

## IMRT for Prostate Cancer



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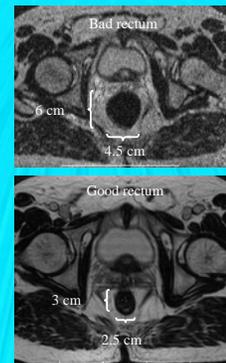
## Routine Use (“Old School”)

All patients are simulated in the supine position. Reproducibility is achieved using a custom alpha cradle cast that extends from the mid-back to mid-thigh. The feet are positioned in a custom plexiglas foot-holder. The patient is told to have a 1/2- 3/4 full bladder because during treatment a full bladder is difficult to maintain.



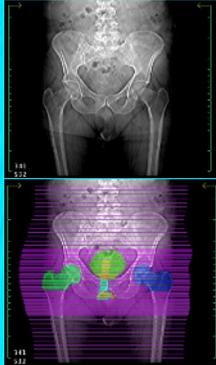
## Simulation (Positioning and Immobilization )

- The patient is asked to **empty the rectum** using an enema prior to simulation. Also, a low residue diet the night before simulation is recommended to reduce gas. If at simulation the rectum is **>3 cm in diameter** due to gas or stool, the patient is asked to try to expel the rectal contents.



### CT Scans

- Scans are acquired from approximately 2 cm above the top of the iliac crest to approximately mid-femur. This scan length will facilitate the use of non-coplanar beams when necessary.
- Scans in the region beginning 2 cm above the femoral heads to the bottom of the ischial tuberosities are acquired using a 2.5 mm slice thickness and 2.5 mm table increment (Beacon patients: 1.25mm). All other regions may be scanned to result in a 1 cm slice thickness.



### MR Scans

1.5 T, GE Medical Systems

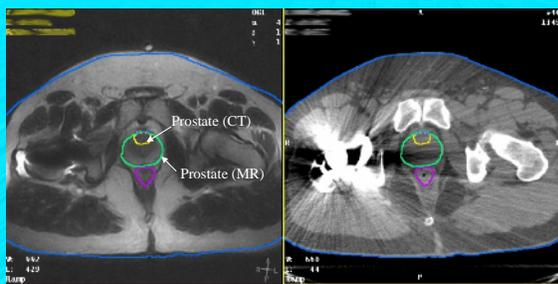
- All prostate patients also undergo MR imaging within the department, typically within one half hour before or after the CT scan. Scans are obtained **without** contrast media. (Calypso patients undergo MR prior to beacon placement; CT is ~ 7-10 days later)
- The MR data set is fused to the CT data set and used for treatment planning.



•Retrograde urethrograms are **not** performed.

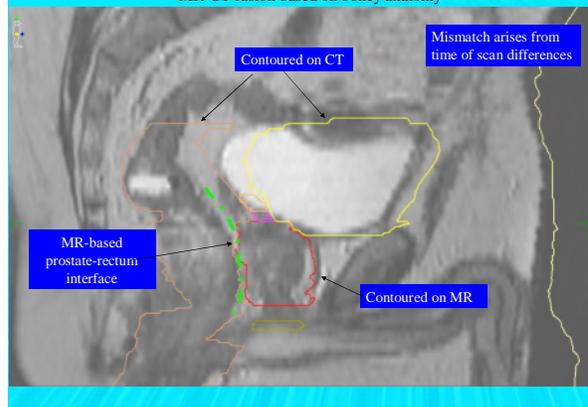
### MRI

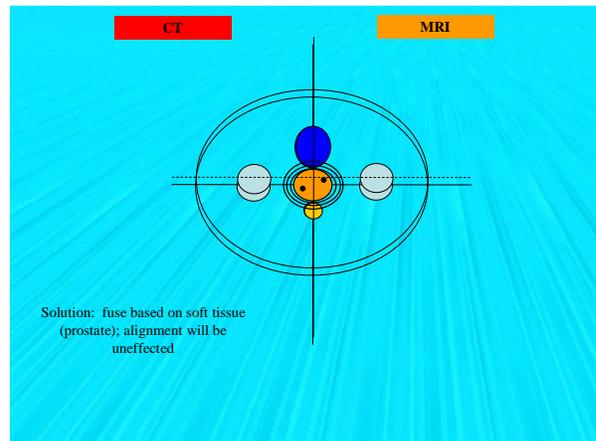
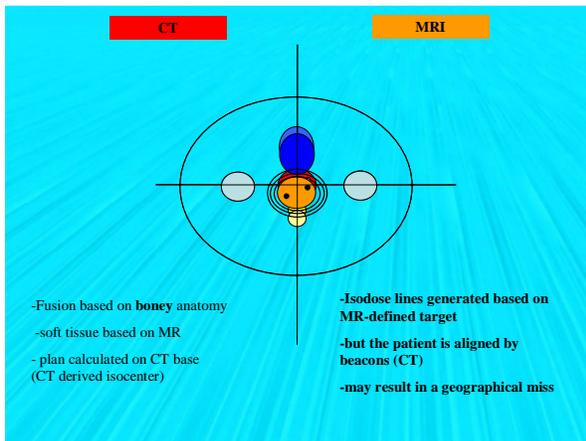
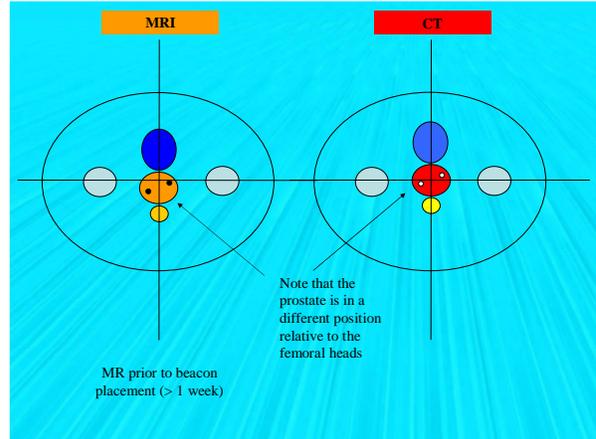
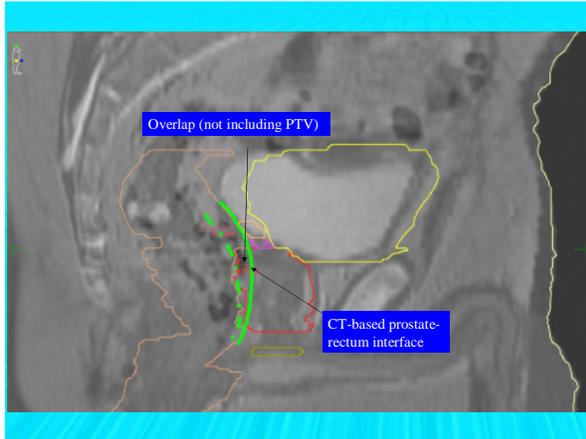
### CT

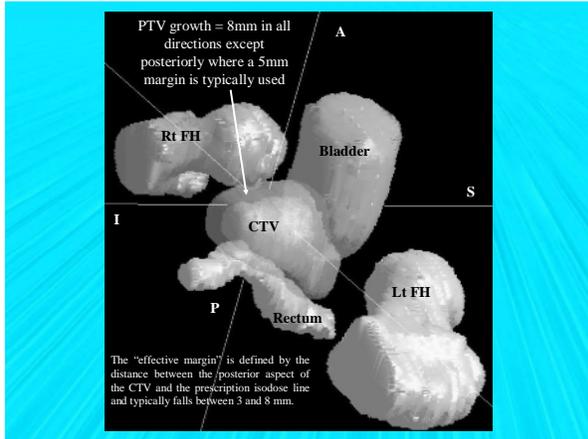


Imaging artifacts may affect contouring

### MR-CT fusion based on boney anatomy







### Localization



BAT Alignment



"CT-on-rails"



Gold Seed and CBCT

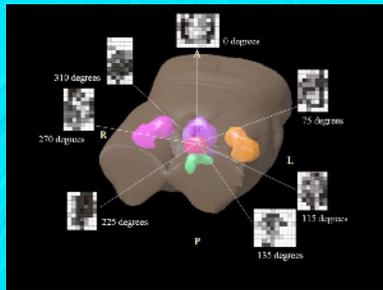


Calypso  
(localization & tracking)

### Number of Beam Directions

In the interest of delivery time we typically begin with 6 and progress to  $\leq 9$

Simpler plans such as prostate only or prostate + seminal vesicles typically result in fewer beam directions than with the addition of lymphatics



### Typical Dose

#### Routine treatments

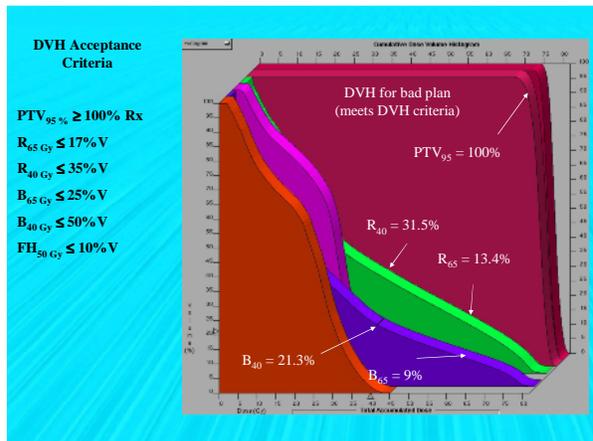
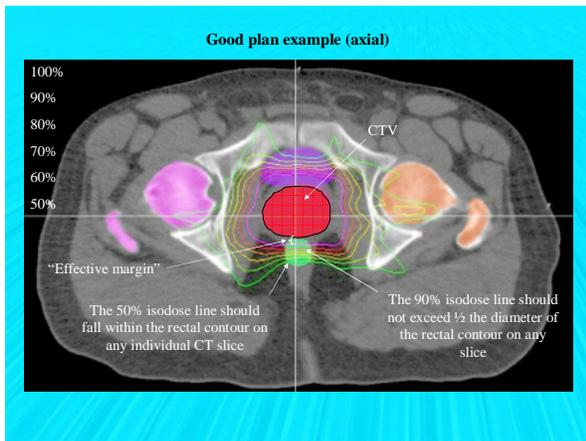
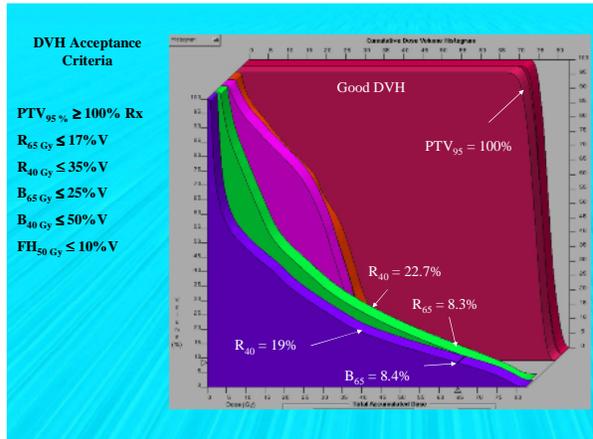
- Prostate + proximal sv (80 Gy @ 2.0 Gy/fx)
- Distal sv, lymphatics (56 Gy @ ~1.4 Gy/fx)

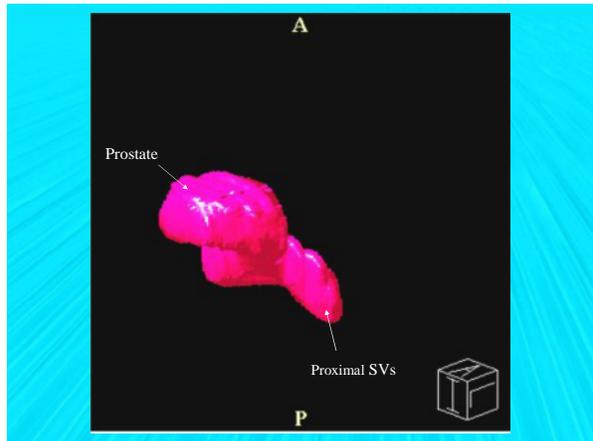
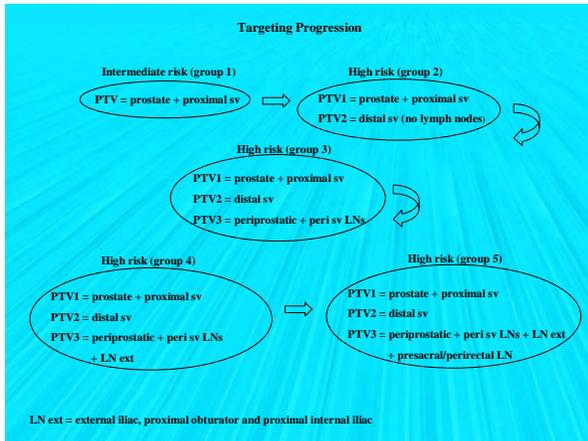
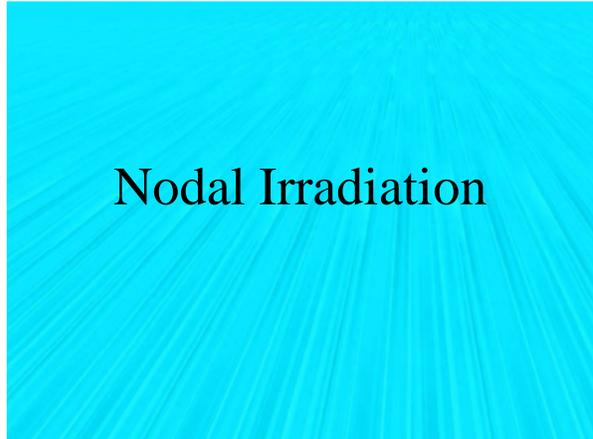
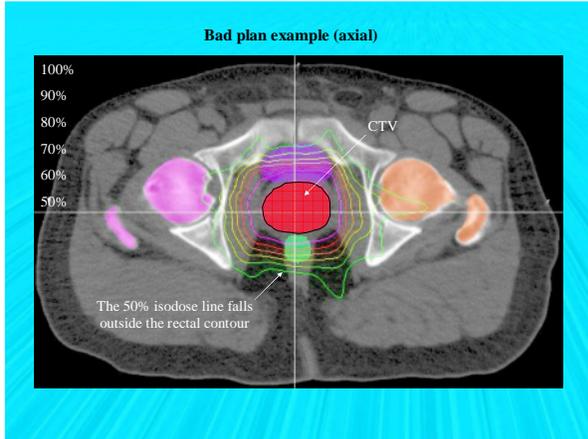
#### Post Prostatectomy

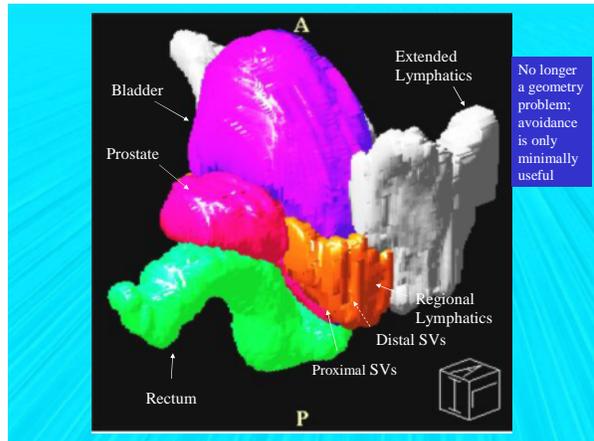
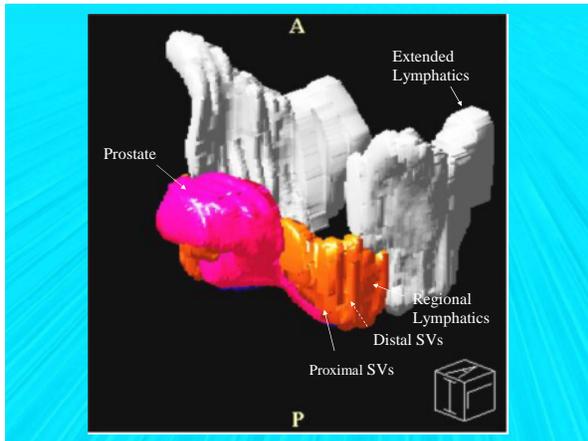
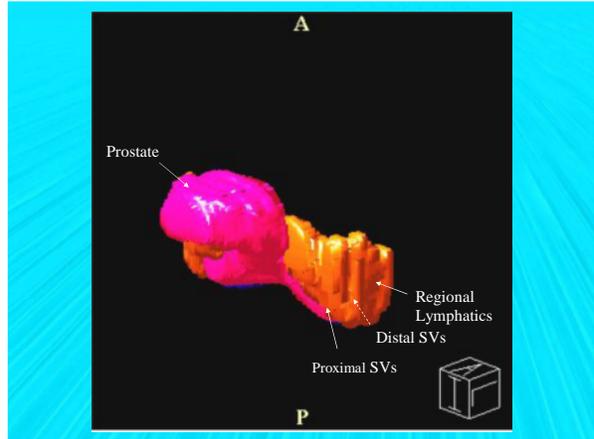
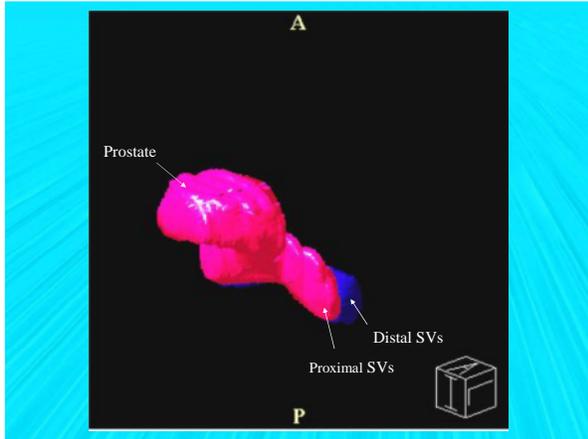
- Prostate bed (64-68 Gy @ 2.0 Gy/fx)

# Acceptance Criteria

What is a good plan?  
When can I stop planning?





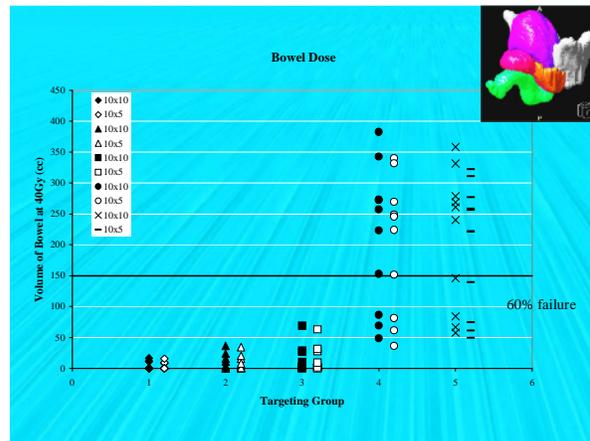
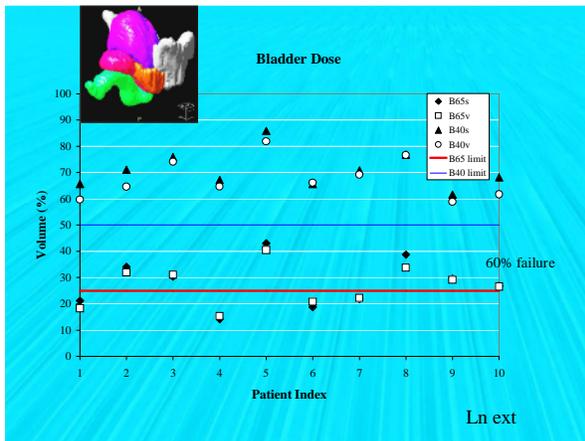
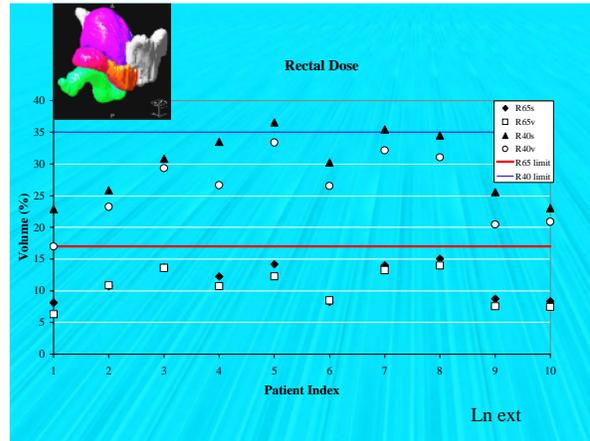


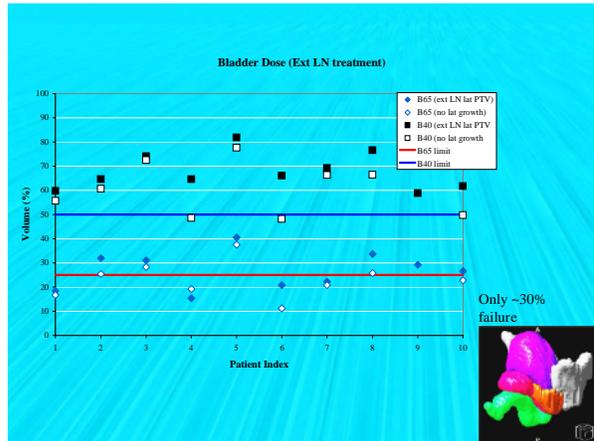
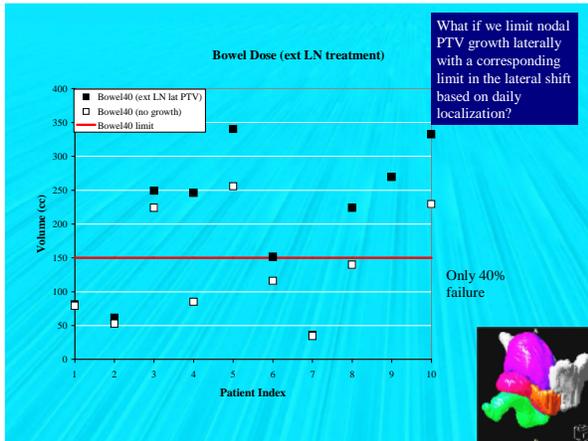
No longer a geometry problem; avoidance is only minimally useful

## Lymphatic irradiation study

- 10 patient data sets
- Generate plans for each stage in targeting progression
- Evaluate effect of nodal irradiation on our routine prostate IMRT plan acceptance criteria
- **Evaluate effect on bowel**
- Treatment time (logistical concerns as well as patient comfort)
- Physics concerns (dose per fraction vs. "cone downs", increased "hot spots", PTV growth and localization technique, rectal expansion and inclusion of presacral nodes, etc.)

Price et al. IJROBP2006



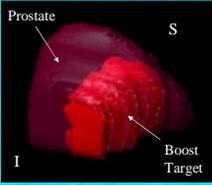


Newer Trends and “Exciting” Ideas

**HYPOFRACTIONATION!**

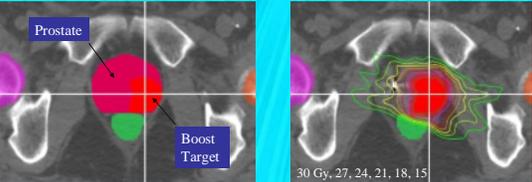
**SBRT!** ( $\leq 5$  fractions)

**PARTIAL PROSTATE BOOSTS!**



We believe we know something about the radiobiology for these scenarios.

$EQD2 = D[(d + (\alpha/\beta))/(2 + (\alpha/\beta))] = 30 \text{ Gy} \{ \alpha/\beta_{\text{prostate}} = 2.0 \text{ Gy} \}$



## PTV Margin Reductions???

How much does motion tracking help during prostate treatment?

- Quantitative analysis of potential PTV reduction

## Population-Based Margin Calculation (CTV to PTV)

$$m_{PTV}^* = 2.0 \Sigma + 0.7 \sigma + S$$

**Total systematic error**  $\Sigma = \sqrt{\Sigma_{del}^2 + \Sigma_{inter}^2 + \Sigma_{intra}^2 + \Sigma_{mid}^2 + \Sigma_{rot}^2 + \Sigma_{bds}^2 + \dots}$

**Total random error**  $\sigma = \sqrt{\sigma_{inter}^2 + \sigma_{intra}^2 + \sigma_{mid}^2 + \sigma_{rot}^2 + \sigma_{bds}^2 + \dots}$

**Total mean**  $S = S_{del} + S_{inter} + S_{intra} + S_{mid} + S_{rot} + S_{bds} + \dots$

\* Stroom JC et al, Int. J. Rad. Onc. Biol. Phys 43(4) pp. 905-919,1999  
With a criteria of  $D_{99}$  of CTV > 95% of the nominal dose on average

## Geometrical Uncertainties

- Delineation Error** (C. Rasch et al) (del)
  - L-R 1.7mm; S-I 2-3.5mm; A-P 2mm;
- Geometrical Uncertainty of the **beam delivery system** (bds)
  - $\Sigma_{bds} = 0.5\text{mm}$ ,  $\delta_{bds} = 0.7\text{mm}$
- Uncertainty of **localization and motion tracking system** (mtd)
- Uncertainty caused by **Beacon migration and prostate size change** -- not included in the margin calculation
- Geometrical Uncertainty Caused by **Prostate Rotation** (rot)
- Setup **residual** error -- included in the intrafractional motion
- Geometrical Uncertainty caused by **intrafractional motion**

### 4D treatments

– moving the couch and/or using DMLC

1. Correction of the translational error

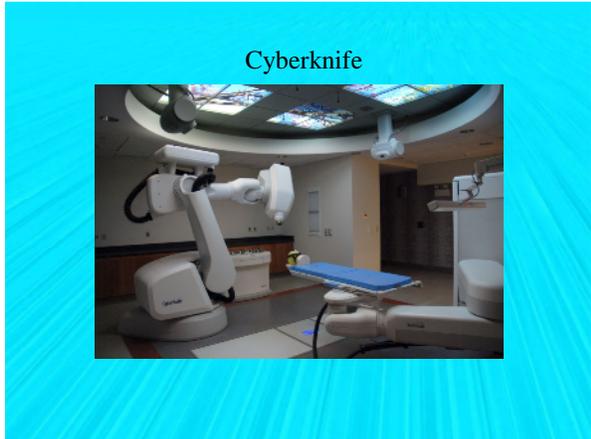
2. Correction of the translational error plus rotation

### PTV Margins for Various Uncertainty Conditions

105 patients with/without intervention

(mm)	Left	Right	Sup	Inf	Ant	Post
No intervention	5.3	5.6	8.1	8.8	8.8	8.8
5mm threshold	5.3	5.6	8.1	8.8	8.7	8.7
3mm threshold	5.3	5.6	8.0	8.5	8.8	8.3
4D Tx	5.5	5.3	7.8	8.3	9.0	7.6
4D Tx + Rotation Correction	4.5	4.3	4.9	5.3	6.0	4.6

*Courtesy Jinsheng Li, Ph.D., FCCC*



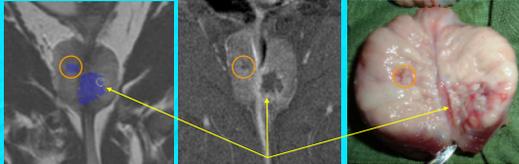
### Prostate Cancer-Endorectal System for High-Intensity Focused Ultrasound (HIFU)

- Endorectal phased array probe
- Steerable beam for focal spot size control (2 x 7mm to 10 x 30mm) for fast treatment and to prevent complications related to nerve bundle
- Combined pelvic and endorectal imaging coil for high resolution target definition

*Steerable beam and spot size control*

*Courtesy of Sheba Hospital, Tel-Aviv, Israel*  
*Lili Chen, Ph.D., FCCC*

## Animal Studies



Accumulated thermal dose following FUS treatment shown on T2w MR coronal image

Contrast enhanced T1w subtraction image showing the lesion

Macro pathology image following the procedure showing the ablated areas

- Correlation between thermal dose, non-perfused volume (NPV) and gross pathology

*Courtesy of Sheba Hospital, Tel-Aviv, Israel  
Lili Chen, Ph.D., FCCC*

## Conclusions (my opinion)

- IMRT for prostate cancer, while routine, should be practiced in a patient specific, systematic way with clearly defined acceptance criteria.
- Hypofractionation, SBRT, partial prostate treatments, etc., should be implemented "on study" and we should not lose sight of the treatment vs. response characteristics gained through conventionally delivered IMRT.
- One should be extremely cautious when reducing the treatment margins even with prostate motion tracking.