

Target Dose Coverage in the Presence of Alignment Rotation for Proton Therapy of Prostate Cancer

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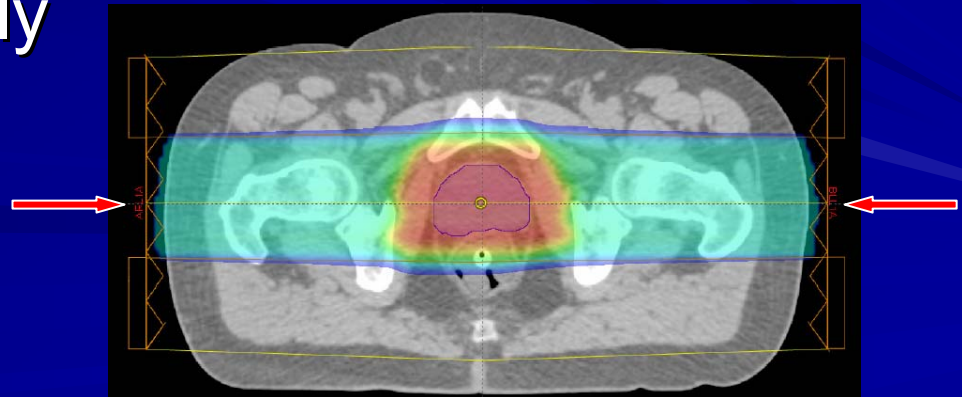
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Purpose

- To verify that the prostate treatment planning technique adopted at MDACC ensures prescription dose coverage for patient axial alignment variation

Prescription and delivery

- 75.60 CGE prescribed to an isodose line (typically 97% – 98%) encompassing the CTV
- CTV includes entire prostate and, in most cases, the proximal seminal vesicles
- Dose delivered in 42 fractions using two parallel opposed passively scattered fields
- Both fields treated daily



Treatment planning parameters

■ Range uncertainty:

- Distal and proximal margins set from the CTV as described by Moyers*:

- $DM = (0.035 \times \text{distal CTV depth}) + 3 \text{ mm}$

- $PM \approx (0.035 \times \text{proximal CTV depth}) + 3 \text{ mm}$

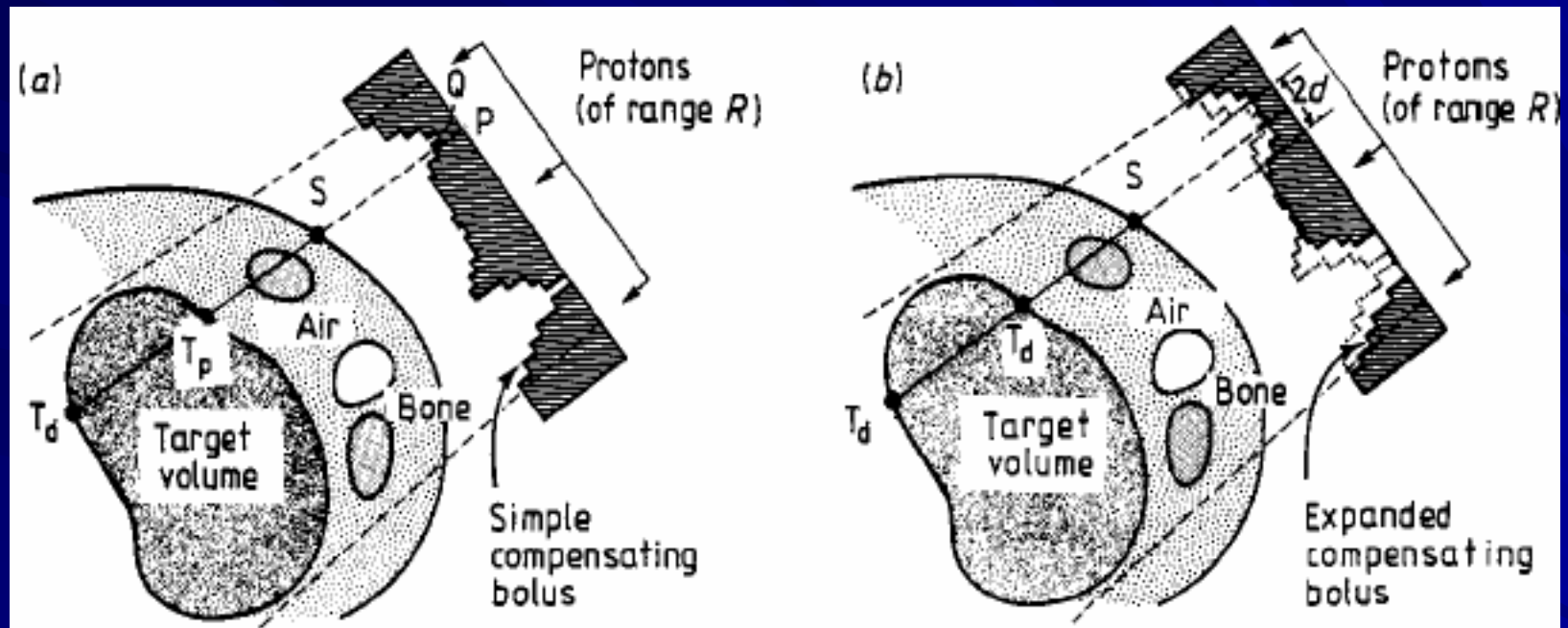
SOBP: Distal 90% - Proximal 95%

■ Position uncertainty:

- Lateral margin from the CTV includes set up uncertainty (5 mm) and penumbra_(98 – 50%) (12 mm)
- **Smearing** applied to range compensator

*Moyers, et. al.

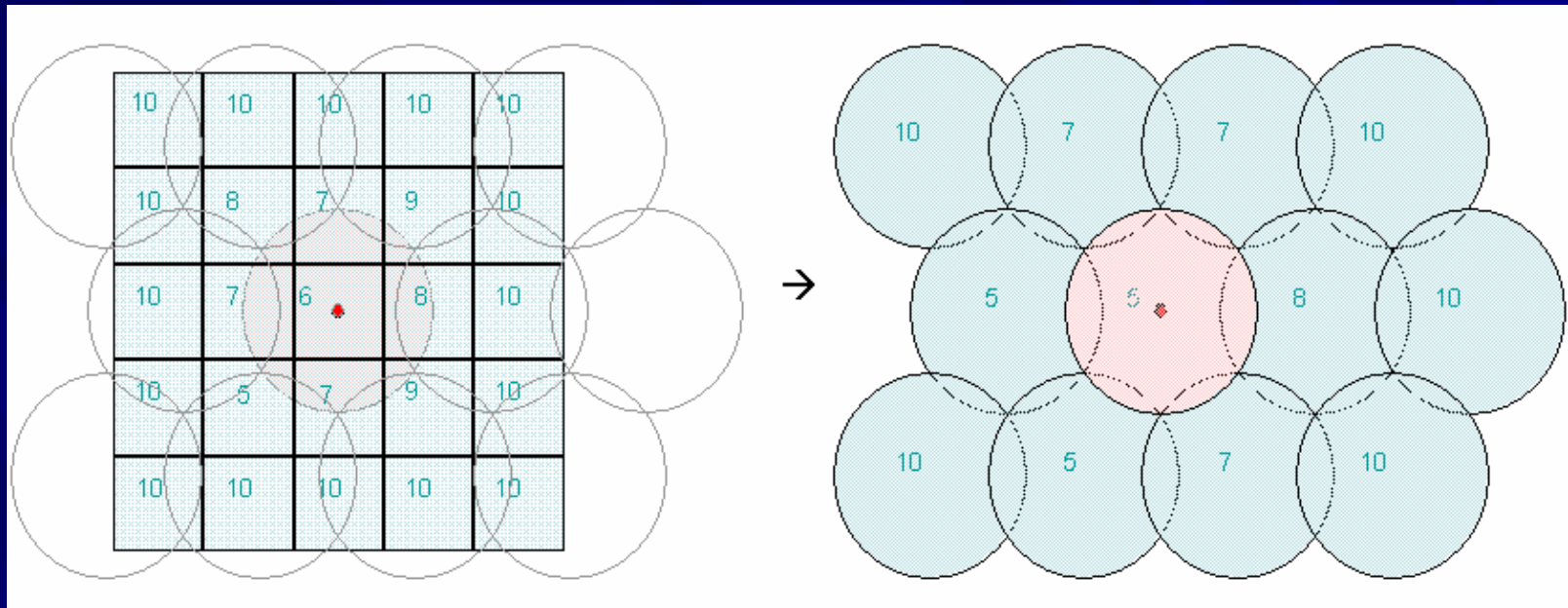
Compensator smearing



Urie, *et. al.*

Phys. Med. Biol. 1983

Smearing radius



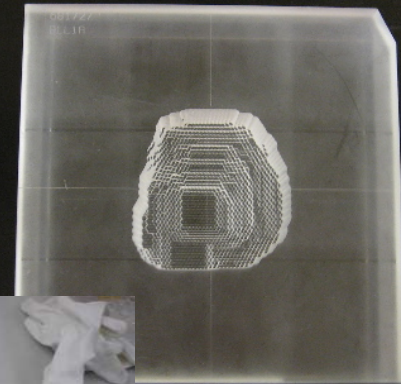
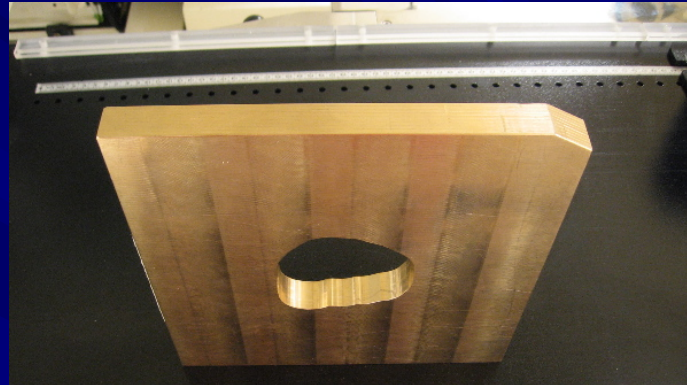
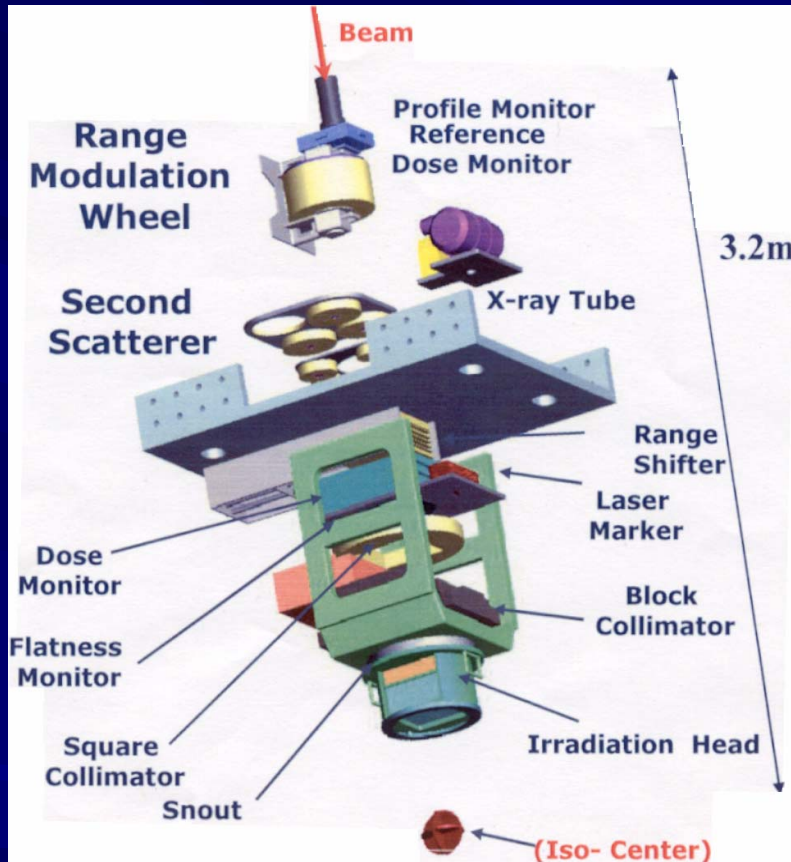
Thickness at each grid point

Thickness after smearing

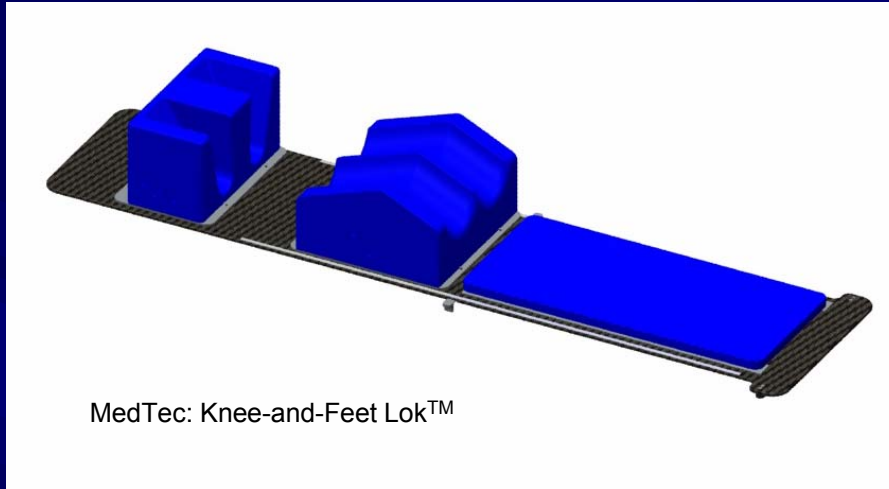
$$*SR = \sqrt{\{(0.03 \times \text{distal CTV depth})^2 + (\text{position uncertainty})^2\}}$$

Typical radius: 9 mm

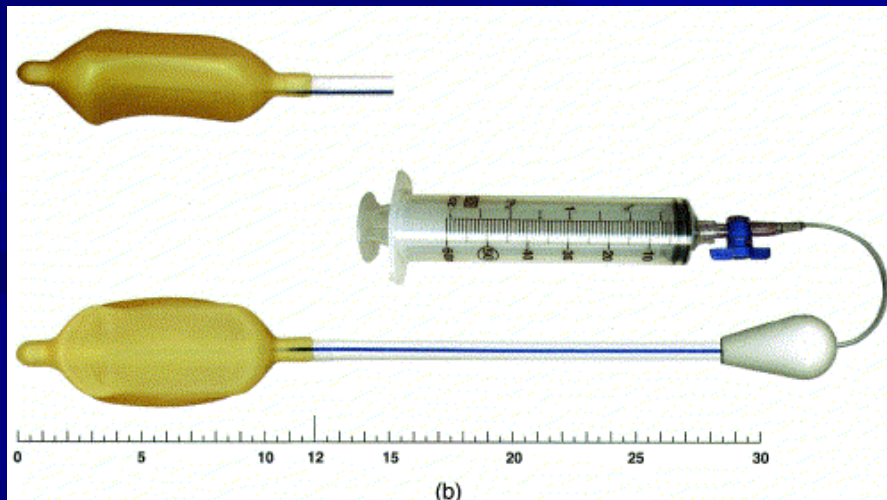
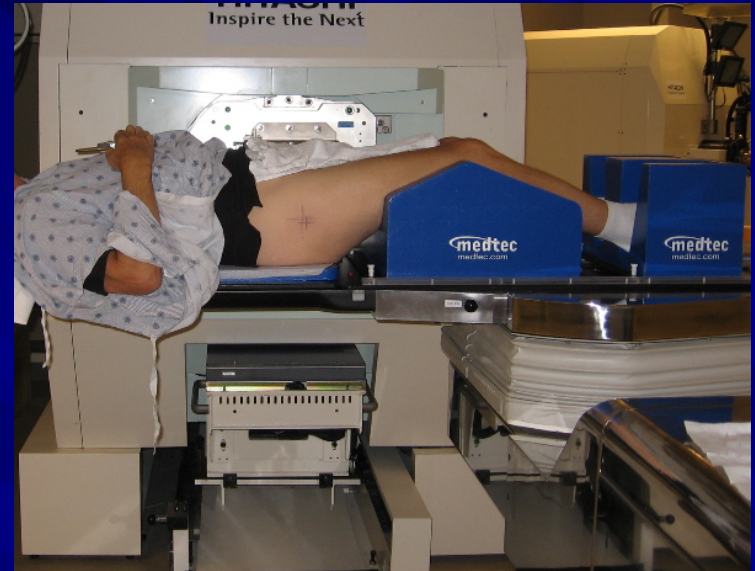
Beam shaping devices



Immobilization



External immobilization



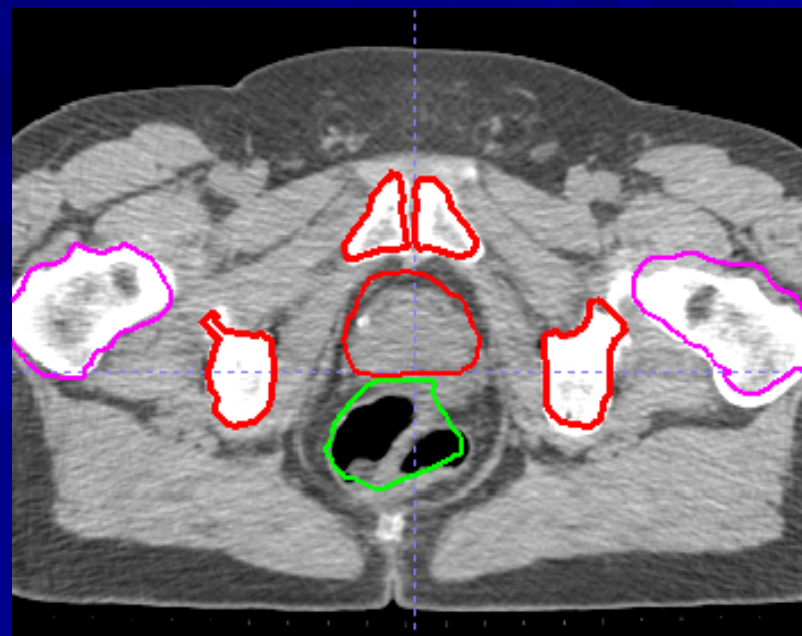
Internal immobilization



Knee and feet lok™

CT-on-rails data comparing
immobilization devices for daily
bony alignment repeatability

(Rotation not explicitly studied)



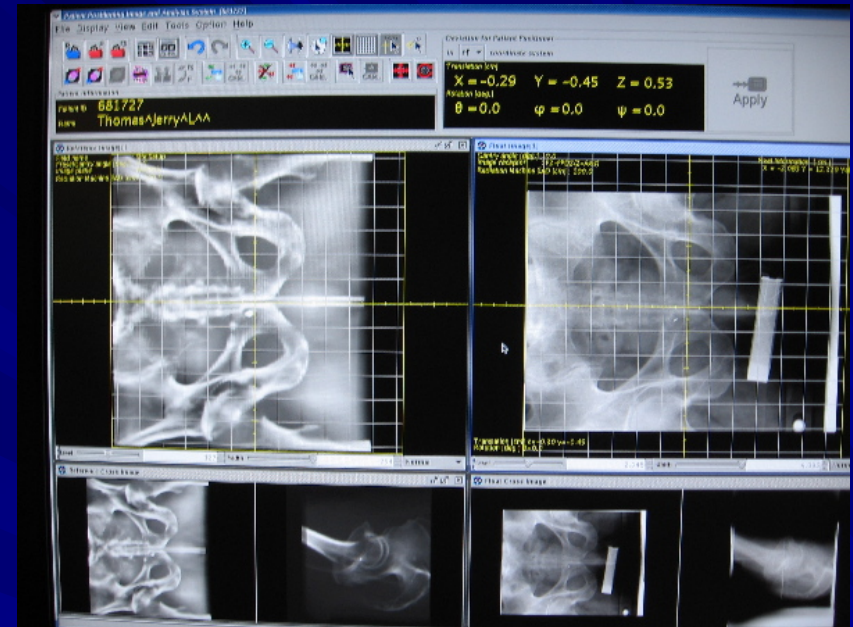
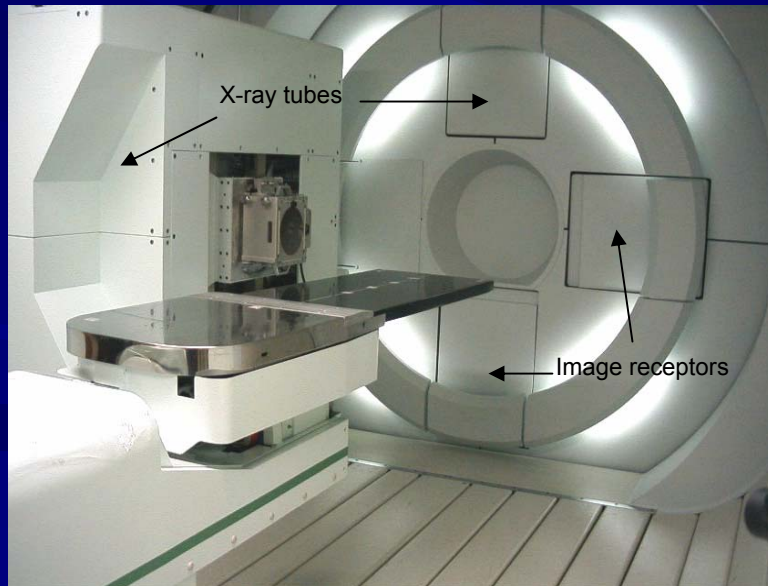
Vacuum bag



Courtesy of Lei Dong, Ph.D.

Patient alignment at PTC-H

- Daily orthogonal kV x-ray images taken to align bony anatomy with reference DRR's using 2-D matching

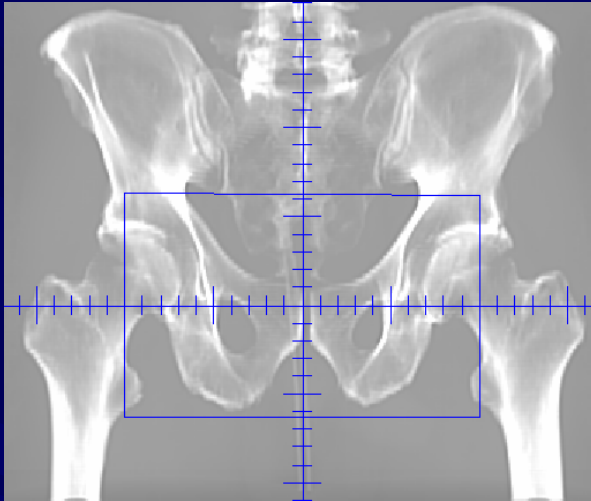


Positioning Image Analysis System, 'PIAS'

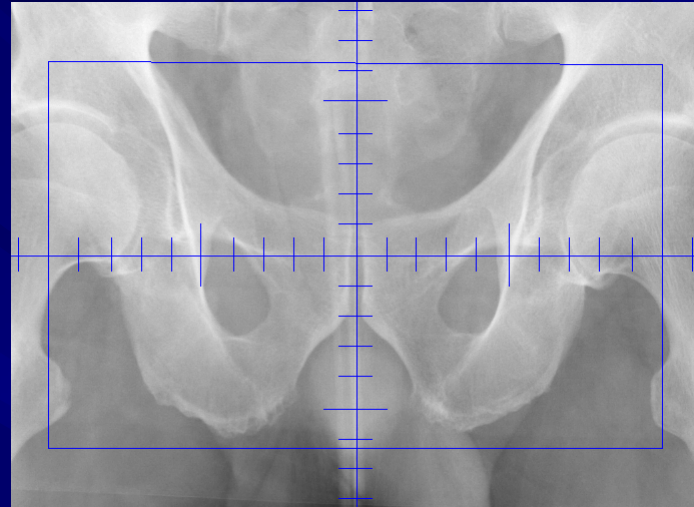
Hitachi



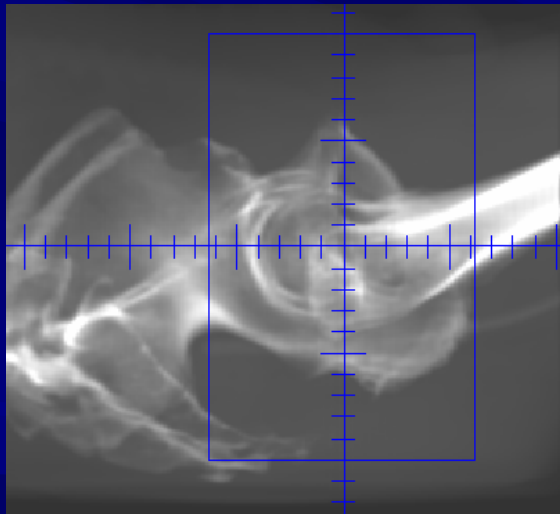
Orthogonal 2-D images are insensitive to small axial rotation of anatomy



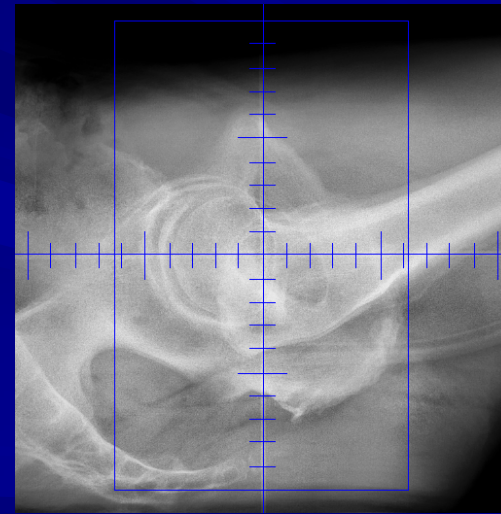
AP DRR



AP x-ray image



Rt Lat DRR



Rt Lat x-ray image

Rotation of pelvic bony structures can significantly alter radiological path lengths along beam projections. This can have an impact on proton dose distribution

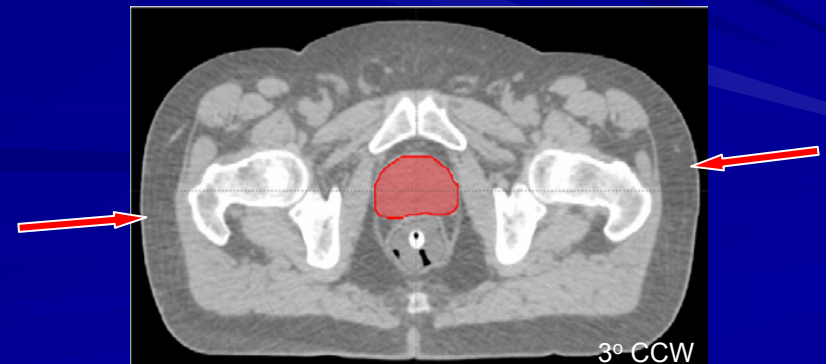
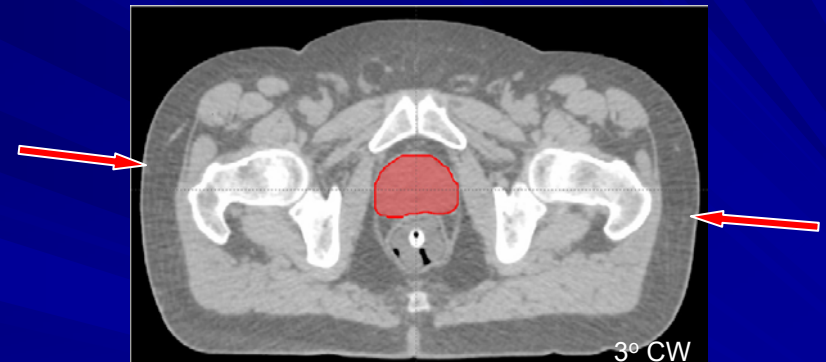
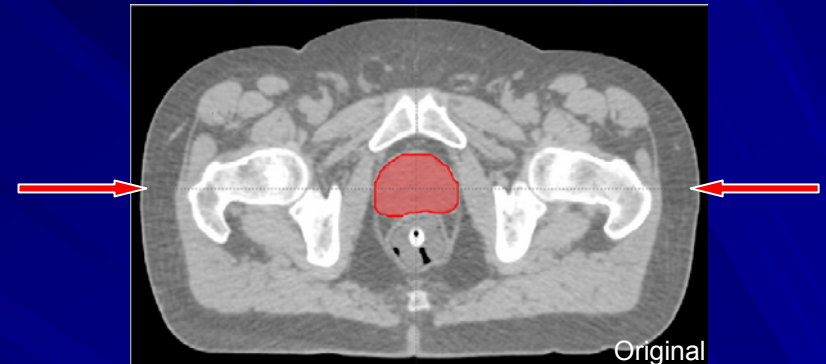
Question:

- Are our treatment planning parameters sufficient to ensure target coverage in the presence of axial rotation of the bony anatomy?



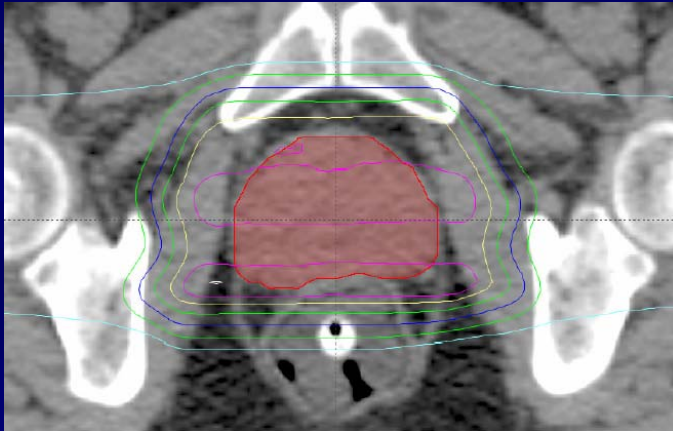
Method

- Eight prostate treatment plans were evaluated
- Original treatment plans re-calculated with parallel opposed fields rotated $\pm 3^\circ$ to simulate patient rotation
- Compensator and aperture designs remained fixed
 - Eclipse ‘verification’ plans
- Other parameters fixed
 - Range, SOBP, etc..



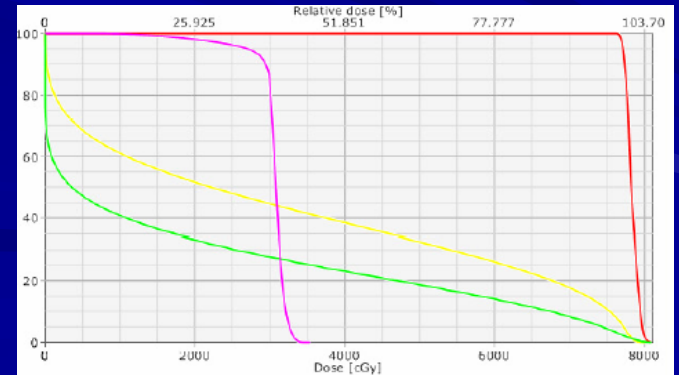
Method

- Each verification plan evaluated in two ways:



Prescription isodose line used to verify CTV coverage

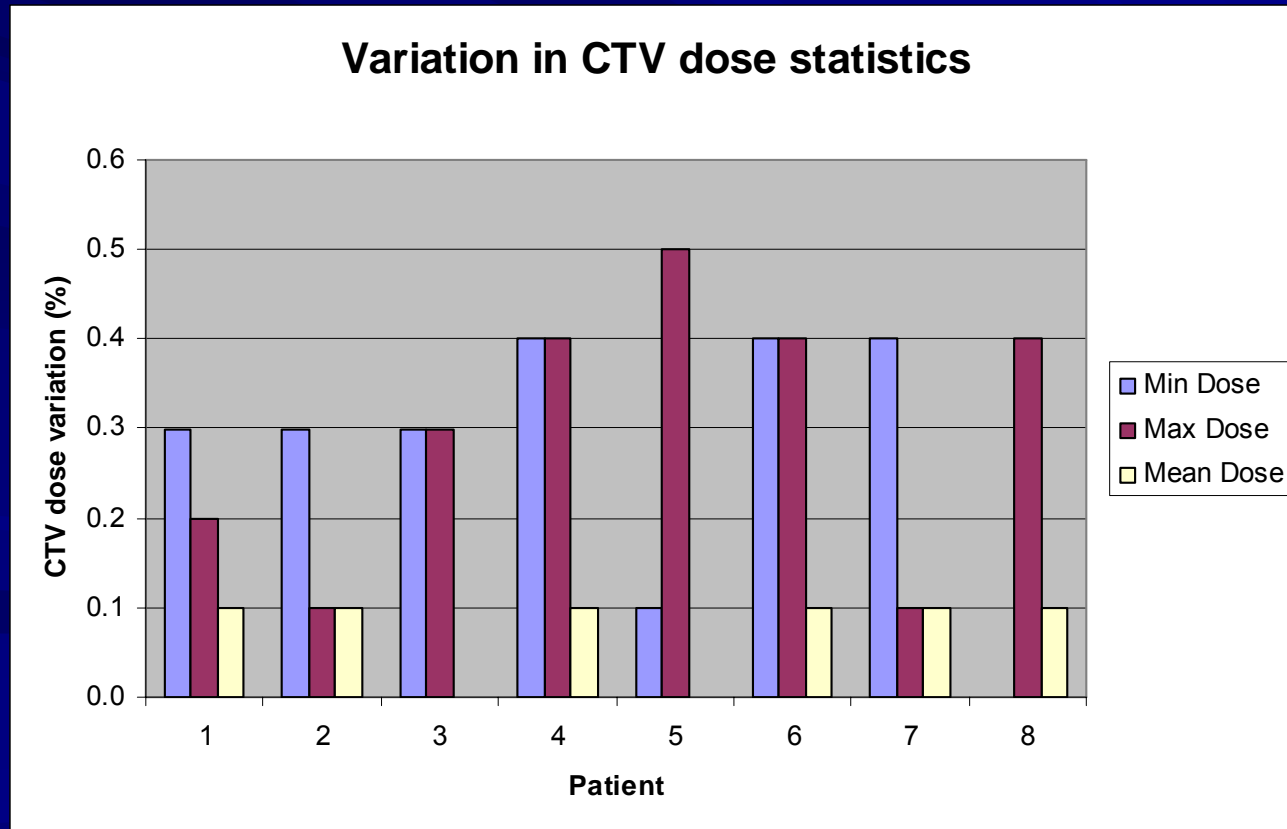
Dose volume histograms (DVH's) evaluated and compared to those from original plan



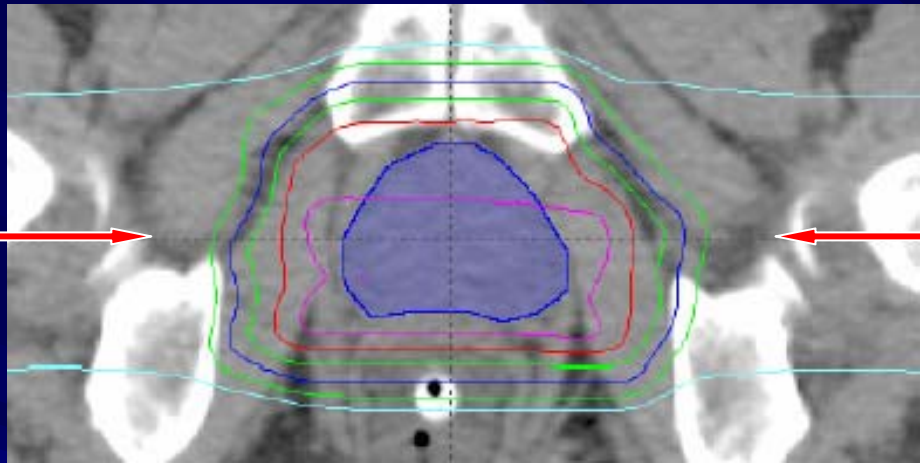
Results

In all cases, the prescription isodose line completely encompassed the CTV for axial rotations of $\pm 3^\circ$. However, in two cases, coverage was extremely tight.

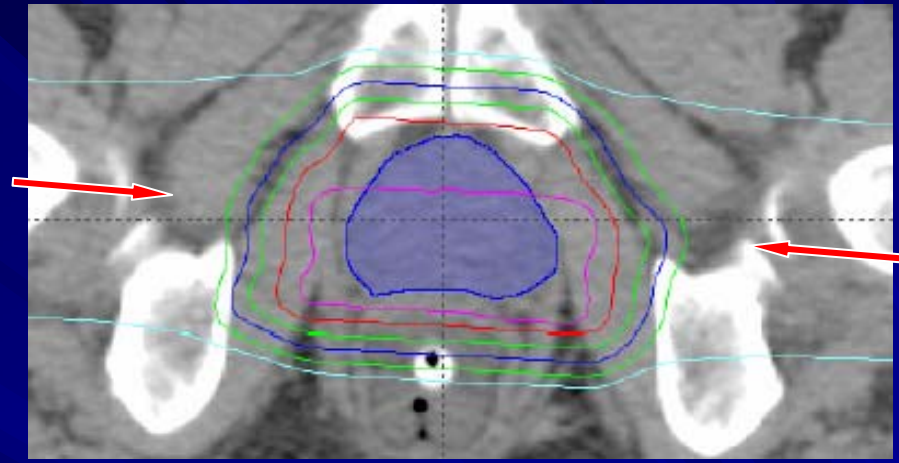
Minor variations ($<0.5\%$) were observed in CTV dose statistics:



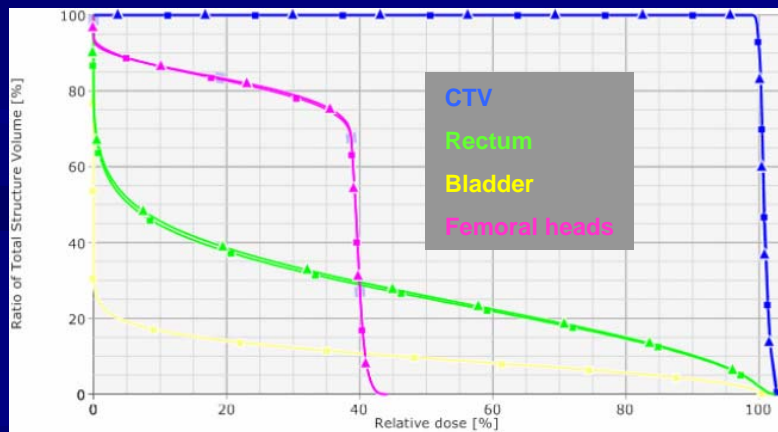
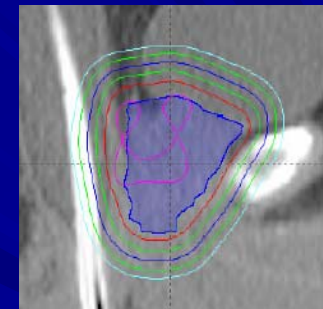
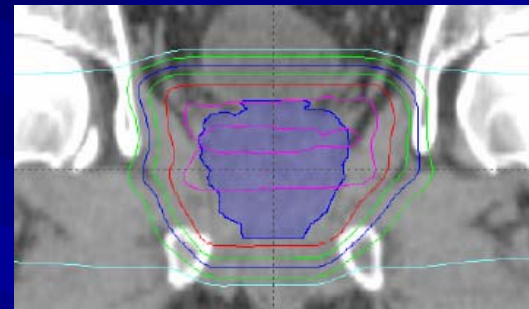
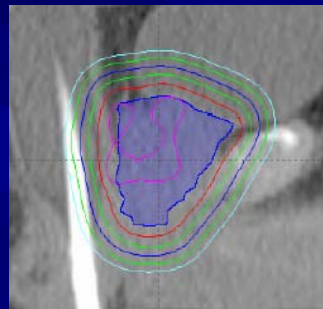
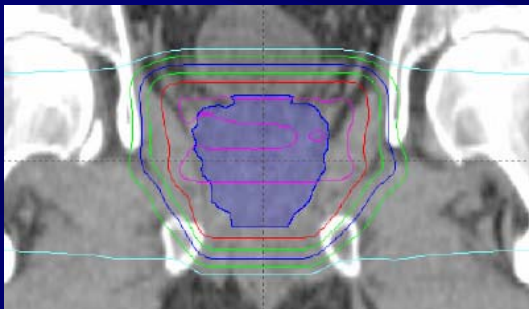
Example patient # 8: Typical



Original plan



CW verification plan



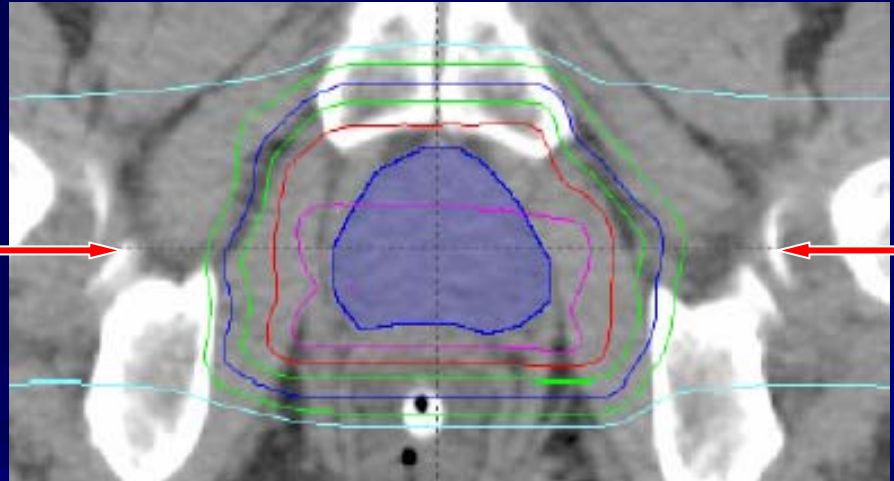
- Original plan
- CW rotation

Prescription isodose line covers CTV with similar margin

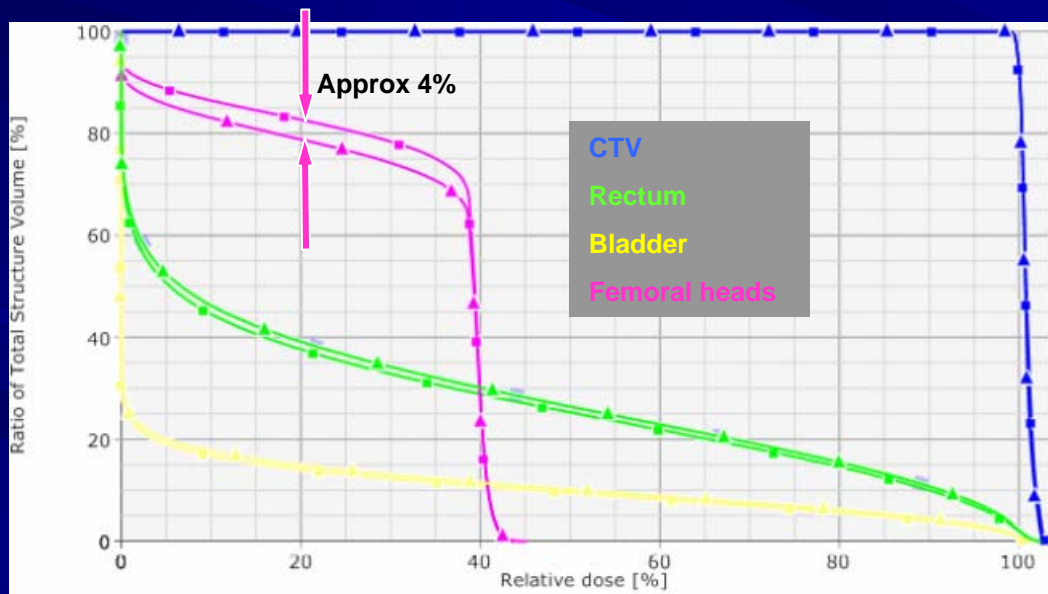
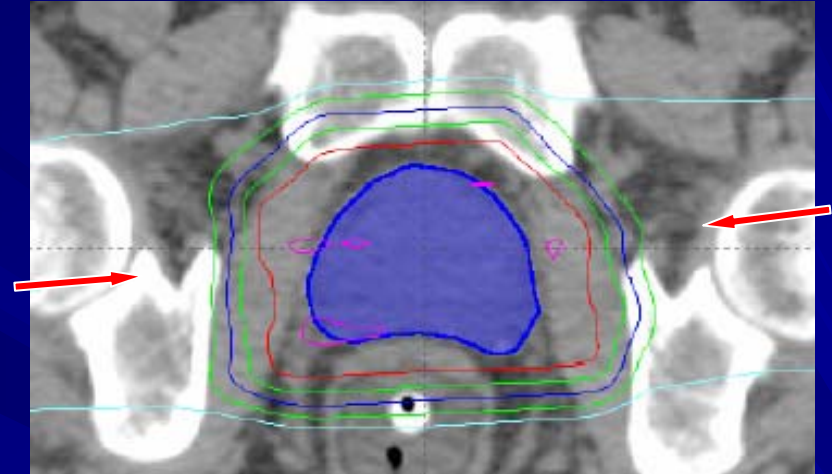
DVH's compare very closely for all structures

Example patient # 8: Typical

CCW verification plan



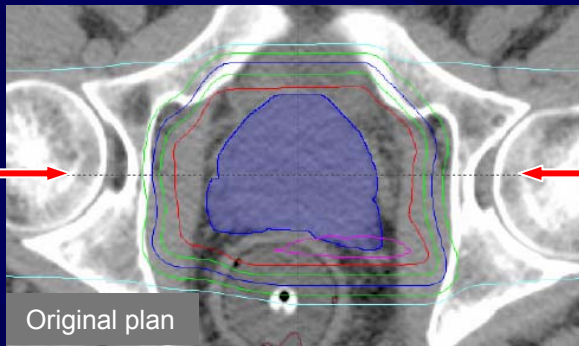
Original plan



- Original plan
- CCW rotation

Prescription isodose line covers CTV with similar margin

4% volumetric reduction in femoral head DVH up to ~ 30 CGE

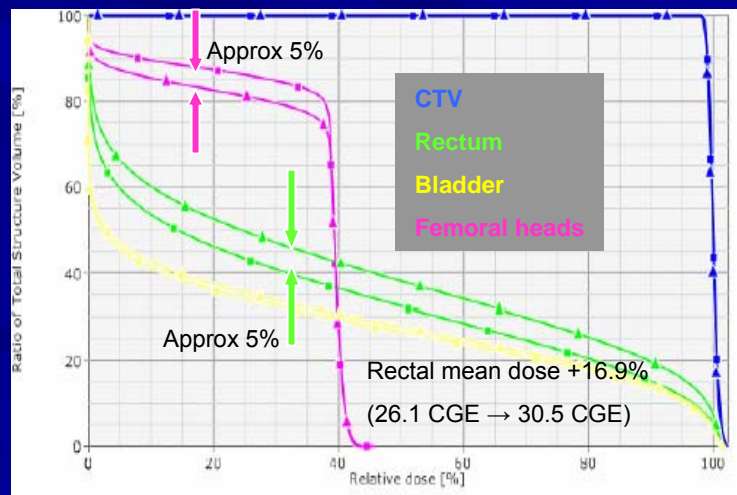
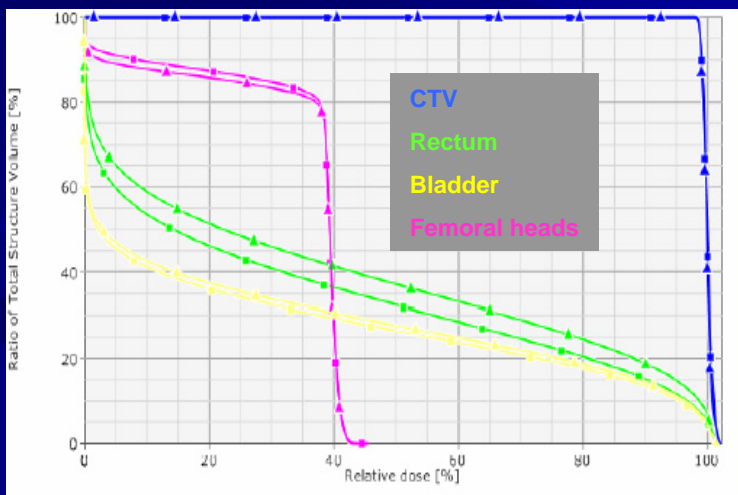


Prescription isodose line has no margin anterior to the CTV in both rotated plans

CTV and bladder DVH's show no change

5% volumetric increase in rectal DVH

5% volumetric reduction in femoral head DVH up to ~ 30 CGE



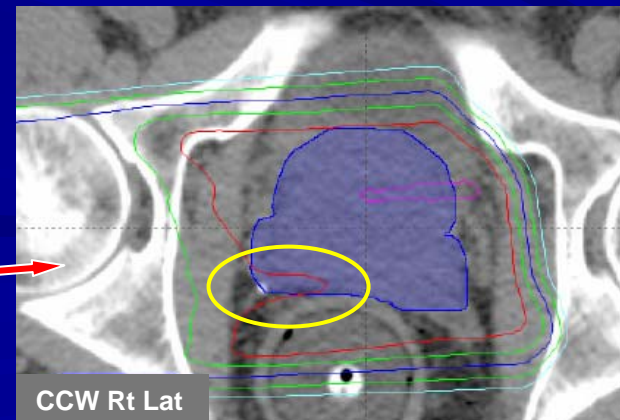
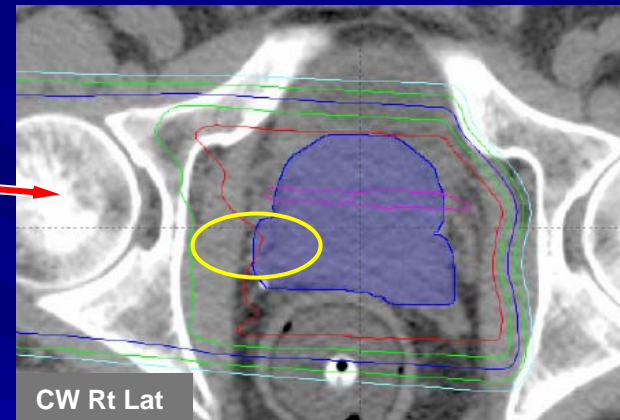
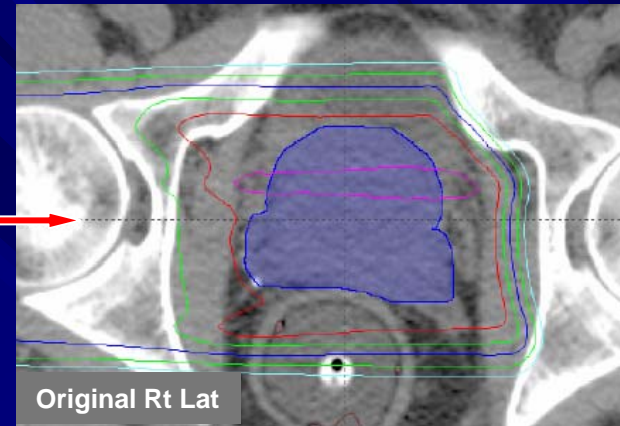
Example patient # 2: Worse case

Original plan

CW / CCW rotation

Single field fractions

- It was observed that dose coverage was compromised in some cases for axial rotation variation when using alternating single field fractions
- Dose statistics and isodose line coverage for the complete treatment plan do not indicate this issue



Summary

- Eight prostate treatment plans were evaluated for target prescription dose coverage in the presence of axial rotation variation of the patient of $\pm 3^\circ$
- In all cases the CTV remained covered by the prescription dose, albeit coverage was tight in two instances
- Minor differences in DVH for OAR were observed, but these were not considered clinically significant

Conclusions

- The parameters used in the treatment planning of these cases were sufficient to ensure target dose coverage for patient axial rotation of $\pm 3^\circ$
- Treating both lateral fields daily may ensure target dose coverage to a greater extent than single field fractions



Thank you