RTOG IGRT Protocol Development

Treatment Dose Assessment: Technical Status & Problems

1. Daily volumetric image

- Deformable organ registration

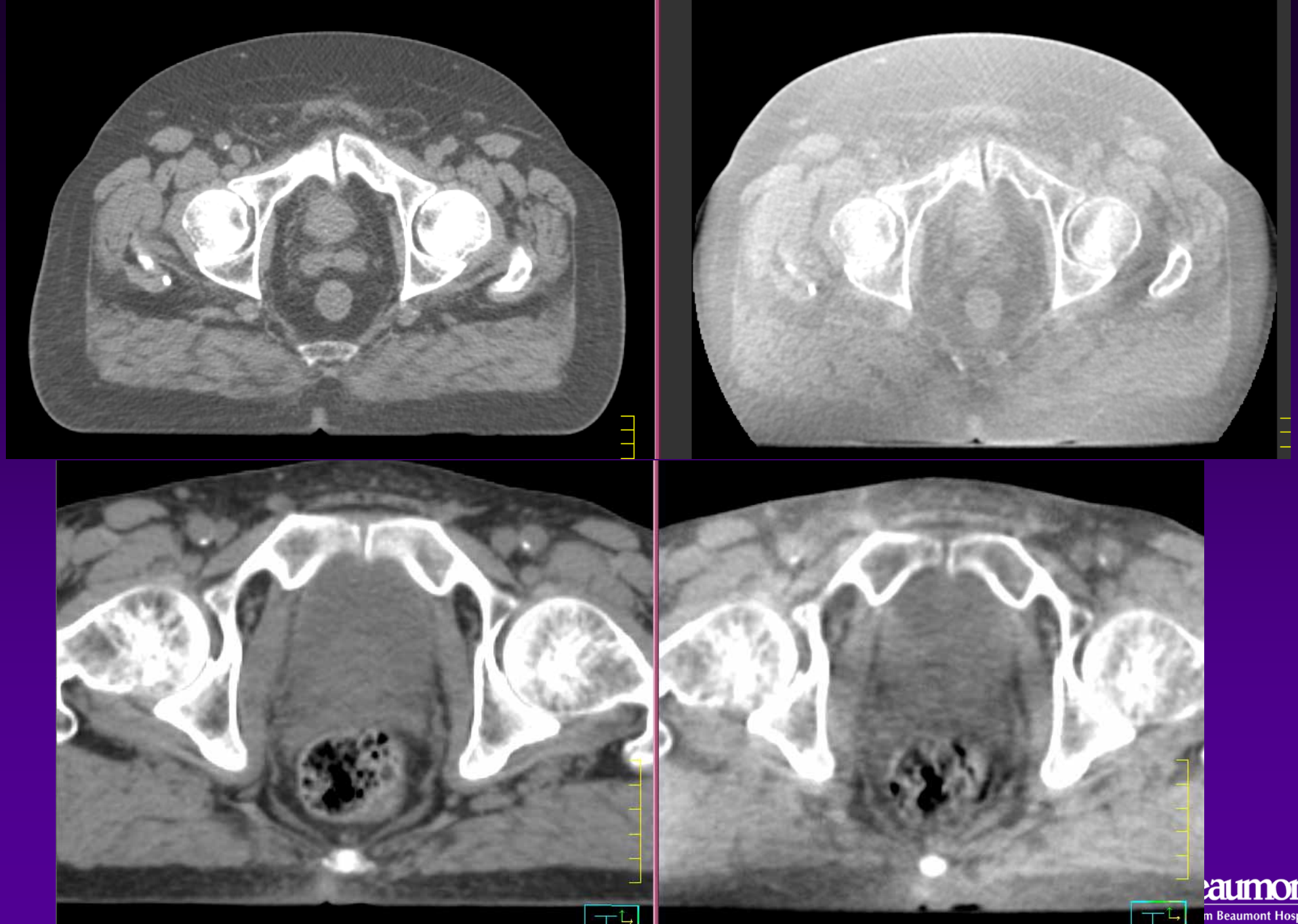
- Dose accumulation

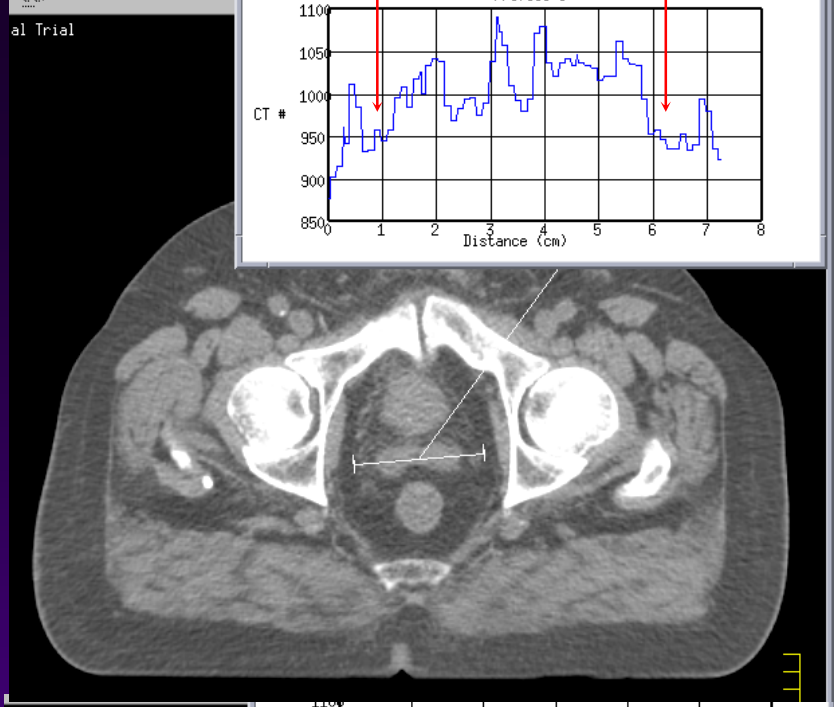
1. CBCT Volumetric Image

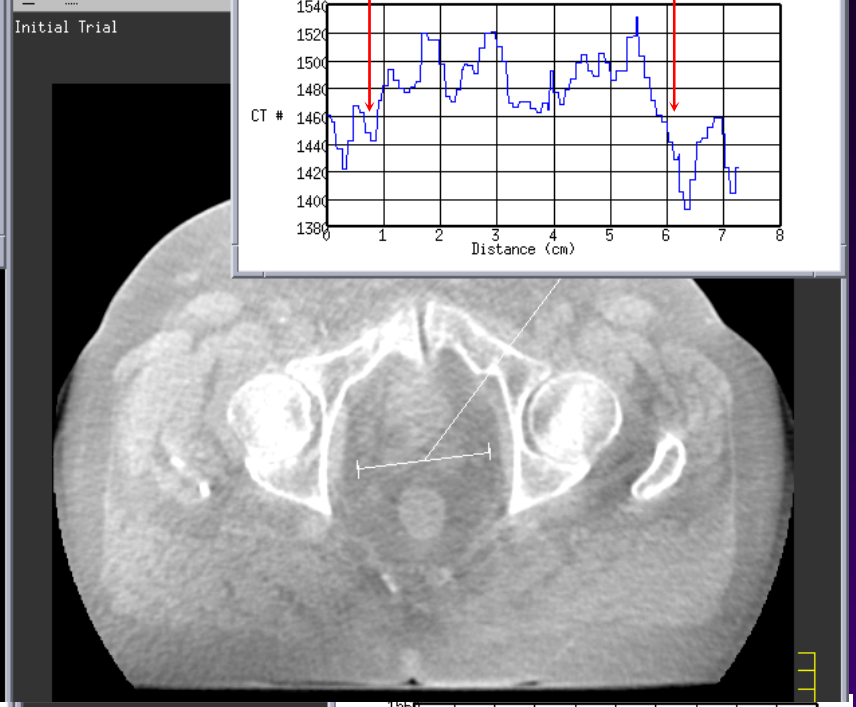
- Problems in Onboard Imaging Technique
  - Large scatter noise
  - Non uniformity
  - Leg & cupping effect
  - Low soft tissue contrast & high noise

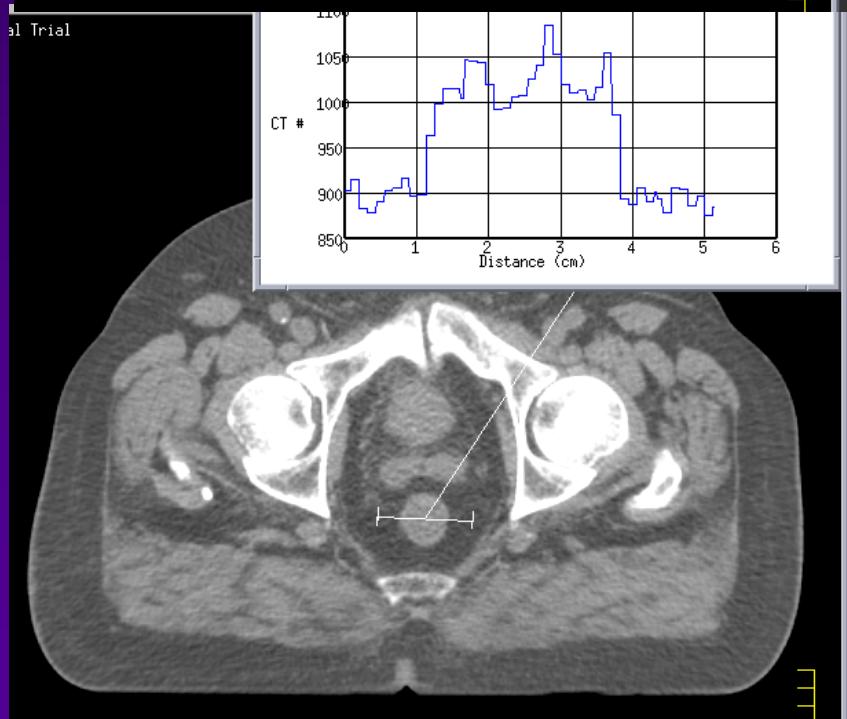
1. CBCT Volumetric Image

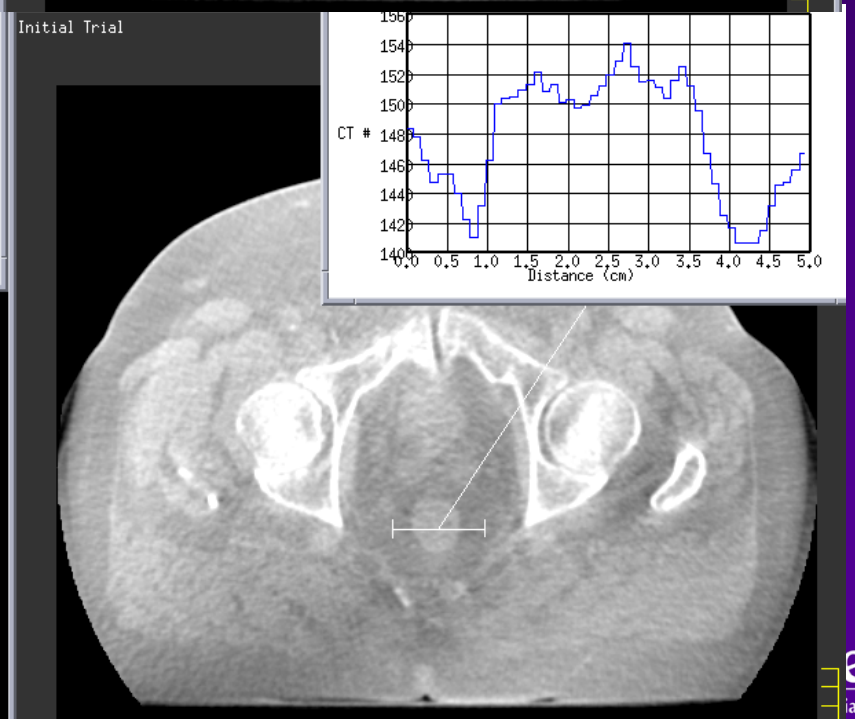
- Problems in Clinical Application
  - Patient size (> 40 cm waist diameter)
  - Imaging techniques (mAs, collimator, filters, grid)
  - Device calibration (geometry and imaging)
  - Imaging artifacts (implants)

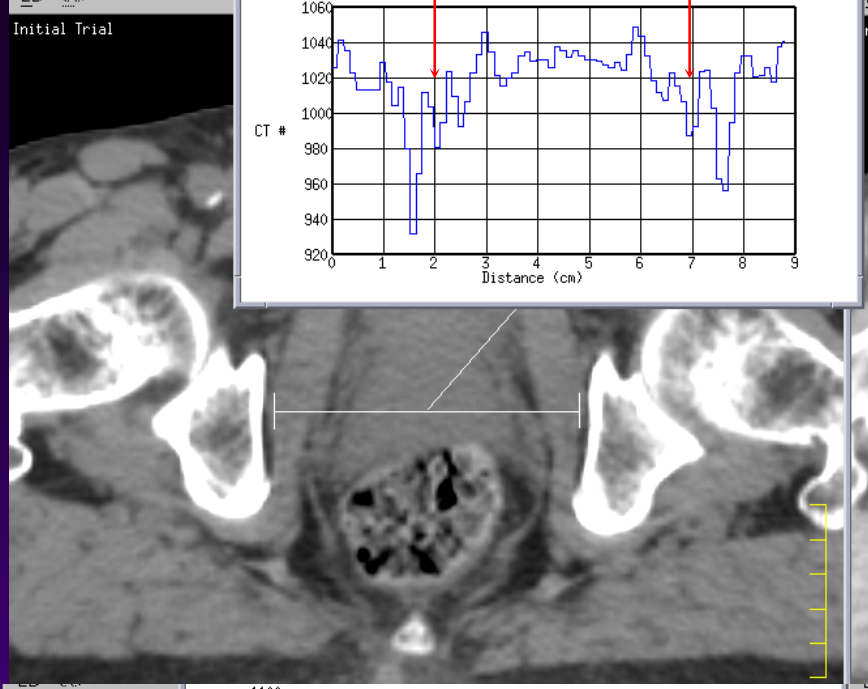


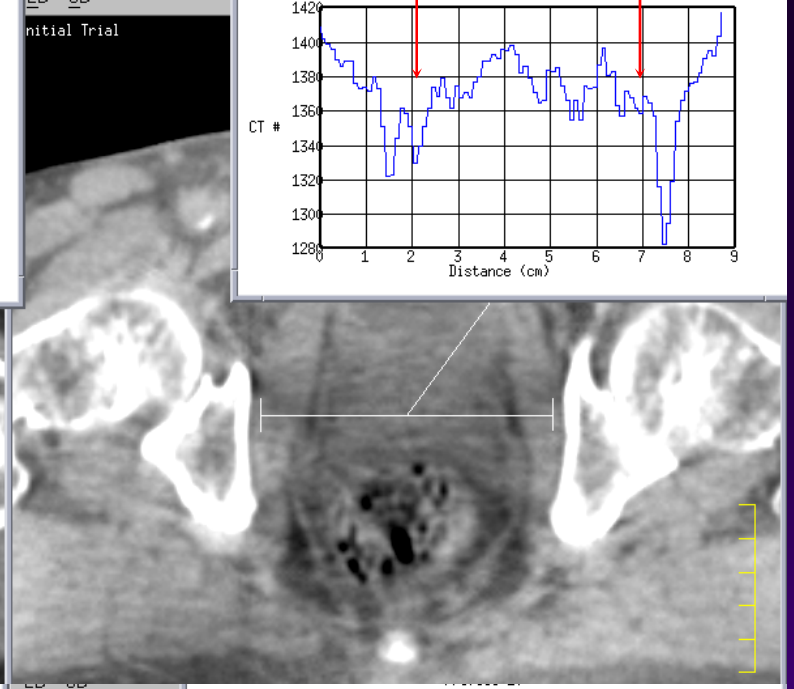


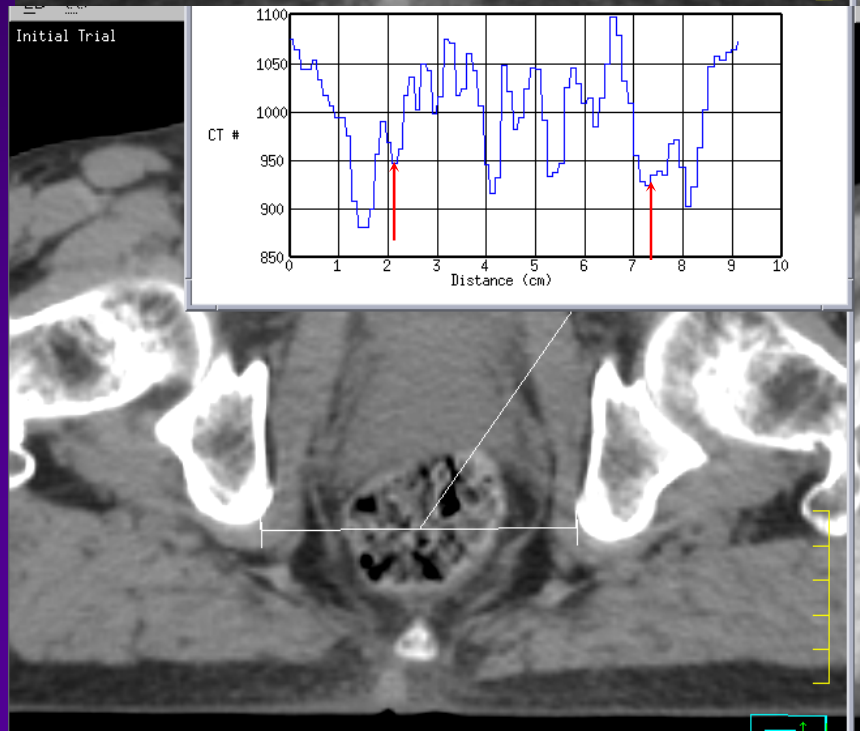


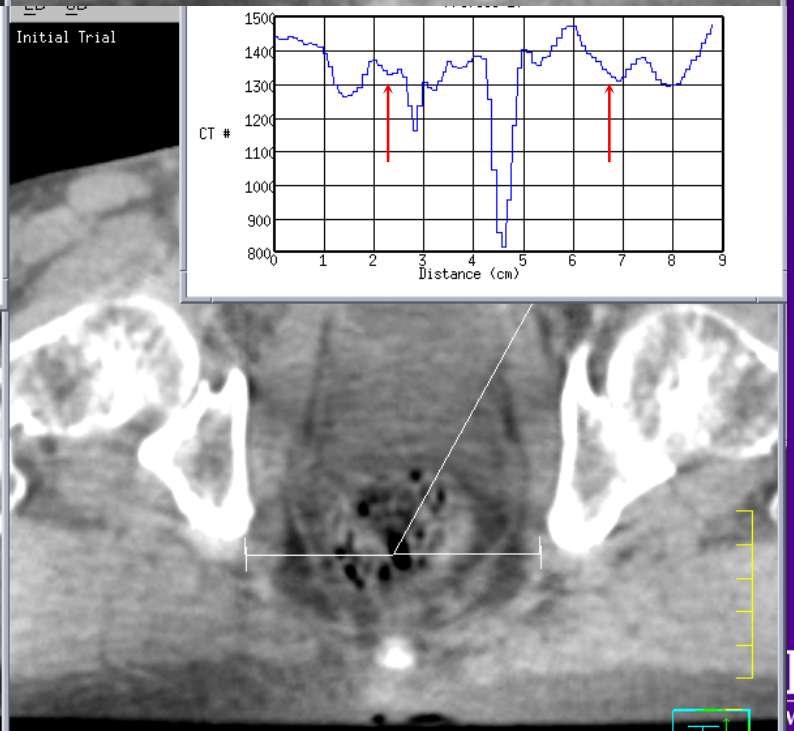




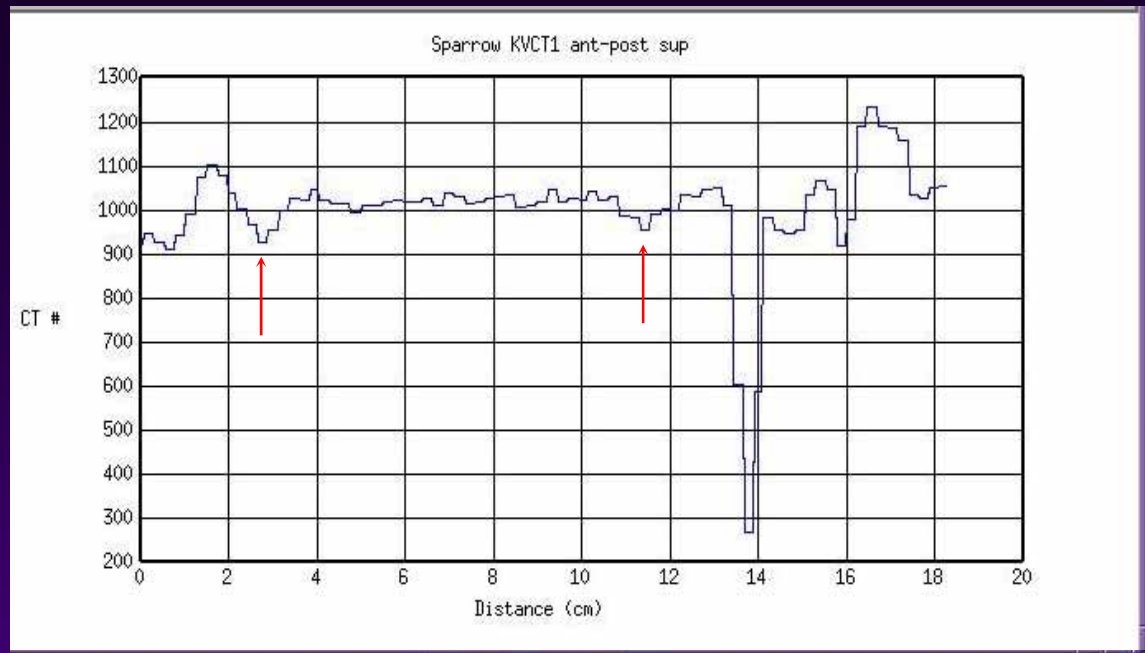


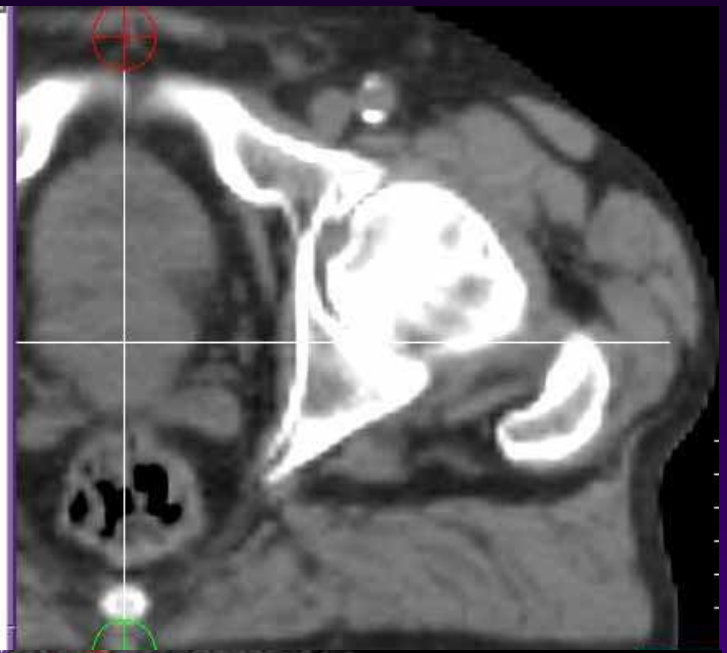


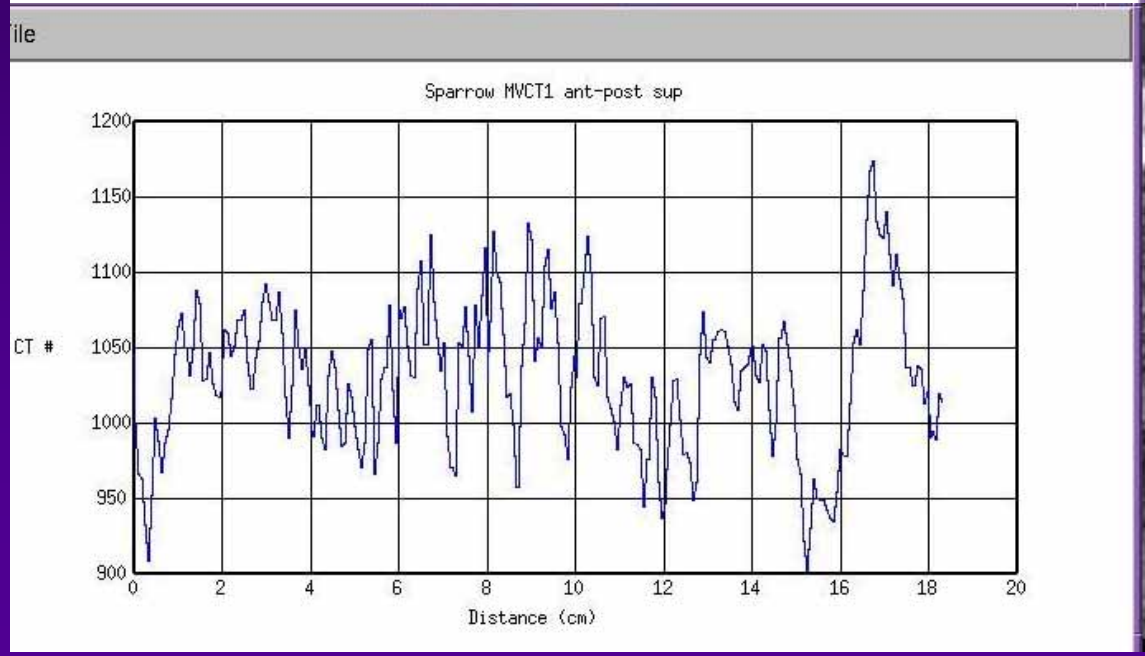


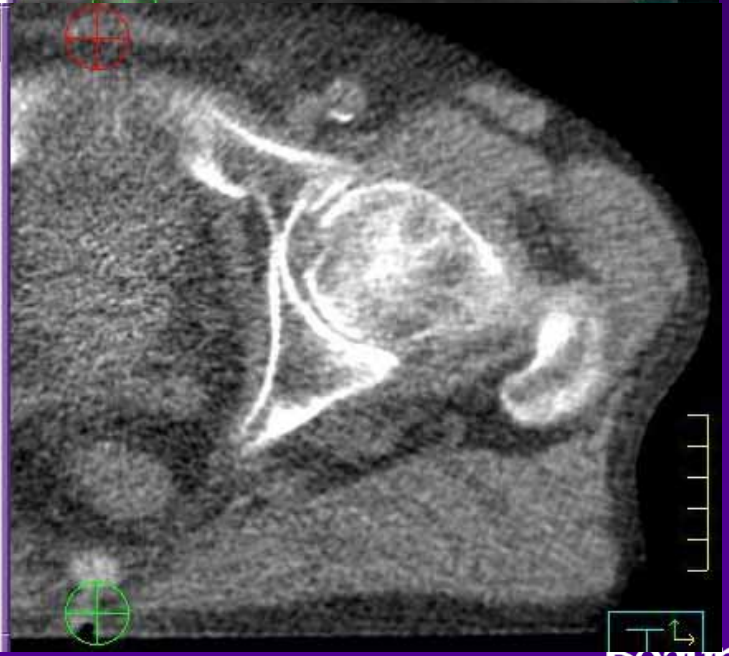


Beaumont
William Beaumont Hospital









2. Deformable Organ Registration

- Methods in Deformable Organ Registration
  - FEM, B-Spline, m-Rep
  - Maximum Mutual Information, Maximum Likelihood
  - Minimal Energy, Free Form, Demons

- Registration for prostate RT need to utilize all information of
  - Image contrast
  - Soft-tissue elasticity
  - Organ morphological shape (Atlas or patient-specific atlas information)

- Also need a friendly GUI for manual editing

3. Dose Accumulation

- Subvolume element displacement
  - Deformable organ registration
- Tissue density redistribution
  - Daily CBCT with tissue density re-mapping
- Intra-treatment motion & Interplay effect
  - Intra-motion detection & MLC segment/MU
- Subvolume description for treatment evaluation
  - TCP& NTCP with considering subvolume changes in shape, size & cell density

Dose Accumulation

Tissue density distribution

VoI element position

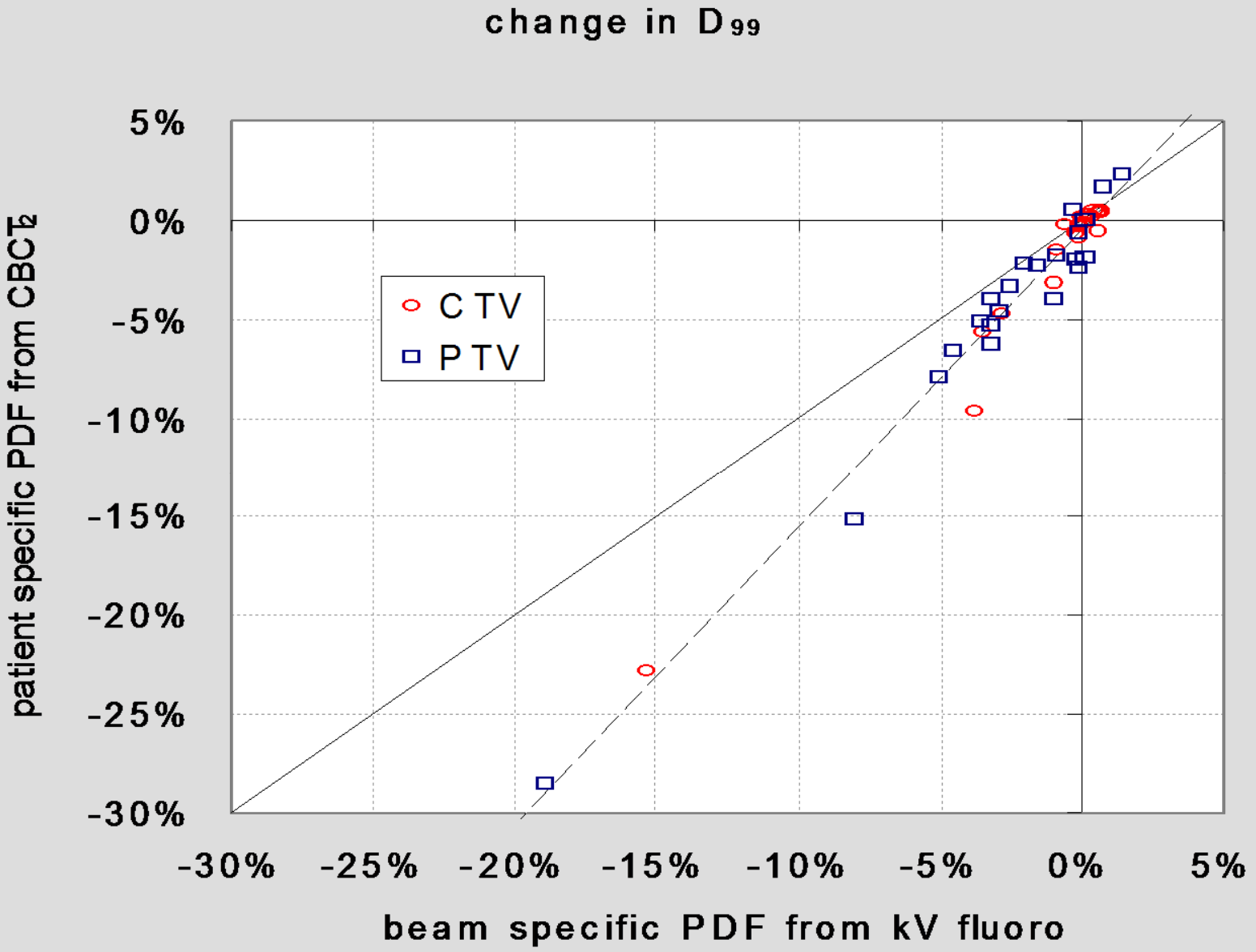
Machine output

$$D(v) = \sum_{i=1}^{n} \int_{t \in T_i} \dot{\mathrm{d}}\left(\vec{x}_t(v),\ \Theta_t(\rho),\ \vec{\phi}_t(\mathrm{u},\ \mathrm{v})\right) \cdot dt$$

3. Dose Accumulation

- Tissue Density Redistribution
  - Without considering rectal air cavity, the rectal wall dose will have maximum 6% discrepancy for single (18 MV) beam, and <3% for 5 beams IMRT.
  - Therefore, we can calculate planning dose with ‘filled’ rectum, and use the planning dose for dose accumulation without recalculating dose on the daily CT image

Interplay Effect: w/o considering intra-treatment motion



Summary

- Treatment dose assessment is possible with improving CBCT image & deform organ registration
- However, certain manual procedure may be needed for rectal wall registration
- In addition, successful image registration could be strongly dependent on image modality and imaging technique
- Without recalculating dose on each daily CT, the discrepancy in cumulative dose construction is small (<2%)
- However, the discrepancy could be large for about 25% of patients if the intra-treatment variation was not considered

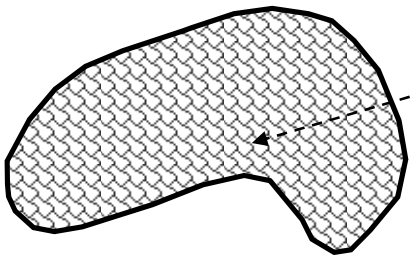
Subvolume Element Description

Given an element in organs of interest, there physical variables, '*volume*', '*position*' & '*density*', describe all physical properties interested in radiotherapy,

Deformation
Mass Preserved

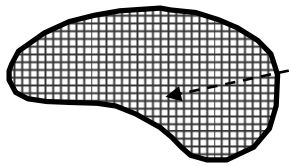
$$\{v_t,\ \vec{x}_t,\ \rho_t\}$$

$$v_t \cdot \rho_t = v_0 \cdot \rho_0$$



Shrinkage
Density
Preserved

$$\{v_t < v_0,\ \vec{x}_t,\ \rho_0\}$$



Density
Change
Volume Preserved

$$\{v_0,\ \vec{x}_t,\ \rho_t < \rho_0\}$$