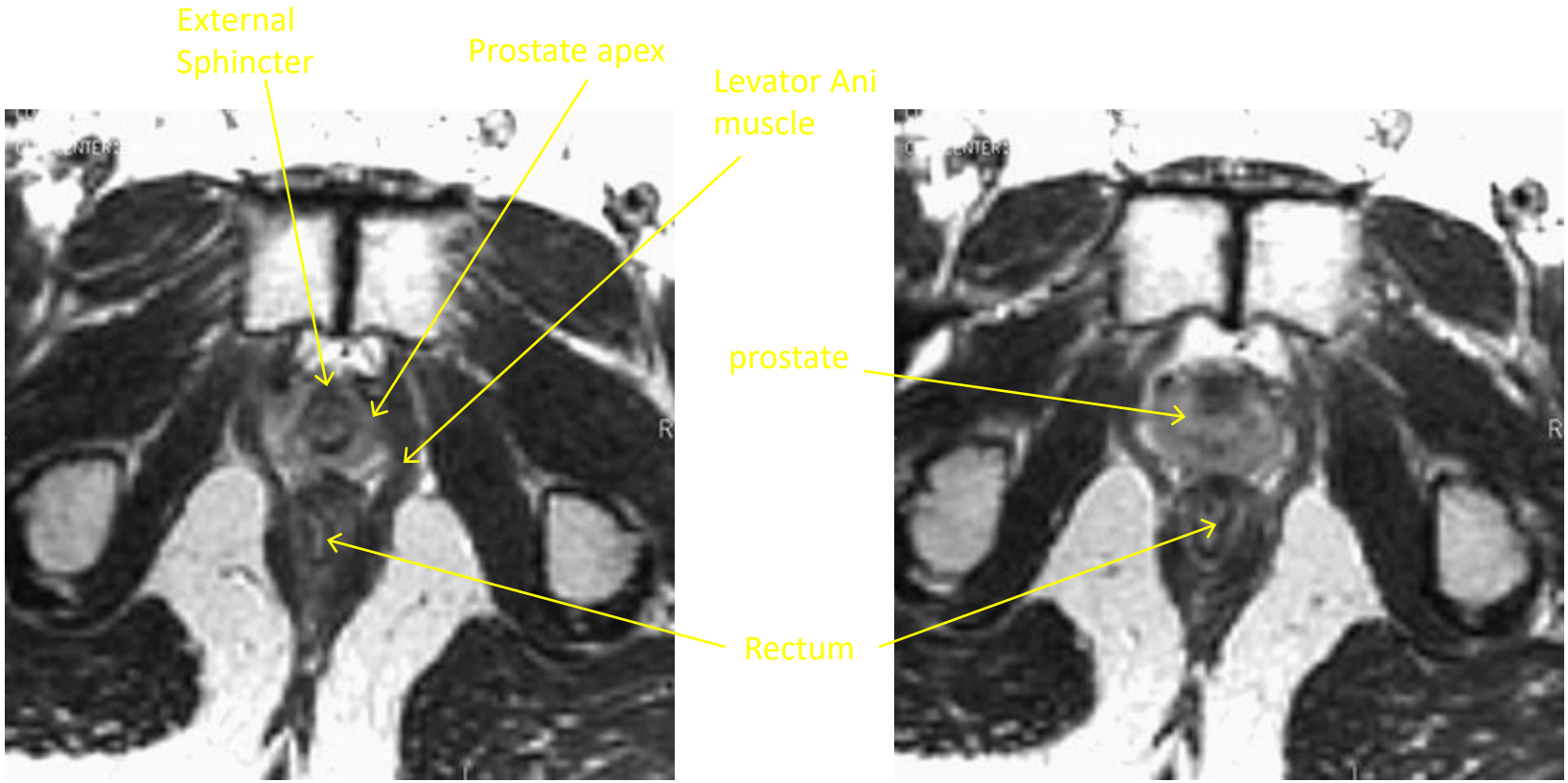


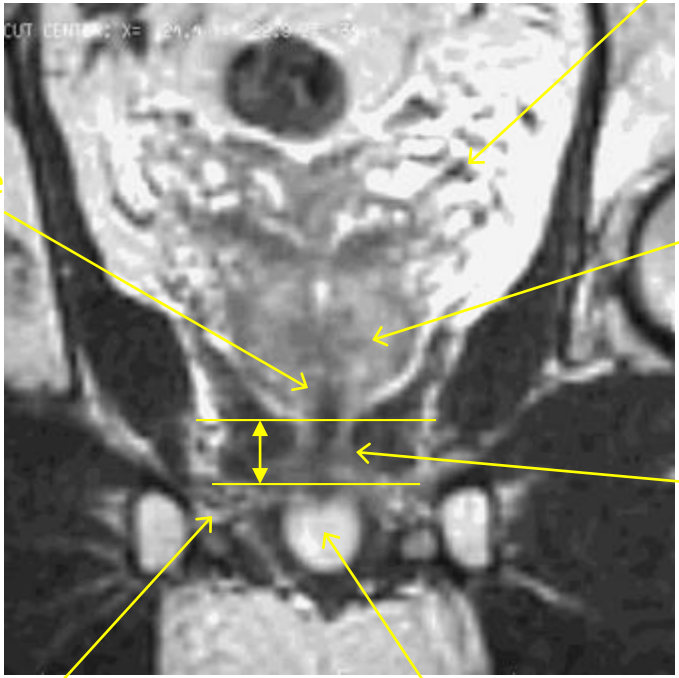
Image 9

Image 10

Note the external sphincter commonly extends into the prostate apex.

Coronal T2 MRI

Level: Mid-Prostate



Seminal vesicles

Prostate apex

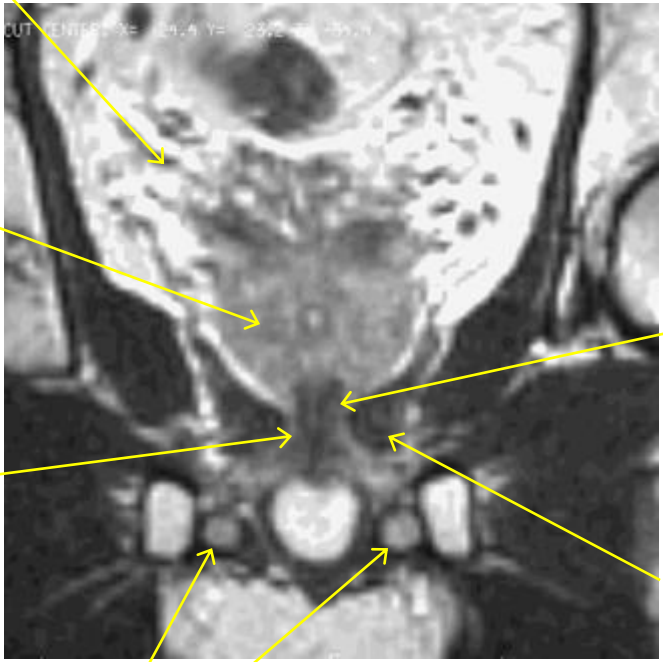
prostate

GUD

Pudendal Canal

Penile Bulb

Image 1



External Sphincter

Levator Ani muscle

Crura of Corpus Cavernosa

Image 2

The distance ↕ between the prostate apex and the penile bulb is visible on the coronal images. Also note, the external sphincter extends through the GUD and into the prostate.

Sagittal T2 MRI

Level: Mid-Prostate

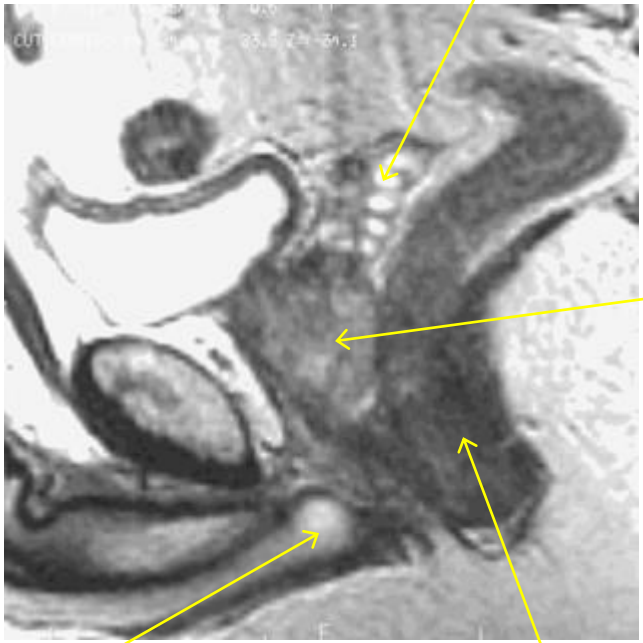


Image 3

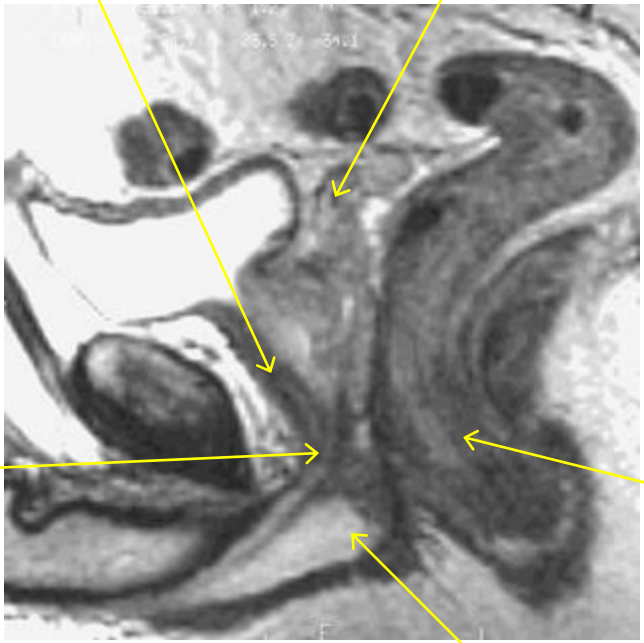
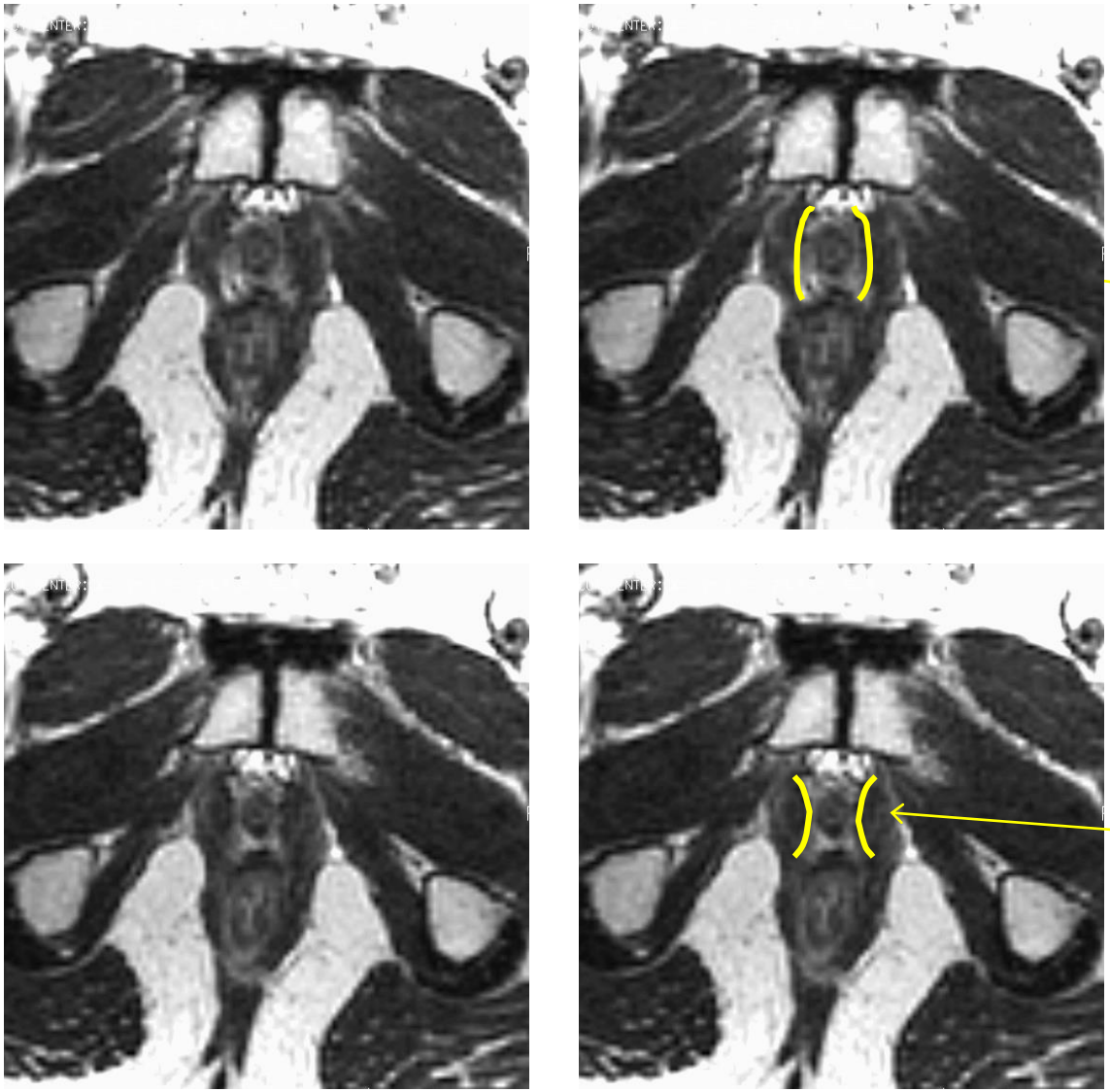


Image 4

Note the urethra is visible through the center of the prostate in image 4. Also, the definition of the apex is less distinct on sagittal than on coronal. Sagittal views often clarify the prostate base/ seminal vesicle region.

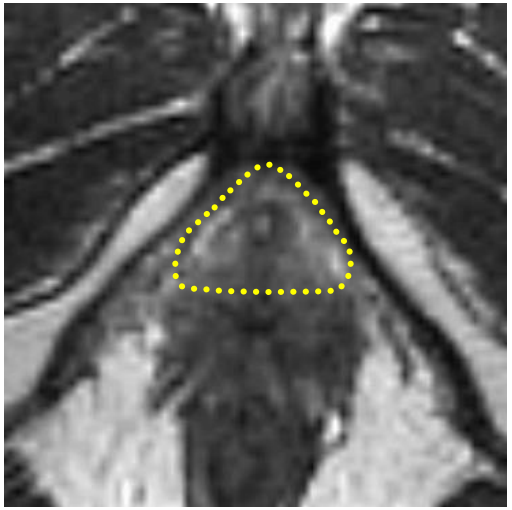
MRI Apex to GUD Transition



Note the transition from concave levator ani
at the apex versus convex just below the apex.

Summary of GUD Shape

Image 1.
just above
penile bulb



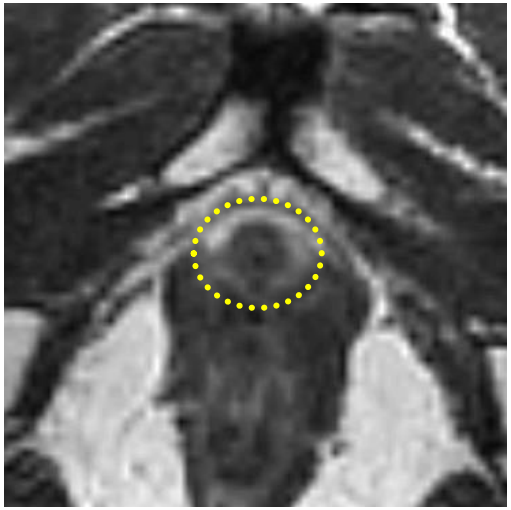
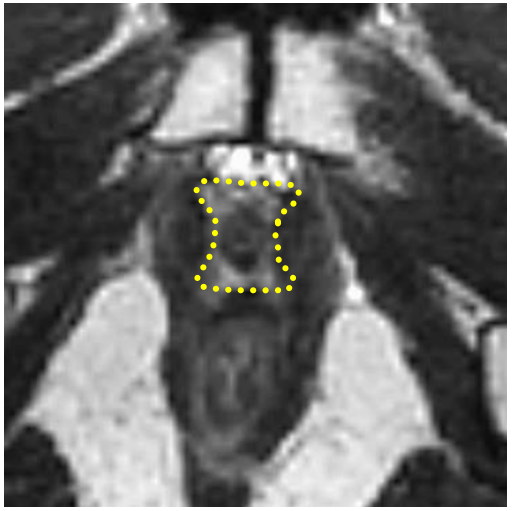


Image 2

Image 3



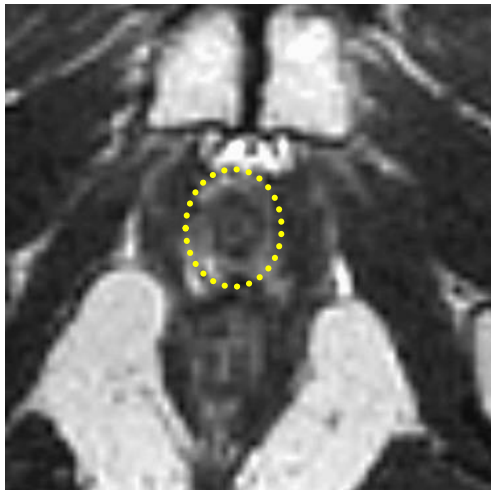
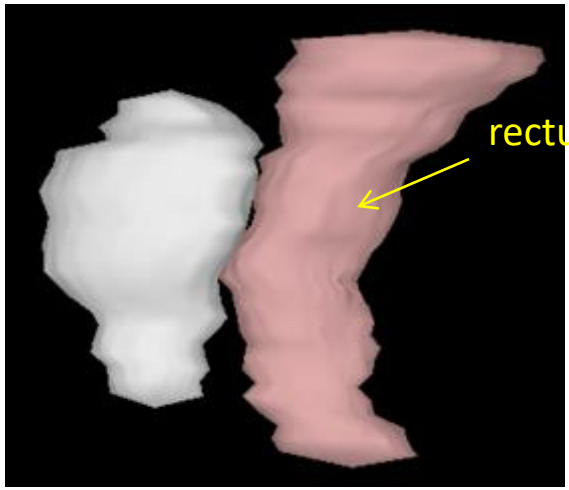


Image 4. apex

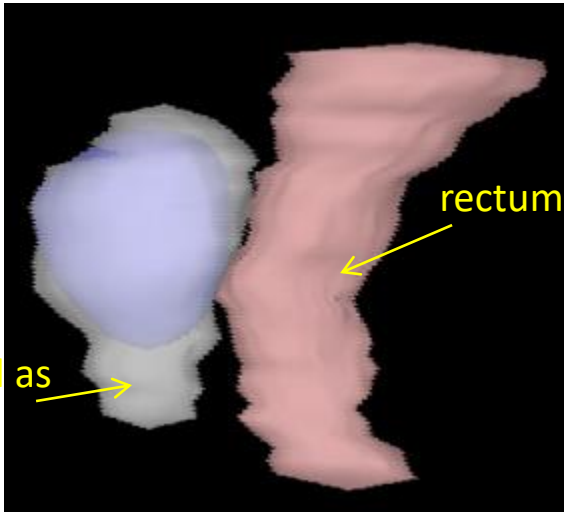
Note the change in shape of the GUD: just above the penile bulb it is triangular in shape, near the mid-diaphragm it is circular, then hourglass shaped. These shapes are often visible in subtle form on CT.

3 D View- contouring GUD as prostate



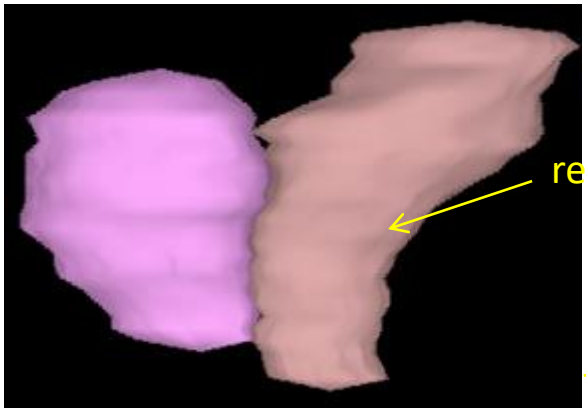
3D view of Prostate contoured on CT to include round GUD and external sphincter often mistaken for prostate.

GUD contoured as prostate

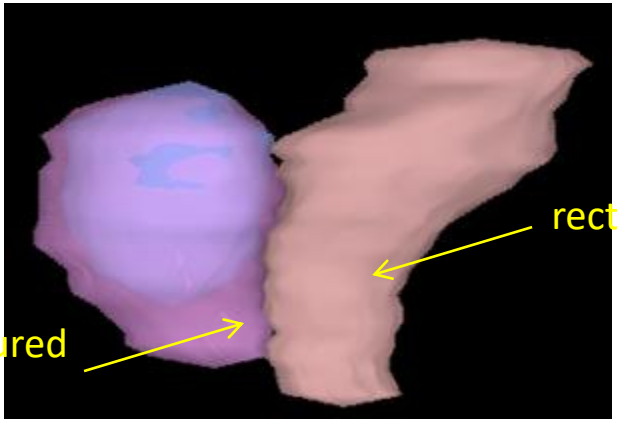


The same figure with the MRI prostate shown in light blue.

3 D View- contouring prostate with rectum as reference



3D view of Prostate contoured to the edge of the rectum on CT



The same figure with the MRI prostate shown in light blue

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0360-3016/10/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2009.02.019

CLINICAL INVESTIGATION **Prostate**

RADIOGRAPHIC AND ANATOMIC BASIS FOR PROSTATE CONTOURING ERRORS AND METHODS TO IMPROVE PROSTATE CONTOURING ACCURACY

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Contouring errors at apex, mid & base

Seminal Vesicles Inclusion in Prostate Radiotherapy

Incidence of SVI is decreasing in PSA era

Expansion of CTV in post-lat direction with inclusion of SV

Higher rectal dose and risk of acute and late toxicities

Predicting risk of SV involvement

- **Partins Nomograms, Roach Equation**

Partin AW, Urology 2001, Roach M3rd, J Urol 1993

- **Risk Stratification**

		Risk of SVI (%)	
Authors	**No. of pts**	**Low Risk Group**	**Intermediate Risk Group**
Katcher et al	368	8	22
D'Amico et al	749	2	17
Pisansky TM et al	2959	<10	-
Zlotta Ar et al	1283	<5	-
Kestin L et al	344	1	15
Schultz et al	5079	4	13

Proportion of SV in CTV?

Int. J. Radiation Oncology Biol. Phys., Vol. 54, No. 3, pp. 686–697, 2002

0360-3016/02/$–see front matter

PII S0360-3016(02)03011-0

CLINICAL INVESTIGATION **Prostate**

TREATMENT OF PROSTATE CANCER WITH RADIOTHERAPY: SHOULD THE ENTIRE SEMINAL VESICLES BE INCLUDED IN THE CLINICAL TARGET VOLUME?

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Purpose: When treating high-risk prostate cancer with radiation therapy, inclusion of the seminal vesicles (SVs) within the clinical target volume (CTV) can dramatically increase the volume of radiated normal tissues and hinder dose escalation. Because cancer may involve only the proximal portion of the frequently lengthy SVs, we performed a complete pathology review of prostatectomy specimens to determine the appropriate length of SV to include within the CTV when SV treatment is indicated.

Methods and Materials: A detailed pathologic analysis was performed for 344 radical prostatectomy specimens (1987–2000). All slides from each case were reviewed by a single pathologist (N.S.G.). Factors recorded for each case included length of each SV (cm), length of cancer involvement in each SV (cm) measured from the prostate-SV junction, and percentage of SV length involved.

Results: Fifty-one patients (15%) demonstrated SV involvement in 81 SVs (21 unilateral, 30 bilateral SV involvement). The median SV length was 3.5 cm (range: 0.7–8.5 cm). Factors associated with SV involvement included the pretreatment PSA level, biopsy Gleason score, and clinical T classification. The commonly used risk group stratification was very effective at predicting SV positivity. Only 1% of low-risk patients (PSA <10 ng/mL, Gleason ≤6, and clinical stage ≤T2a) demonstrated SV involvement vs. 27% of high-risk patients. Patients with only one high-risk feature still demonstrated a 15% risk of SV involvement, whereas 58% of patients with all three high-risk features had positive SVs. The median length of SV involvement was 1.0 cm (90th percentile: 2.0 cm, range: 0.2–3.8 cm). A median of 25% of each SV was involved with adenocarcinoma (90th percentile: 54%, range: 4%–75%). For the 81 positive SVs, no factor was associated with a greater length or percentage of SV involvement. In the entire population, 7% had SV involvement beyond 1.0 cm. There was an approximate 1% risk of SV involvement beyond 2.0 cm or 60% of the SV. In addition, this risk was less than 4% for all subgroups, including high-risk patients.

Conclusions: A portion of the SV should be included in the CTV only for higher-risk patients (PSA ≥10 ng/mL, biopsy Gleason ≥7, or clinical T stage ≥T2b). When treating the SV for prostate cancer, only the proximal 2.0–2.5 cm (approximately 60%) of the SV should be included within the CTV.

Clinical Oncology (2007) **19**: 302–307
doi:10.1016/j.clon.2007.03.005

Overview

When Should the Seminal Vesicles be Included in the Target Volume in Prostate Radiotherapy?

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Conclusions

We recommend excluding the seminal vesicles from the CTV in patients with prostate cancer treated with definitive radiotherapy who have a pre-treatment PSA $\leq$ 10 ng/ml, a biopsy Gleason score of 6 or less, stage $\leq$ T2a, and a percentage of positive biopsy $\leq$ 50%. The risk of SVI in this group of patients is $\leq$ 5%. Most of the evidence suggests that

patients with $\leq$ T2b disease and use a cut-off of 15% to decide the need for seminal vesicle irradiation. Patients with T3 disease should have the seminal vesicles included.

Although the best evidence suggests that only the proximal half needs to be treated, the evidence is contradictory, so we cannot make firm recommendations regarding the length of the seminal vesicles to treat. It seems reasonable to avoid treating the entire seminal vesicles to the tips at the

Seminal Vesicles Inclusion in Prostate Radiotherapy

- **No consensus on extent as well as dose to SV**
- **Proximal 2cm of SV to be included if risk of SVI>15%**
- **Dose – 60Gy – 78Gy (? Volume reduction)**

Take Home Message

- **IMRT is the *de facto* standard of care in prostate radiotherapy**
- **Image guidance imperative to ensure accurate and safe delivery of radiation**
- **Learning curve involved in structure delineation, treatment verification procedures**