

SAM-Brachytherapy II: Integrating Imaging with HDR

Imaging with limited or no access to MRI

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Conflict of Interest



Nothing to disclose



MRI: golden, but still out of reach

- GEC-ESTRO/ABS Guidelines: Defined role of MRI in IGBT
 - MRI better suited for assessing the target (the cervix and any residual disease)
- MRI: Gold Standard
- MRI:
 - Still limited availability
 - When available outside Rad Onc, logistically hard to use



What to do when:

- Limited Access to MRI: Hybrid Methods
 - MRI + CT
 - MRI + CBCT
- NO access to MRI
 - CT alone
 - CBCT alone
 - US-based



Limited Access: Hybrid Methods

- Use of MRI at least at 1st FX and identify HRCTV/IRCTV
- Continue subsequent fractions with
 - CT
 - CBCT
- Why MRI 1st FX?
- Is the Hybrid Flow an acceptable alternative to MRI for each FX?

Why at least 1 MRI? For HR CTV delineation



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doi:10.1016/j.ijrobp.2006.12.021

CLINICAL INVESTIGATION

Cervix

COMPUTED TOMOGRAPHY VERSUS MAGNETIC RESONANCE IMAGING-BASED CONTOURING IN CERVICAL CANCER BRACHYTHERAPY: RESULTS OF A PROSPECTIVE TRIAL AND PRELIMINARY GUIDELINES FOR STANDARDIZED CONTOURS

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Purpose: To compare the contours and dose–volume histograms (DVH) of the tumor and organs at risk (OAR) with computed tomography (CT) vs. magnetic resonance imaging (MRI) in cervical cancer brachytherapy.

Methods and Materials: Ten patients underwent both MRI and CT after applicator insertion. The dose received by at least 90% of the volume (D_{90}), the minimal target dose (D_{100}), the volume treated to the prescription dose or greater for tumor for the high-risk (HR) and intermediate-risk (IR) clinical target volume (CTV) and the dose to 0.1 cm³, 1 cm³, and 2 cm³ for the OARs were evaluated. A standardized approach to contouring on CT (CT_{Std}) was developed, implemented (HR- and IR-CTV_{CTStd}), and compared with the MRI contours.

Results: Tumor height, thickness, and total volume measurements, as determined by either CT or CT_{Std} were not significantly different compared with the MRI volumes. In contrast, the width measurements differed in HR-CTV_{CTStd} ($p = 0.05$) and IR-CTV_{CTStd} ($p = 0.01$). For the HR-CTV_{CTStd} this resulted in statistically significant differences in the volume treated to the prescription dose or greater (MRI, 96% vs. CT_{Std}, 86%, $p = 0.01$), D_{100} (MRI, 5.4 vs. CT_{Std}, 3.4, $p < 0.01$), and D_{90} (MRI, 8.7 vs. CT_{Std}, 6.7, $p < 0.01$). Correspondingly, the IR-CTV DVH values on MRI vs. CT_{Std} differed in the D_{100} (MRI, 3.0 vs. CT_{Std}, 2.2, $p = 0.01$) and D_{90} (MRI, 5.6 vs. CT_{Std}, 4.6, $p = 0.02$). The MRI and CT DVH values of the dose to 0.1 cm³, 1 cm³, and 2 cm³ for the OARs were similar.

Conclusion: Computed tomography-based or MRI-based scans at brachytherapy are adequate for OAR DVH analysis. However, CT tumor contours can significantly overestimate the tumor width, resulting in significant differences in the D_{90} , D_{100} , and volume treated to the prescription dose or greater for the HR-CTV compared with that using MRI. MRI remains the standard for CTV definition. © 2007 Elsevier Inc.

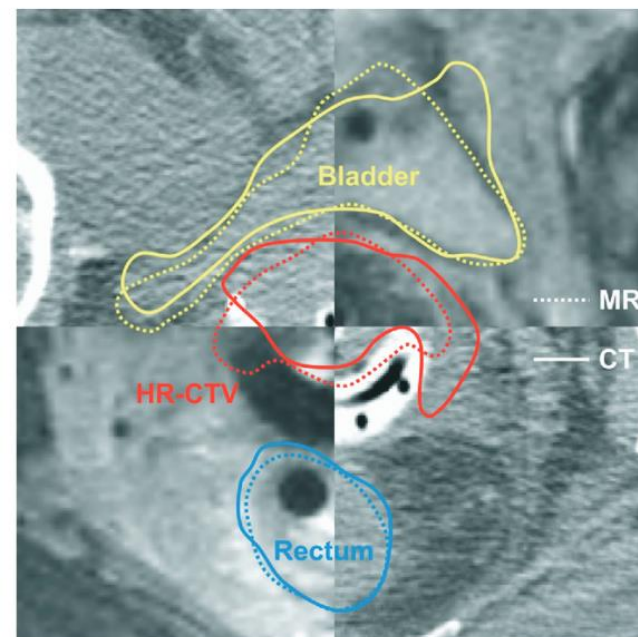


Fig. 1. Example of fusion between axial computed tomography (solid line) and magnetic resonance imaging (dotted line) scans with contours for rectum, bladder, and high-risk clinical target volume in patient with tandem and ring brachytherapy applicator inserted into cervix. Outer rectum contours overlap nicely; bladder contours show only slight deviations. The high-risk clinical target volume contour highlights the difference in lateral extension seen between computed tomography and magnetic resonance imaging and reveals difficulty in accurately assessing the lateral dimension.



MRI + CT Hybrid

Original Article

Three-dimensional High Dose Rate Intracavitary Image-guided Brachytherapy for the Treatment of Cervical Cancer Using a Hybrid Magnetic Resonance Imaging/Computed Tomography Approach: Feasibility and Early Results

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Abstract

Aims: To evaluate the feasibility and outcome of image-guided brachytherapy (IGBT) for treating cervical cancer using magnetic resonance imaging (MRI)-based planning for the first fraction followed by computed tomography (CT)-based planning for subsequent fractions.

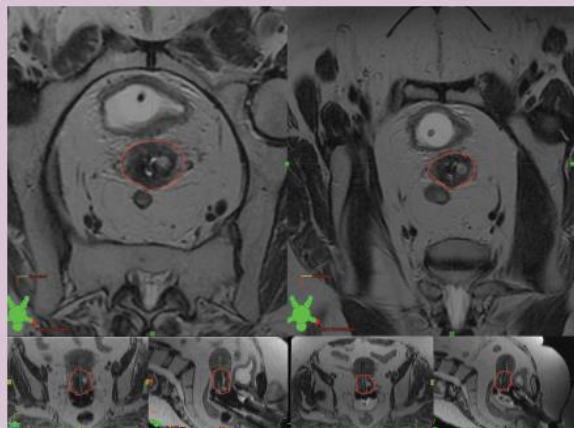
Materials and methods: Forty-four patients with cervical cancer were treated with three-dimensional high dose rate IGBT. The brachytherapy dose was 5.0–6.0 Gy × five fractions. All but five patients received concurrent weekly cisplatin at 40 mg/m². All patients received external beam radiotherapy (EBRT) with a median dose of 45 Gy over 25 fractions. Total doses for the high-risk clinical target volume (HRCTV) and organs at risk, including the rectum, bladder and sigmoid, from EBRT and brachytherapy were summated and normalised to a biologically equivalent dose of 2 Gy per fraction (EQD₂). At 3 months after therapy, any early response was assessed with positron emission tomography (PET)/CT imaging.

Results: The mean D₉₀ for the HRCTV was 83.3 (3.0) Gy. The mean 2 cm³ dose to the bladder, rectum and sigmoid colon organs was 79.7 (5.1), 57.5 (4.4) and 66.8 (5.7) Gy, respectively. All but one (2.3%) patient had a complete response. Follow-up PET/CT was carried out in 41 (93.0%) patients, of whom 38 (92.5%) had a complete response. Of the 38 patients with a complete response on PET/CT, two had local recurrences at 6 and 8 months, respectively. Actuarial 2 year local control, disease-specific and overall survival rates were 88, 85 and 86%, respectively.

Conclusion: This is the first report of three-dimensional high dose rate IGBT for the treatment of cervical cancer using a hybrid MRI/CT approach. Early results have shown the feasibility of this approach with excellent local control. Additional studies are needed to assess long-term outcomes of local control and associated morbidities.

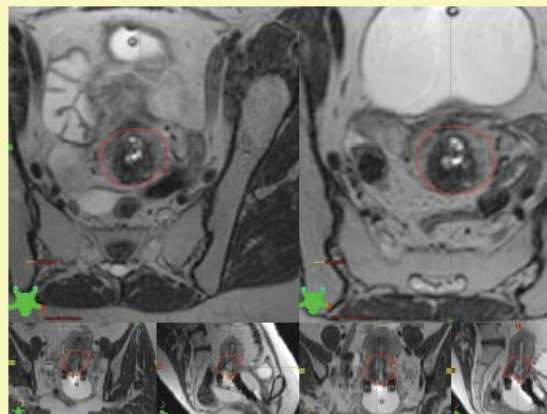
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Duke: Role of MRI for each fraction



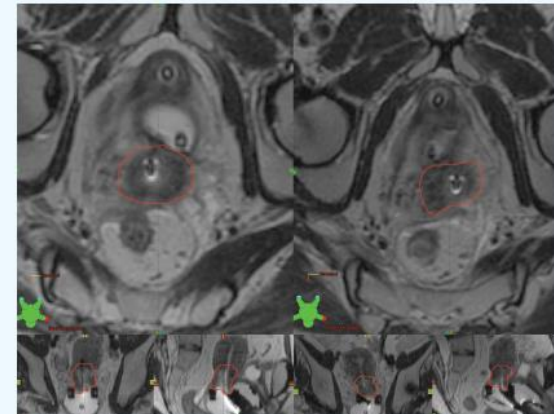
Patient 4 Fraction 2 Patient 4 Fraction 4

Figure 1. MRI based HRCTV contours for patient 4 showing good accord across fractions with minimal volume difference. Plans varied to optimize sparing of normal tissue on each fraction.



Patient 1 Fraction 3 Patient 1 Fraction 5

Figure 2. MRI based HRCTV contours for patient 1 showing subtle volume differences due to tandem rotation within the pelvis. Plans varied to optimize sparing of normal tissue on each fraction



Patient 6 Fraction 2 Patient 6 Fraction 3

Figure 3. MRI based HRCTV contours for patient 6 showing large deviation of the HRCTV due to tandem divergence into the myometrium during placement. Plans varied to cover HRCTV and spare normal tissues.

- The HRCTV volumes displayed variability between fractions (median 47% @planning, 33%), and resulted in variability in the plans developed to meet GEC-ESTRO dose goals.
- Use MRI for each FX

J. Chino, J. Maurer, B. Steffey, J. Cai, J. Adamson, O. Craciunescu, "IS AN MRI REQUIRED ON EACH FRACTION? AN EXPERIENCE WITH MRI GUIDED BRACHYTHERAPY FOR CERVICAL CANCER", World Congress of Brachytherapy, Barcelona 2012, S107.



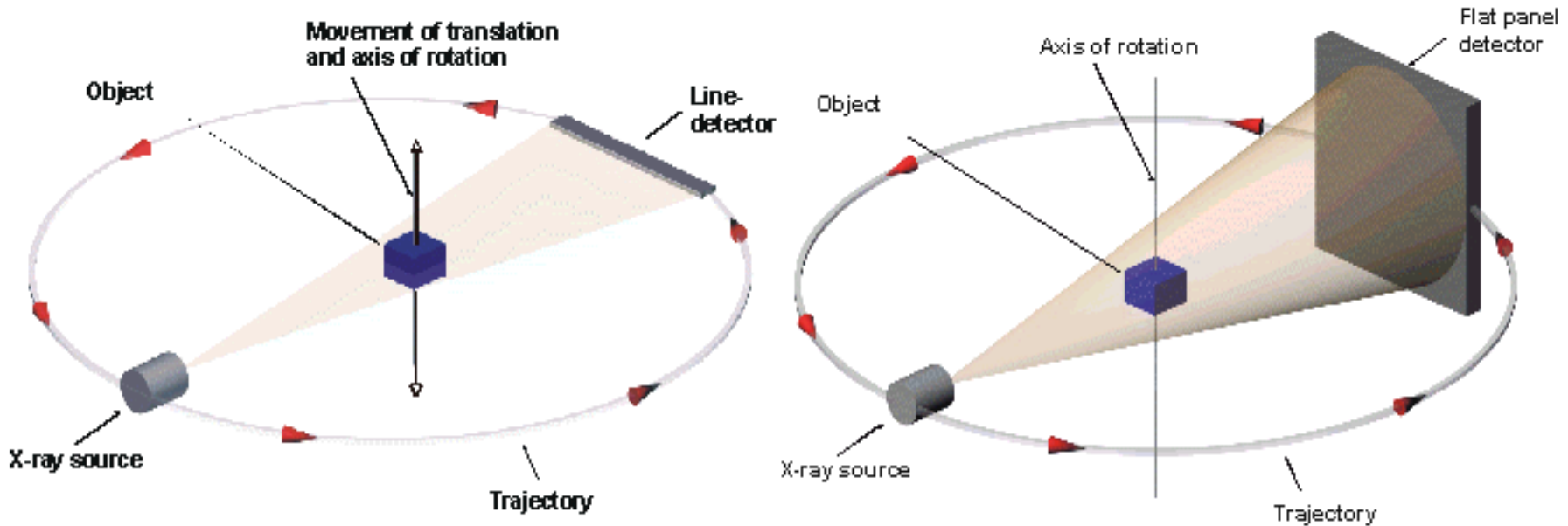
MRI-CBCT Hybrid

- Similar with MRI+CT
- Challenges related to quality of CBCT
- Commercially available systems:
 - Varian, Acuity
 - Nucletron, Simulinx



Basic Principle

- Regular CT vs. CBCT: acquisition



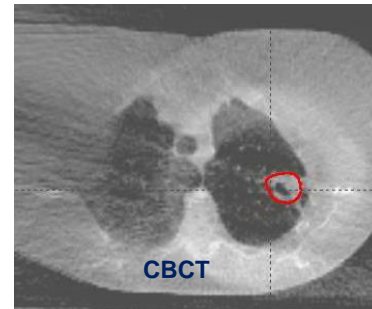
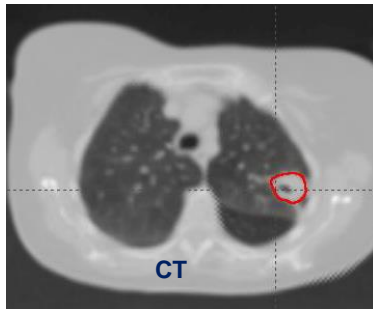
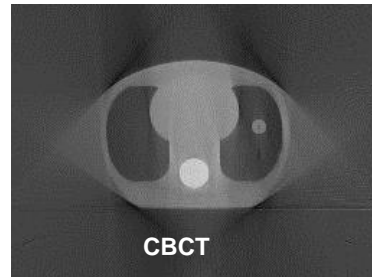
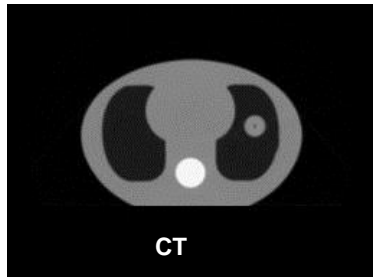
**Regular CT: fan-beam
line-detector
multiple-rotations**

**CBCT: cone-beam
flat panel-detector
one-rotation**

Limitations vs. CT



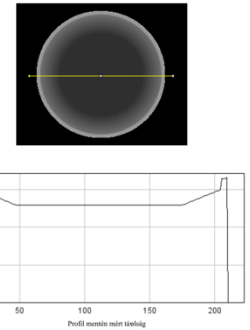
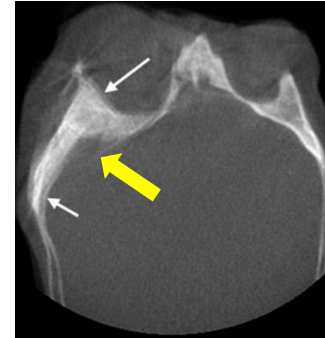
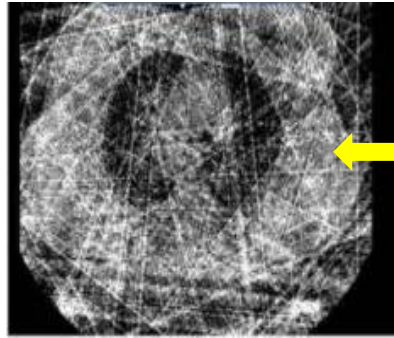
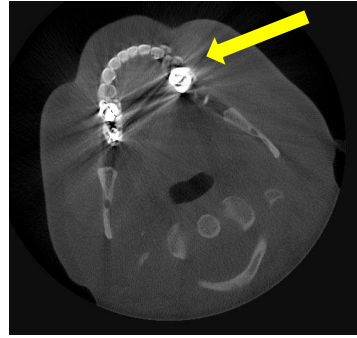
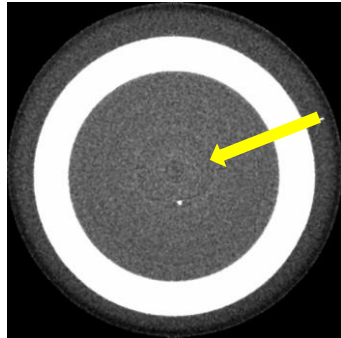
- Regular CT vs. CBCT: image quality



More noise, lower SNR, and less accurate HU number for CBCT due to more scatter in CBCT imaging

Limited FOV and scan extent of CBCT

Artifacts



Ring artifact by defective detector elements

Metal streak artifact by photon starvation

Under-sampling aliasing

Motion-induced blurring

Beam hardening-induced cupping artifact

1. Ring artifact & motion induced blurring : R Schulze et al, Dentomaxillofacial Radiology 2011
2. Metal streak artifact: http://www.exxim-cc.com/metal_artifact_reduction.html
3. Beam-hardening induced cupping artifact: http://oftankonyv.reak.bme.hu/tiki-download_file.php?fileId=434&display



CBCT – General Image Quality Issues

- The imaging quality in a kV-CBCT scanner is inferior to a regular fan-beam CT scanner due to increased photon scatter intercepted by the larger 2D detection panel leading to **reduced imaging contrast**, increased cupping, streaking artifacts, and less accurate HU.
- The spatial resolution of the CBCT scanner in the axial direction is superior to a fan beam CT scanner, however the CT spatial resolution is adequate enough.
- CBCT imaging is slower than most regular fan-beam CT scanners.
- Limited FOV and Sup-Inf scan extent



CBCT in Brachy

- Applicator reconstruction
- OAR segmentation (as compared to CT and/or MRI)
- Model-based dose calculations on CBCT
 - Calibration of the kV-CBCT scanner in terms of HU versus ρ_e is essential for model based dose calculation algorithms, but not important for conventional TG43 in water calculations
 - No published data yet
 - “Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation”, L. Beaulieu et al, Med. Phys. 39 (10), October 2012.



Brachy Suite



BrachySuite Console



CBCT Console

**+ Access to 1.5 T MRI in Rad Onc on
same hallway**



CBCT Image Quality

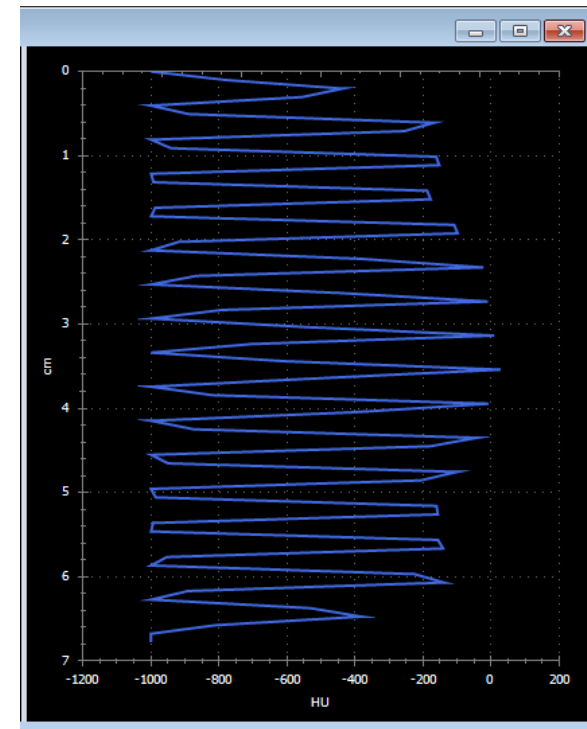
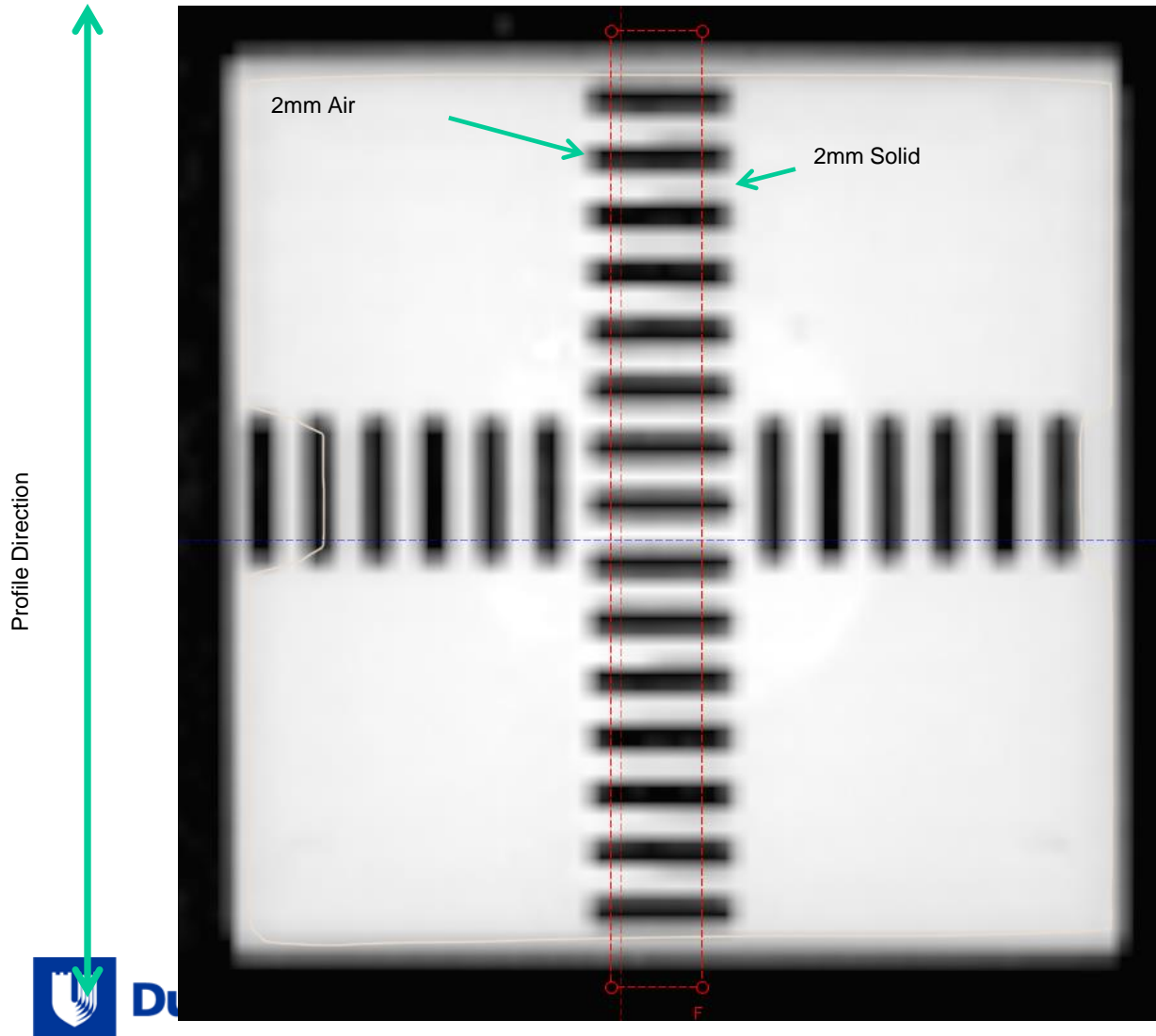
- Understand the effects of scan slice thickness vs reconstructed slice thickness on resolution and contrast in CBCT images acquired on the Acuity.
 - Image quality for soft tissue contouring
 - Image quality for applicators reconstruction
- Understand artifacts
- Understand limitation due to imaging parameters and patient size



Effects of Slice Thickness vs. Reconstructed Slice Thickness

- Resolution
 - Line pair insert from the Steev phantom
 - Scanned the phantom twice – once with 1mm slice thickness (chosen prior to scanning) and again with 2mm slice thickness.
 - Using the “Reconstruct Existing Scan” option on the Acuity: the 2mm scan was reconstructed a second time with 1mm slice thickness
 - The filter and ring artifact suppression remained at default values for the scans and reconstructions
- Contrast
 - CatPhan low contrast insert
 - Scanned twice – 1mm slice thickness and 2mm slice thickness
 - No additional reconstructions
 - Filter and ring artifact suppression at default values

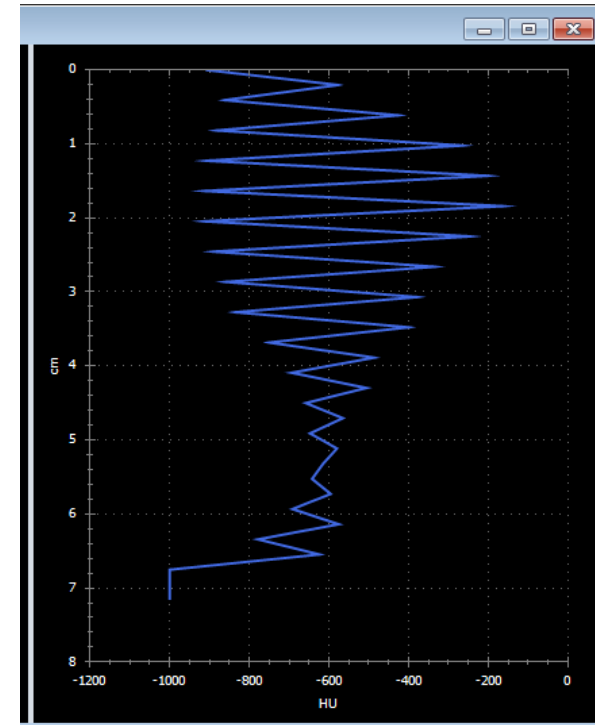
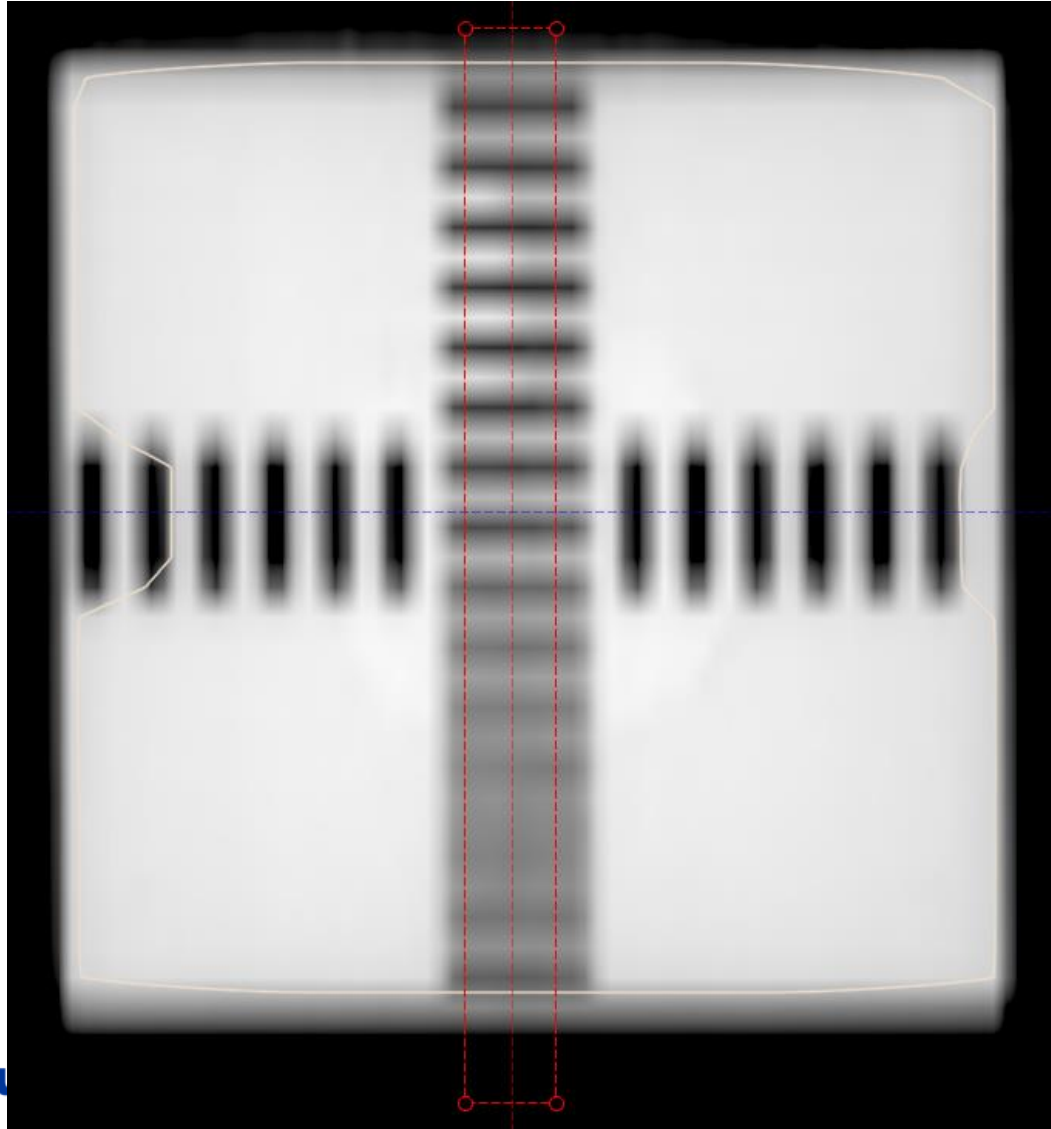
Resolution: 1mm Scan 1mm Recon



Resolution: 2mm Scan 2mm Recon



Profile Direction

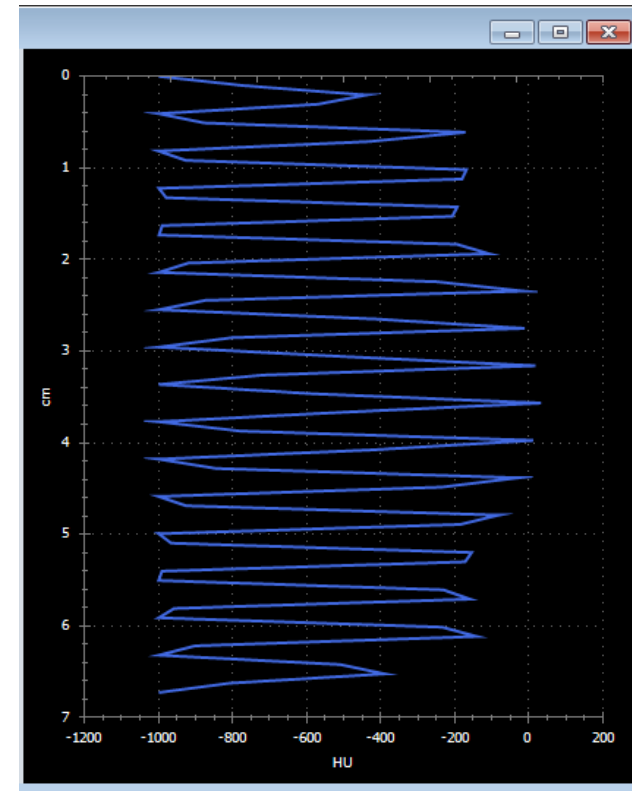
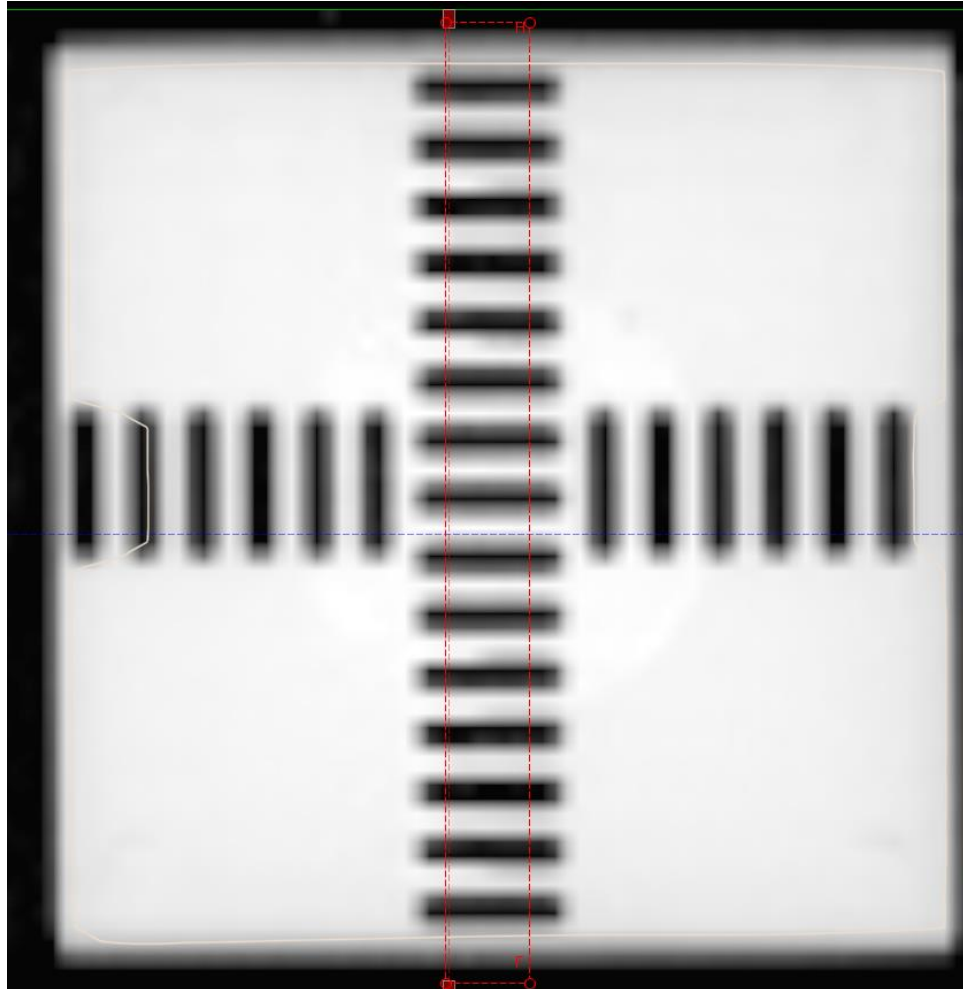


DU

Resolution: 2mm Scan 1mm Recon

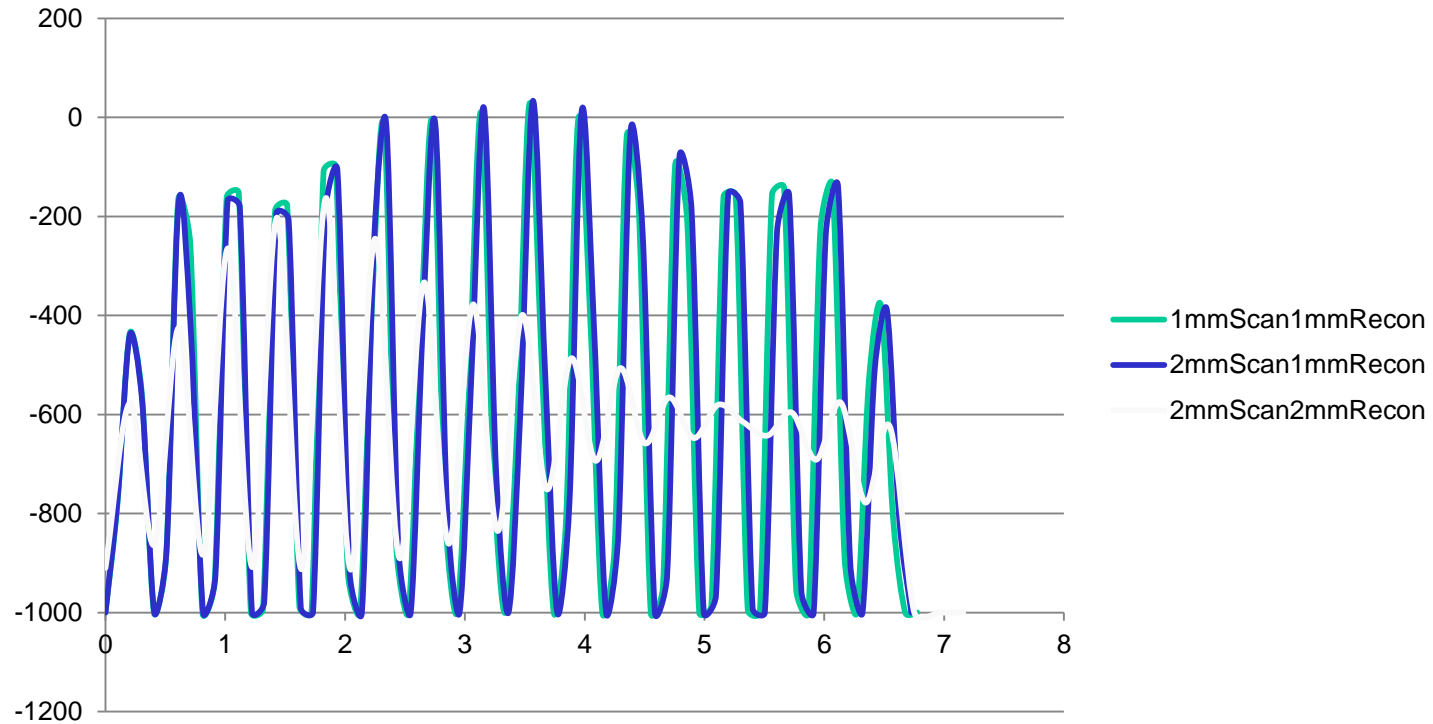


Profile Direction





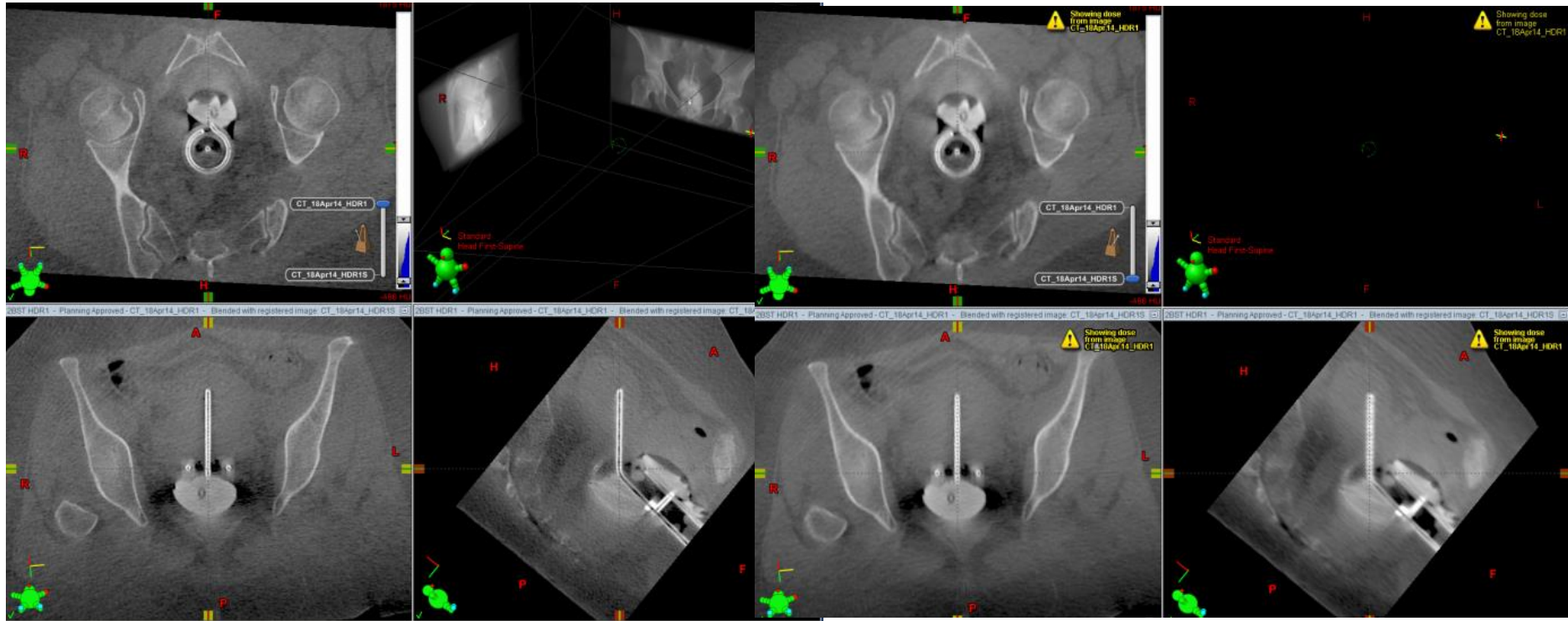
Resolution: Profiles



Reconstructing the 2mm scan at 1mm recovered the full resolution of the 1mm scan



Slice thickness



**1mm rec
Applicator Reconstruction**

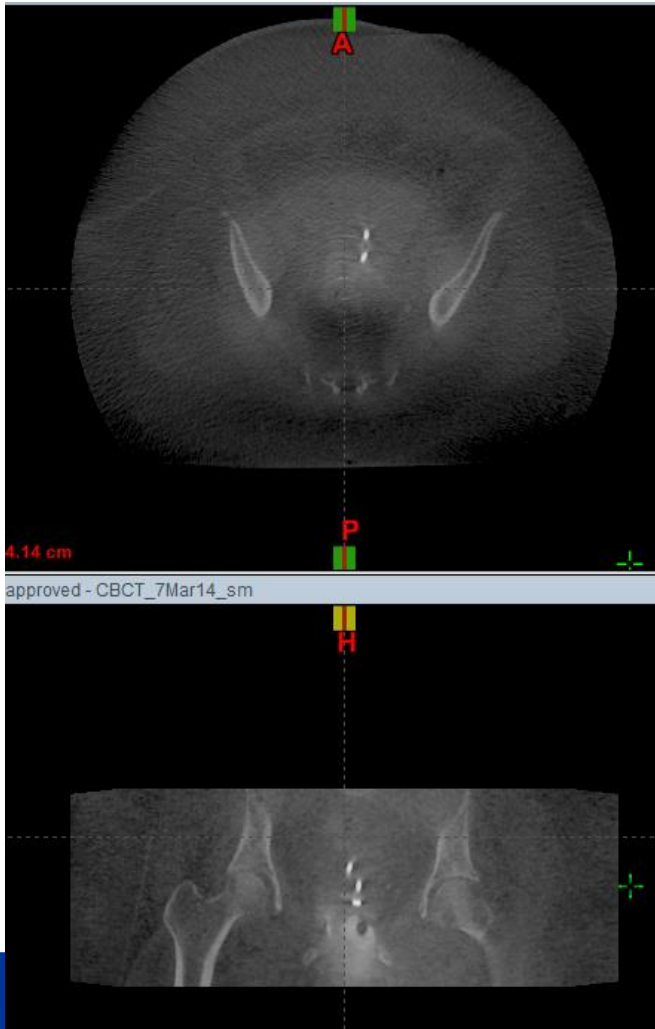
**2.5 mm
OAR Contouring**

Artifacts: ring artifacts



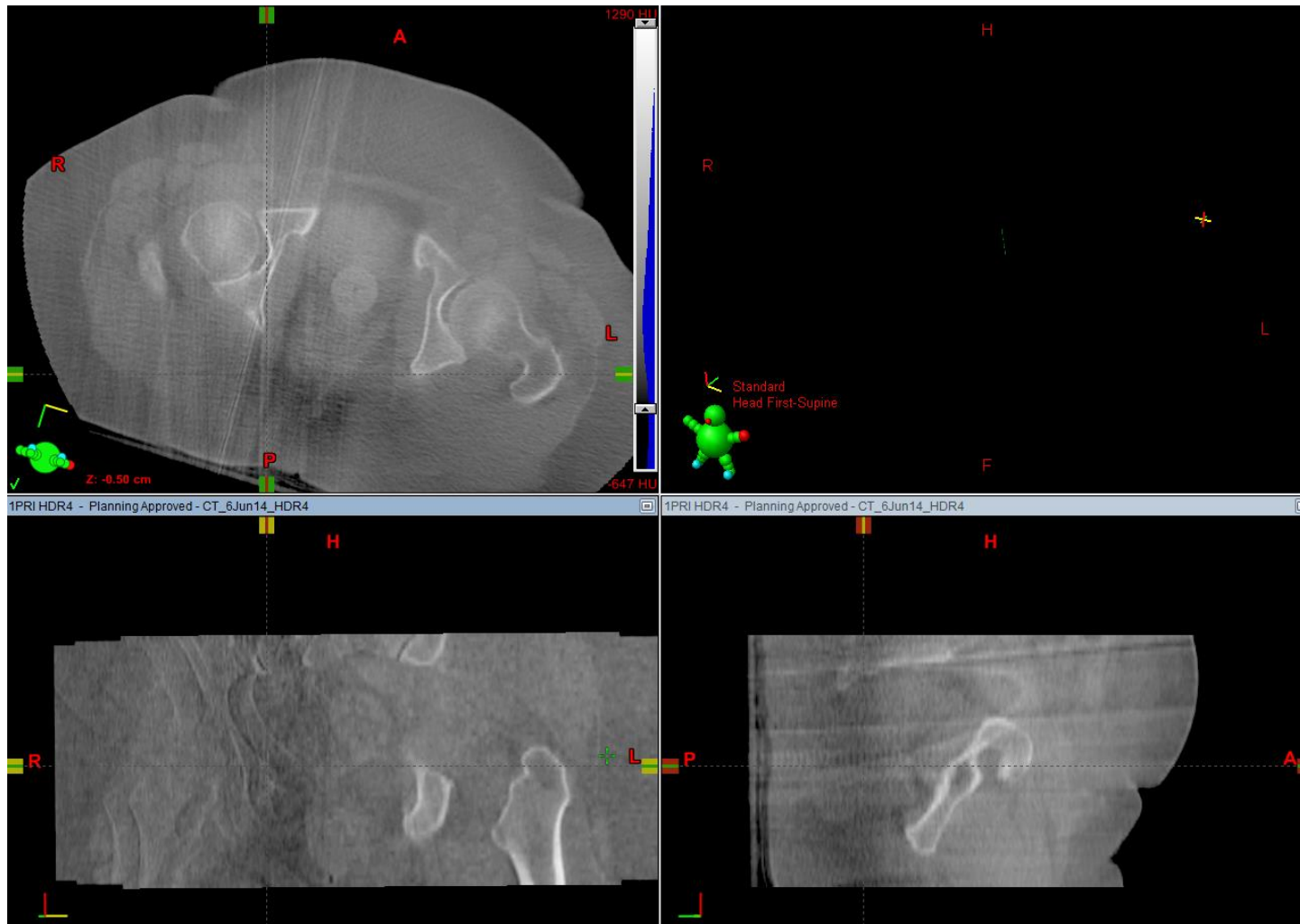
Original Acquisition

After Smoothing and Strong Ring Artifact Correction (RAC)





Artifacts: Motion artifact

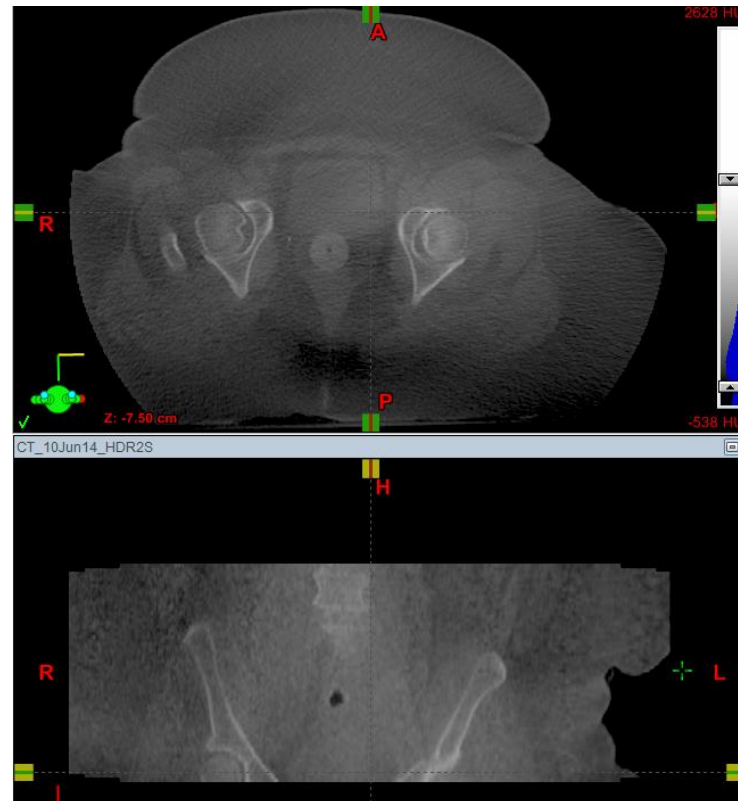




Artifacts:

Bow tie filter construction offset at imaging

Different FX, centered, patient + 2.5 mm slices, smooth, Strong RAC





Artifacts: Contrast in Vaginal Balloons

20% IsoVue, 80% Saline

5% Isovue, (5% Saline)

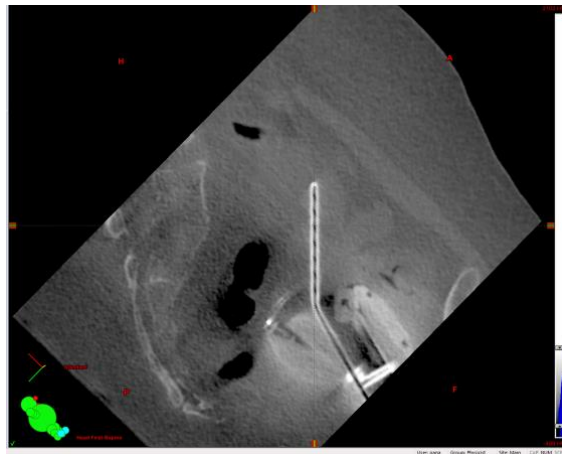
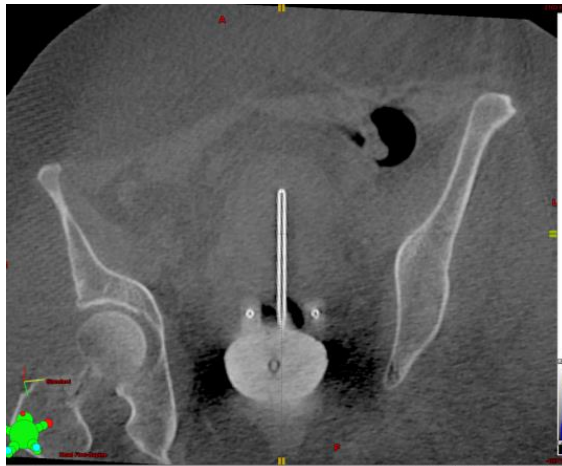




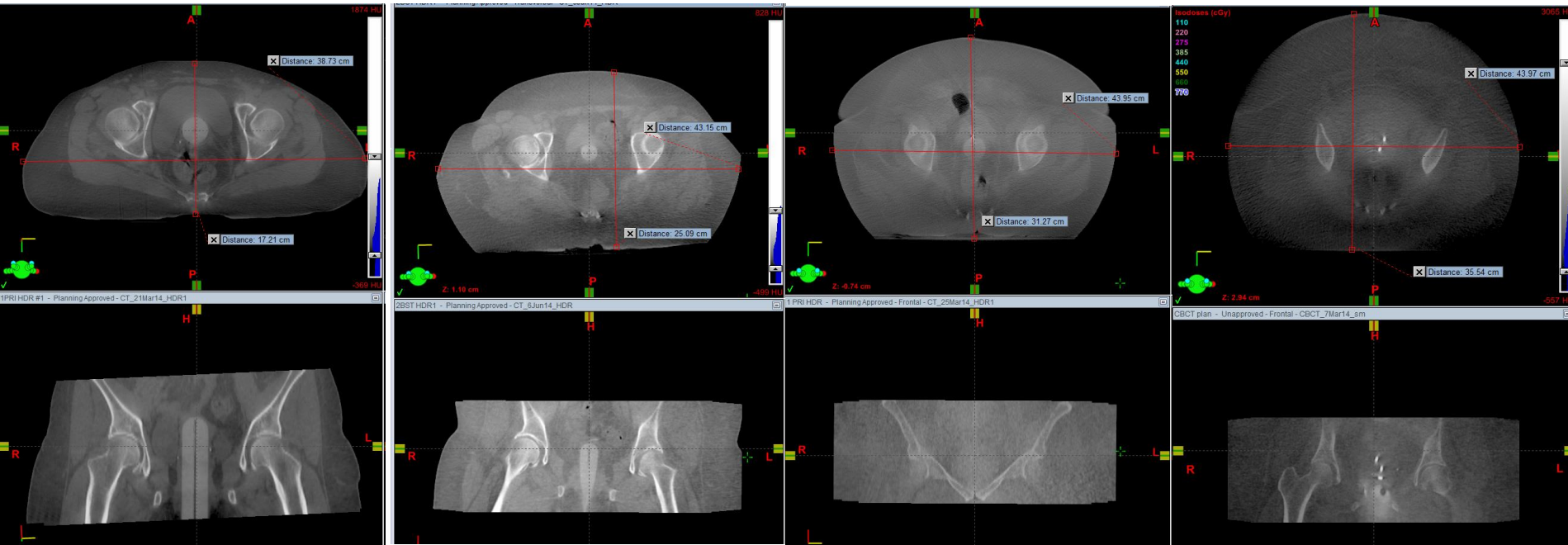
Image Quality vs. Patient Size

AP = 17 cm

AP = 25 cm

AP = 31 cm

AP = 35 cm



Technique: 150 SID, kVp = 125 , mA = 80, ms = 13

At Duke, we are in the process of investigating changes in techniques and SID to improve image quality for large AP separations.



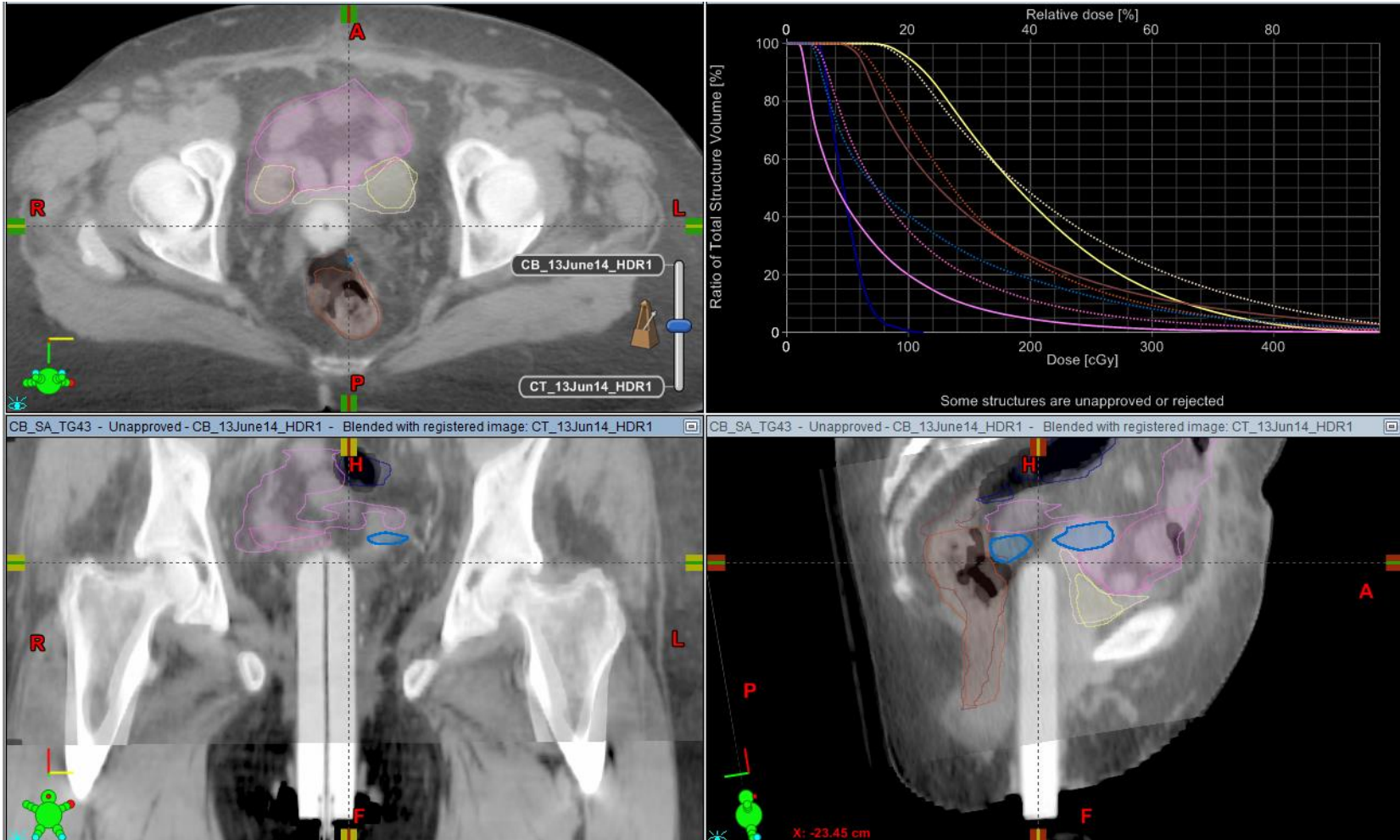
CBCT vs CT





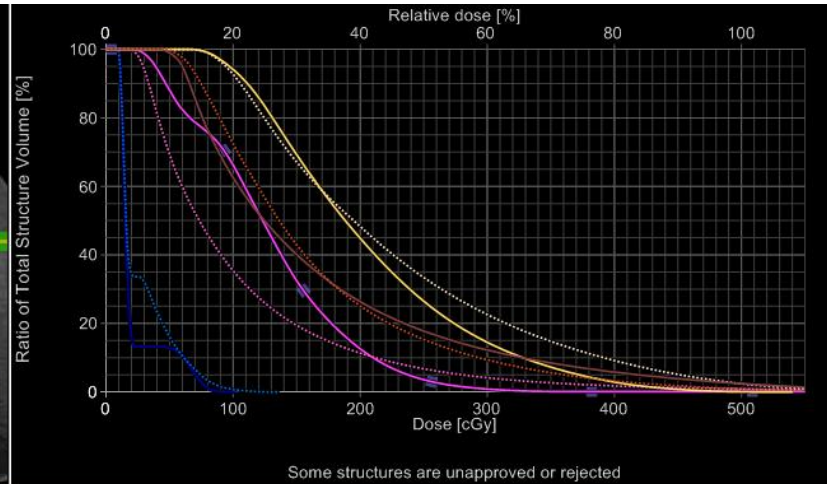
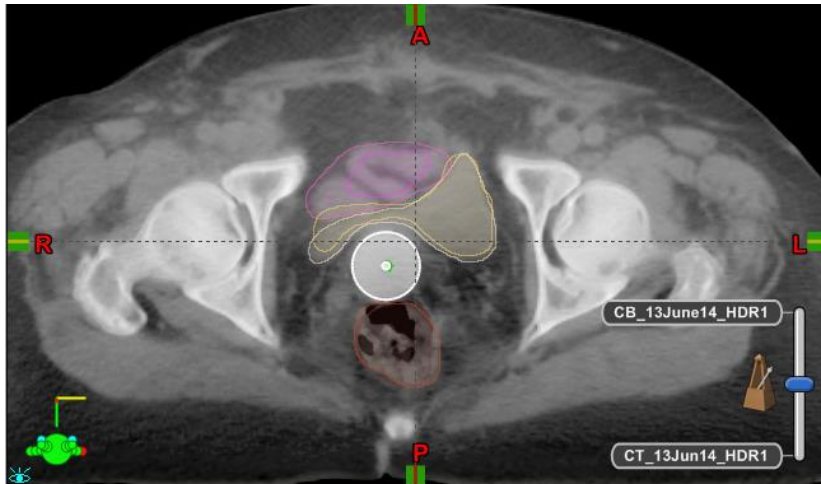
CT vs CB contours (User 1, MD Resident)

All CT contouring was done by dosimetrist



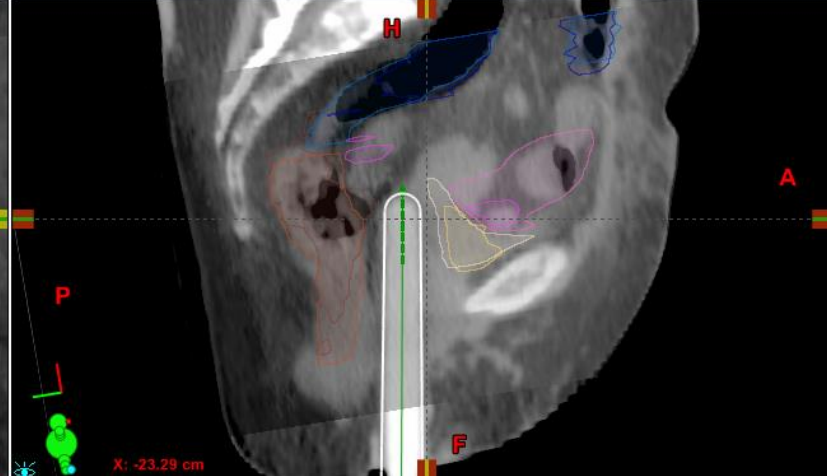
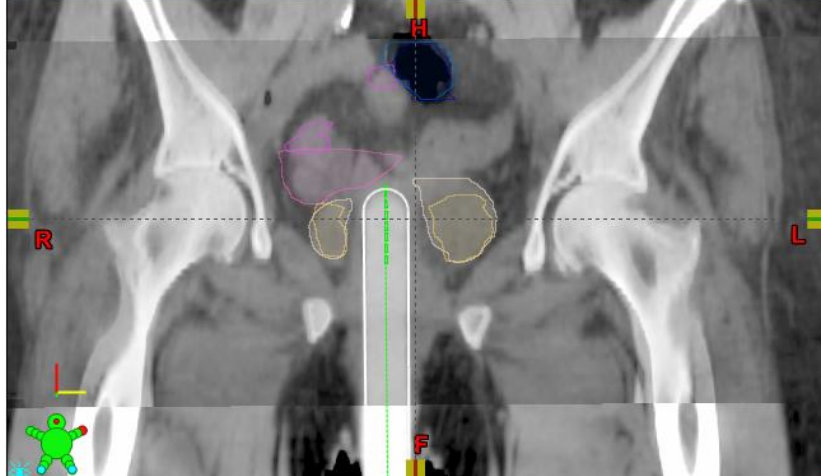


CT vs CB contours (User 2,MD)



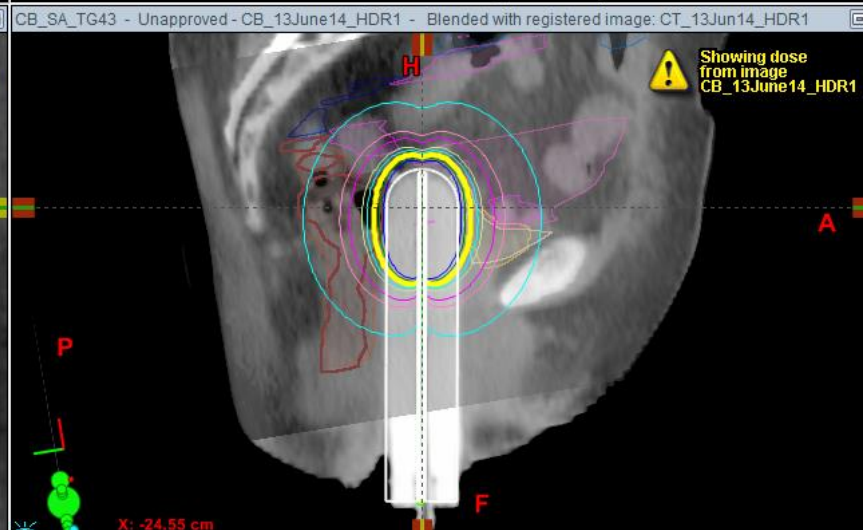
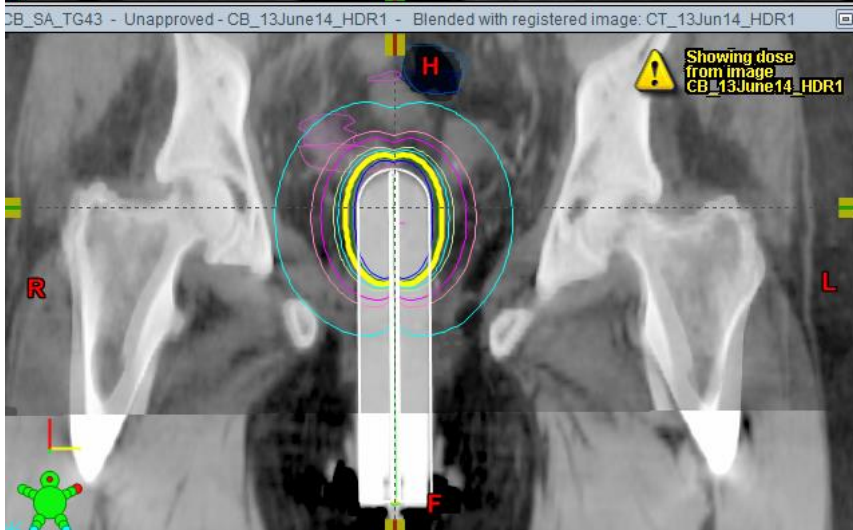
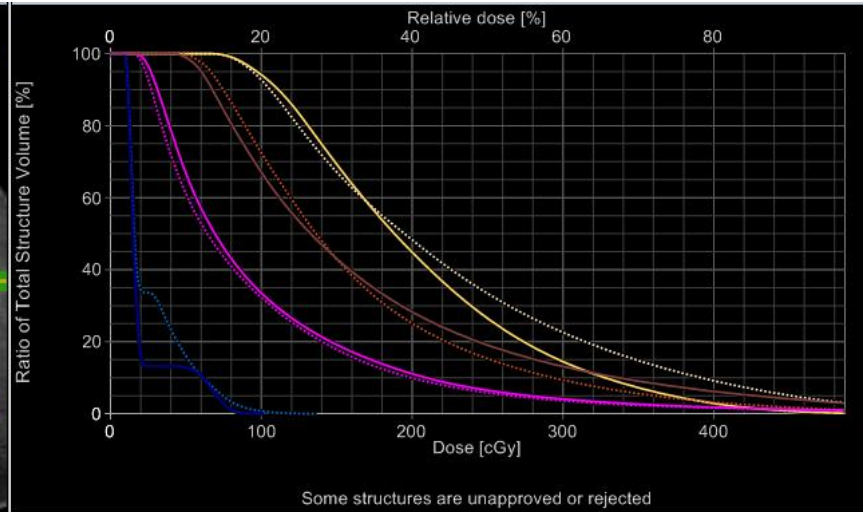
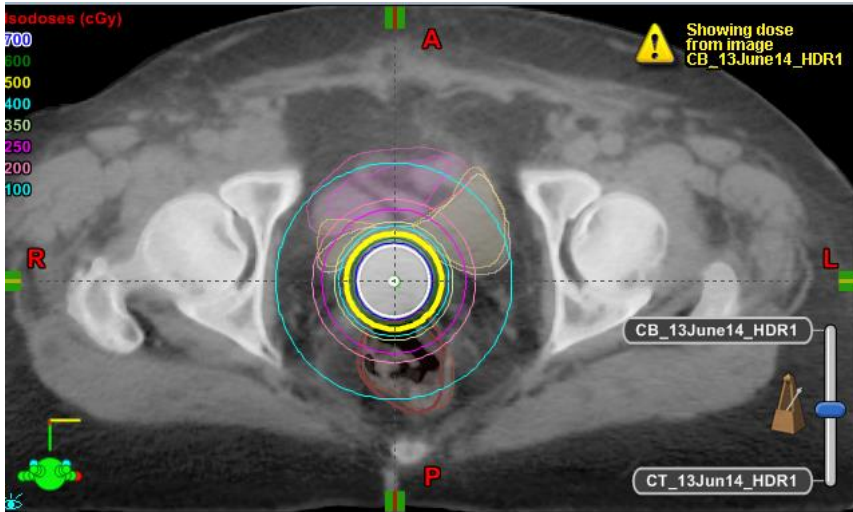
CB_SA_TG43 - Unapproved - CB_13June14_HDR1 - Blended with registered image: CT_13Jun14_HDR1

CB_SA_TG43 - Unapproved - CB_13June14_HDR1 - Blended with registered image: CT_13Jun14_HDR1





CT vs CB contours (User 3,CMD)



Examples from Duke's HDR GYN Practice



- FLOW (if T&R, T&O, Capri)
 - US-aided applicator insertion (T&R, T&O)
 - CBCT
 - MRI (patient moved to MRI room)
 - Planning: CBCT used for applicators, MRI for target + OARs
 - CBCT right before TX
- FLOW (VBT)
 - Marker insertion (FX 1 only)
 - Cylinder insertion
 - CBCT (planning from template done simultaneous with imaging)
 - TX
 - Post TX plan on CBCT: OAR contouring on CBCT
 - For selected patients, CT acquired for plan and CBCT before TX



Retrospectively

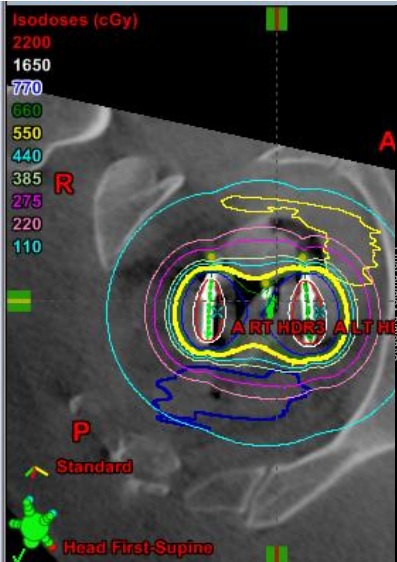
- Compare CT vs CBCT contours for OARs
 - Different users
- Compare dose metrics ($D_{2\text{cm}^3}$) for OARs between planning image and pre-TX image
 - CBCT volumes vs. CBCT volumes
 - MRI volumes vs. CBCT volumes
- Establish if MRI + CBCT Hybrid (1FX MRI, subsequent CBCT) is an acceptable alternative



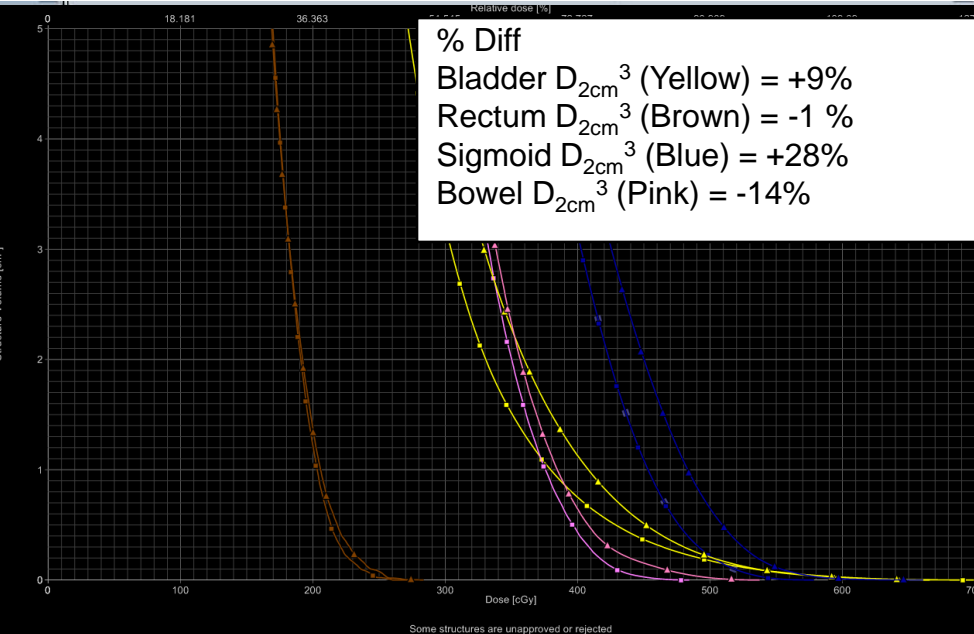
Examples

Larger variations between:

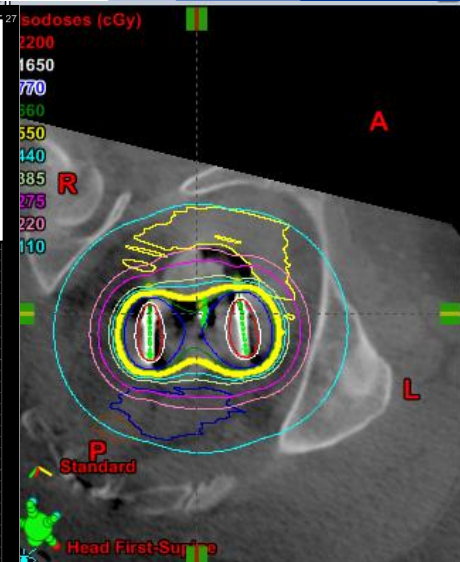
- 1) planning and pre-TX contours**
- 2) planning MRI and CBCT contours**



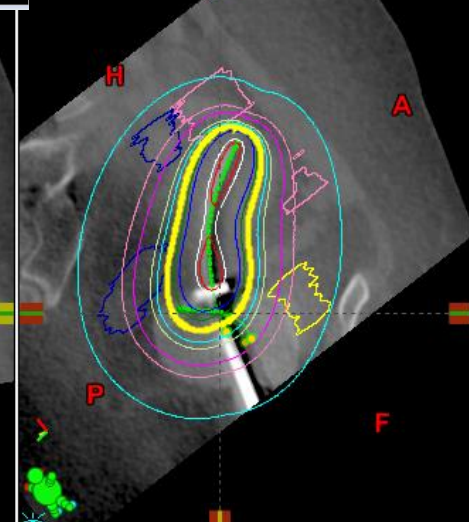
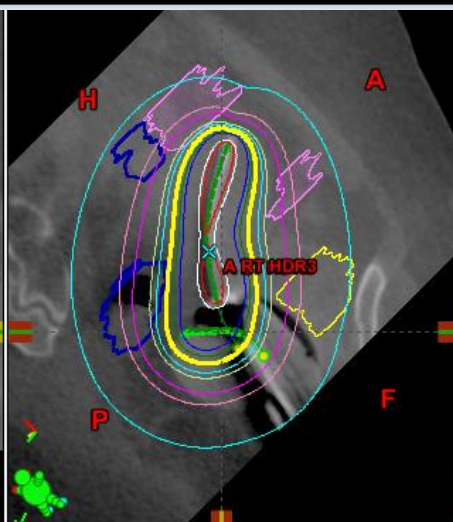
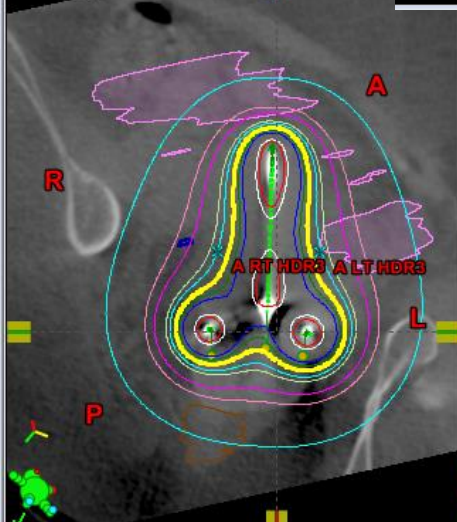
2BST HDR3 - Planning Approved - CT_25Apr14



% Diff
 Bladder D_{2cm^3} (Yellow) = +9%
 Rectum D_{2cm^3} (Brown) = -1 %
 Sigmoid D_{2cm^3} (Blue) = +28%
 Bowel D_{2cm^3} (Pink) = -14%

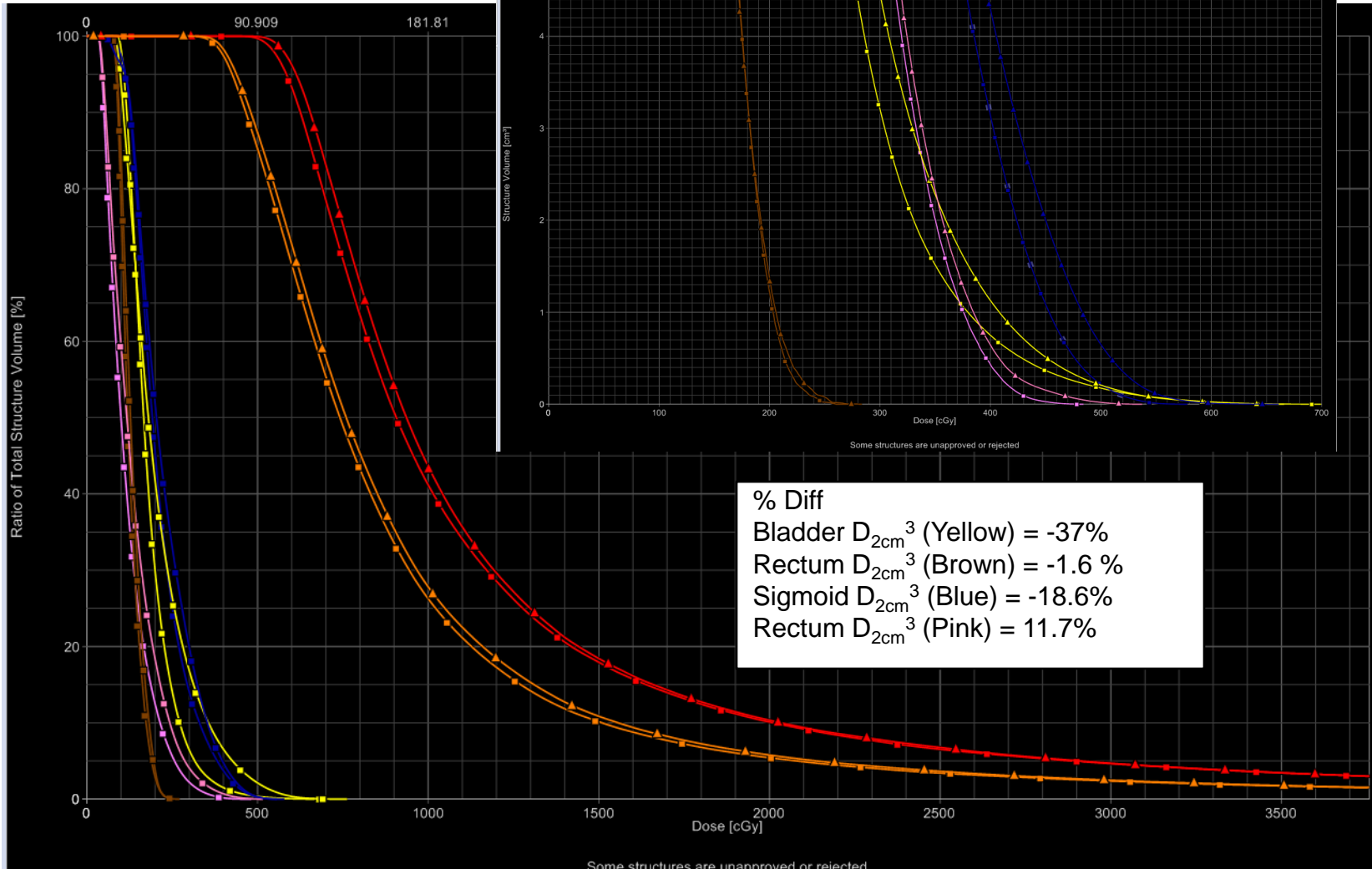


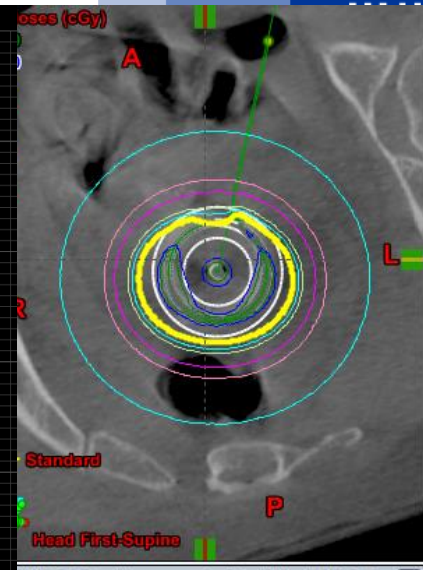
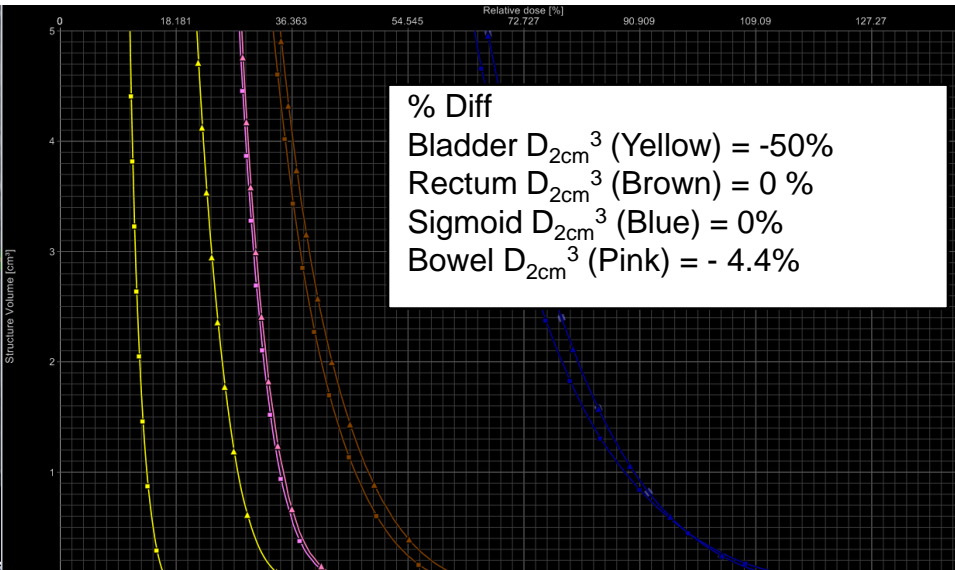
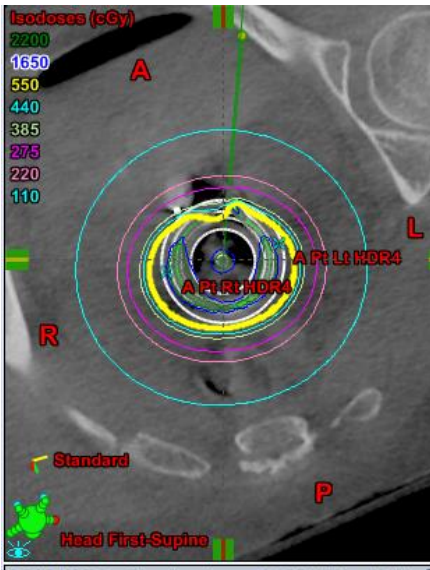
2BST HDR3 POS - Unapproved - CB_25Apr14_HD...



T&O, Planning (Triangles) ; Pre-TX (squares): CBCT contours

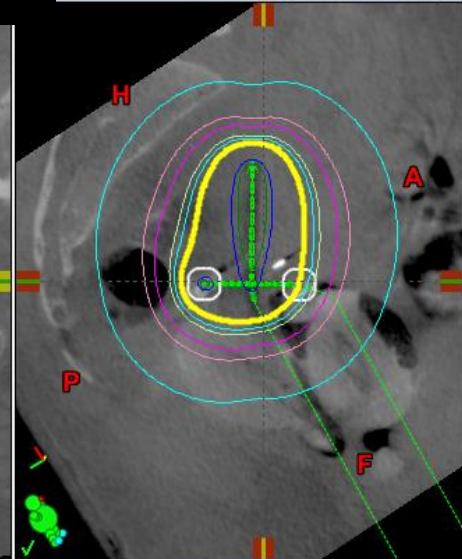
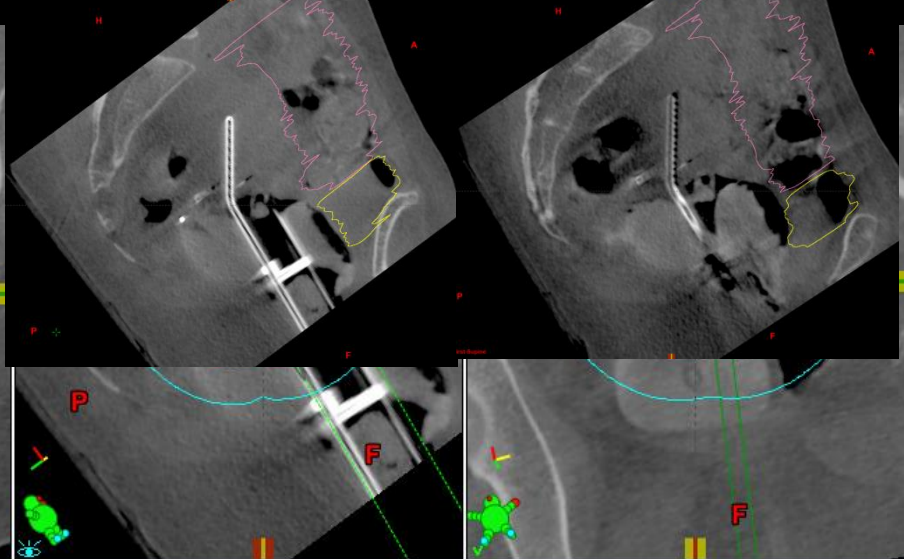
Planning MRI (Squares) vs Pre-TX CBCT volumes (Triangles)



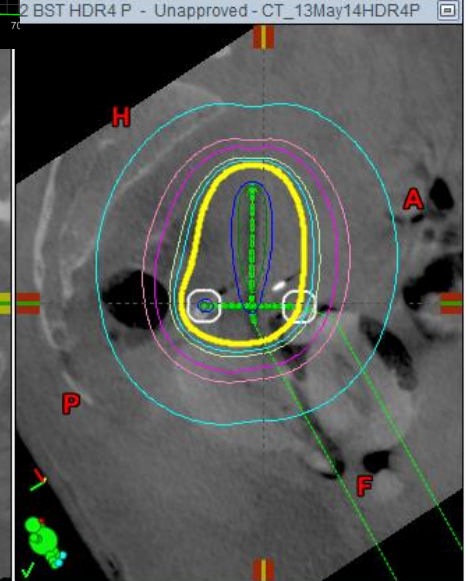
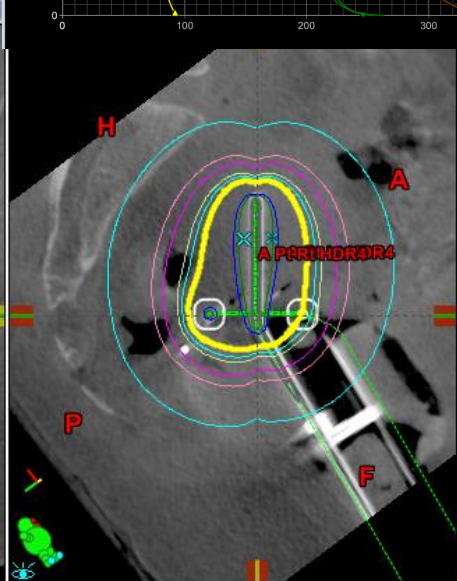
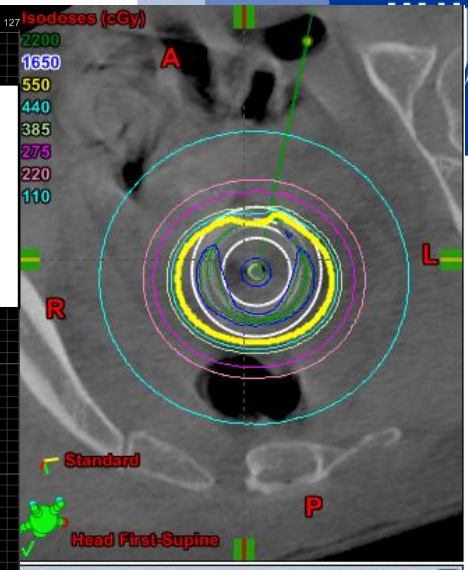
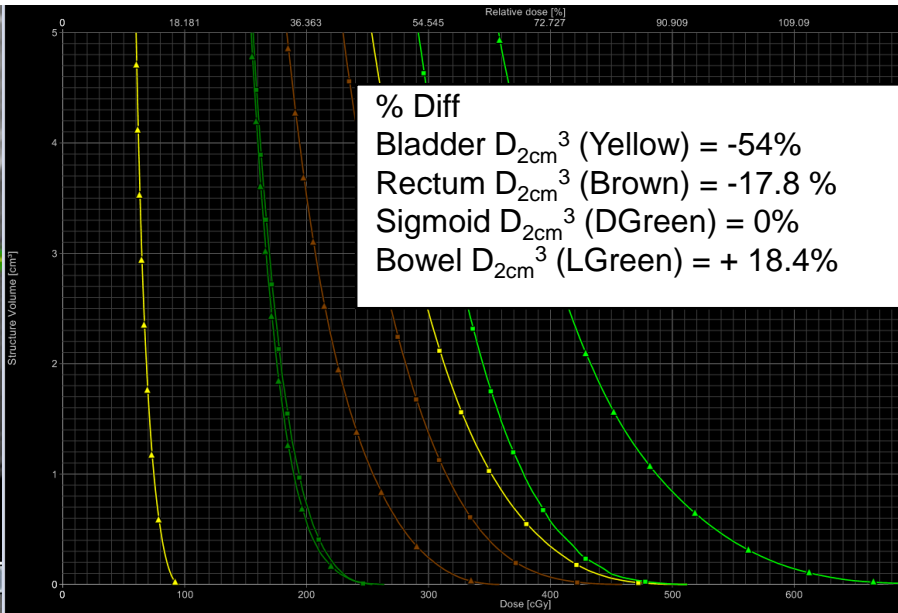
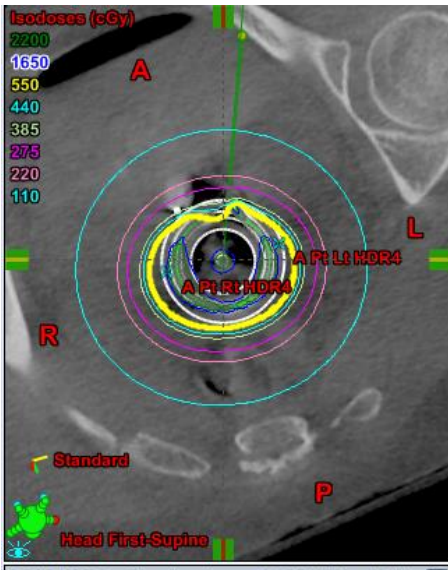


2 BST HDR4 - Planning Approved - CT_13May14_H...

T HDR4 P - Unapproved - CT_13May14HDR4P



T&R, Planning (Triangles) ; Pre-TX (squares): CBCT contours

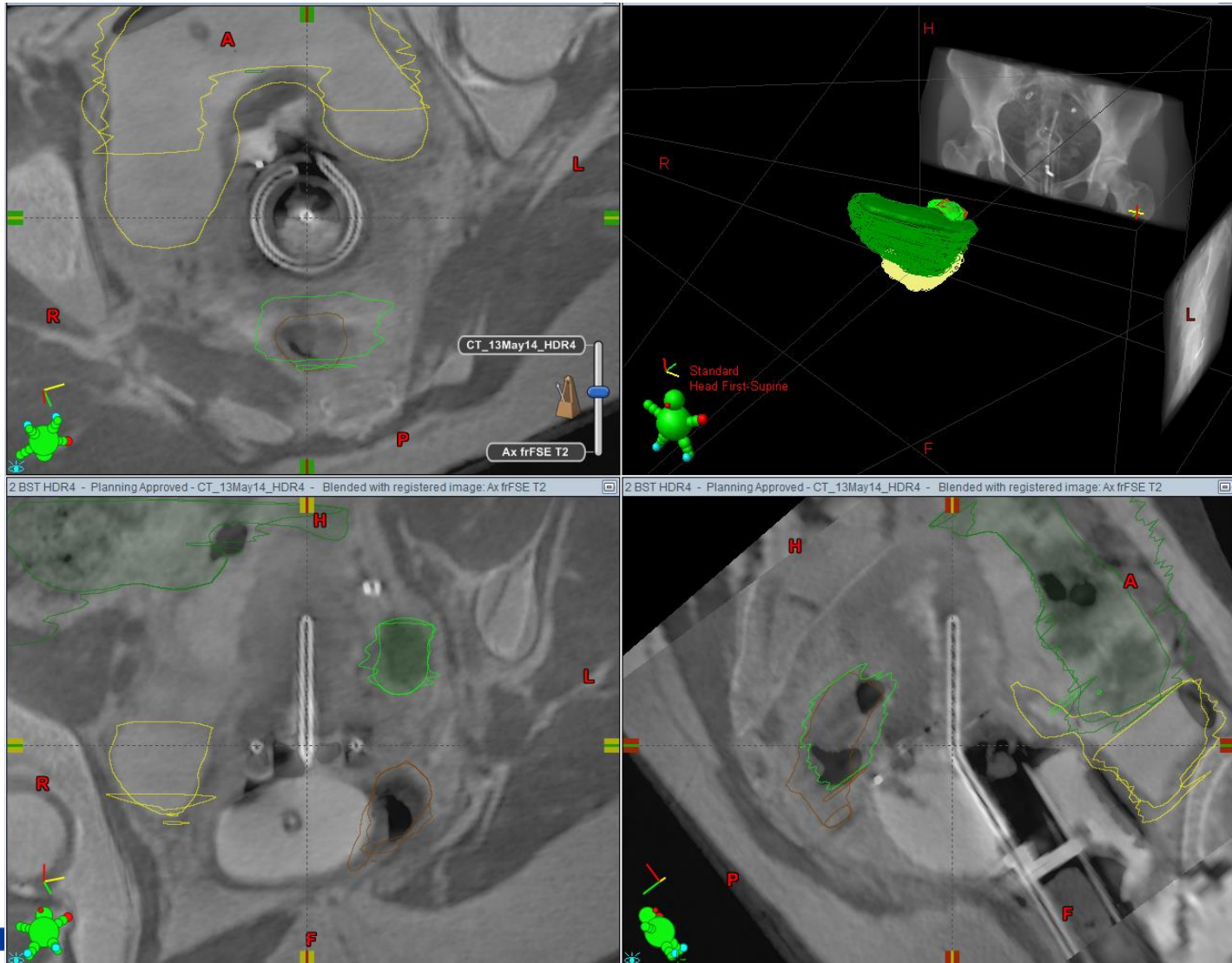


T&R, Planning (Squares) ; Pre-TX (Triangles): MRI vs.

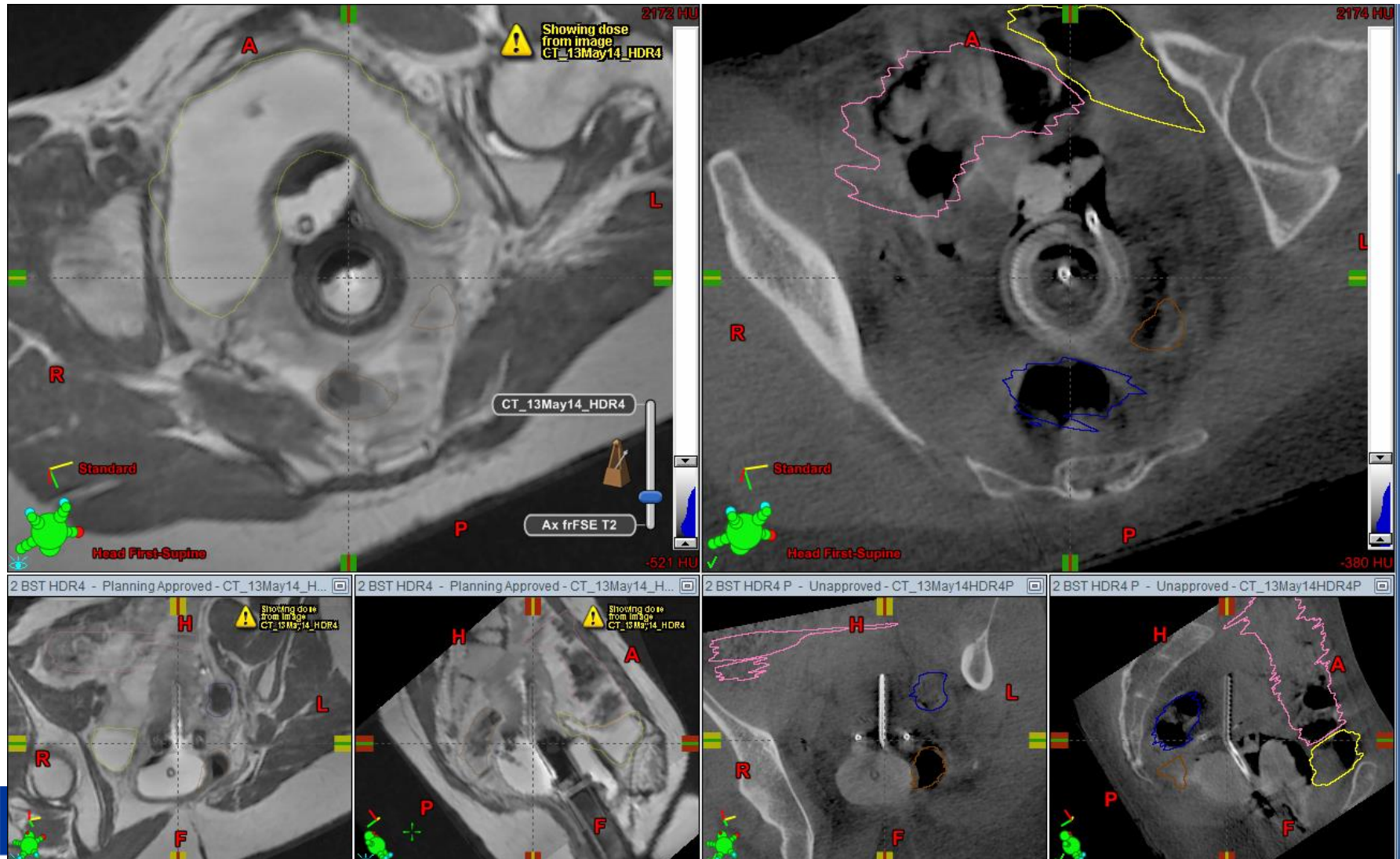
CBCT contours



Variations in OAR contouring between planning MRI and planning CBCT



Completely different image quality between planning MRI and pre-TX CBCT

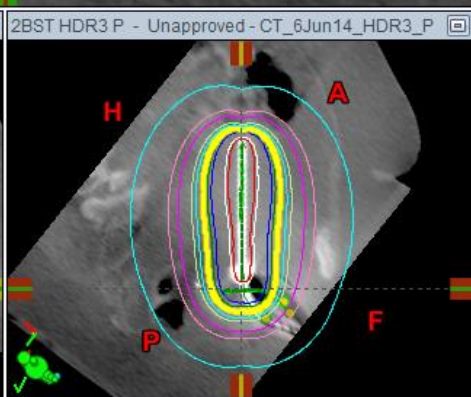
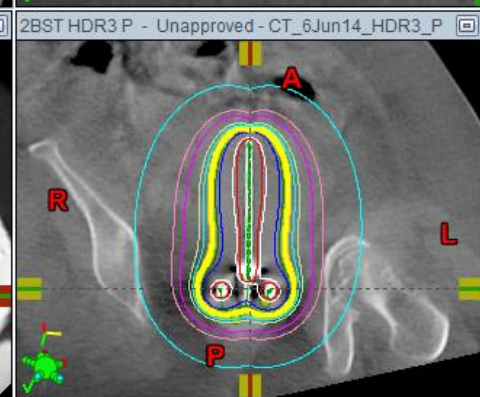
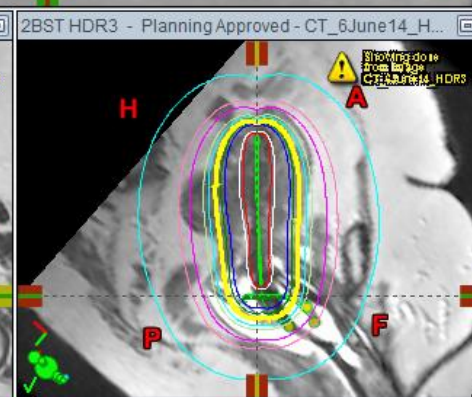
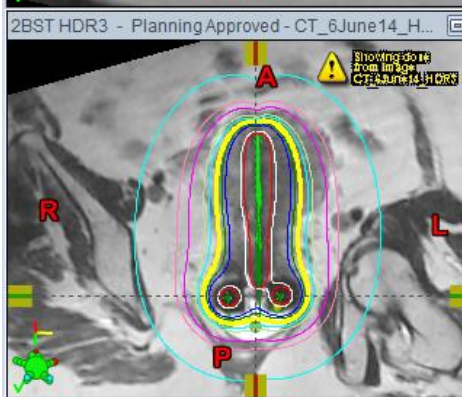
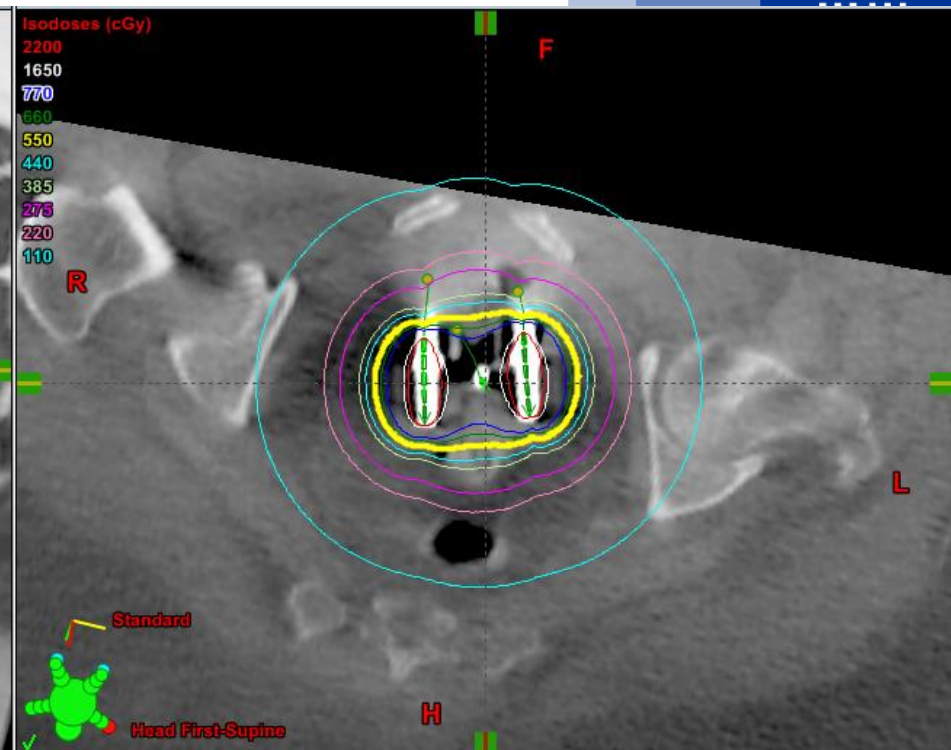
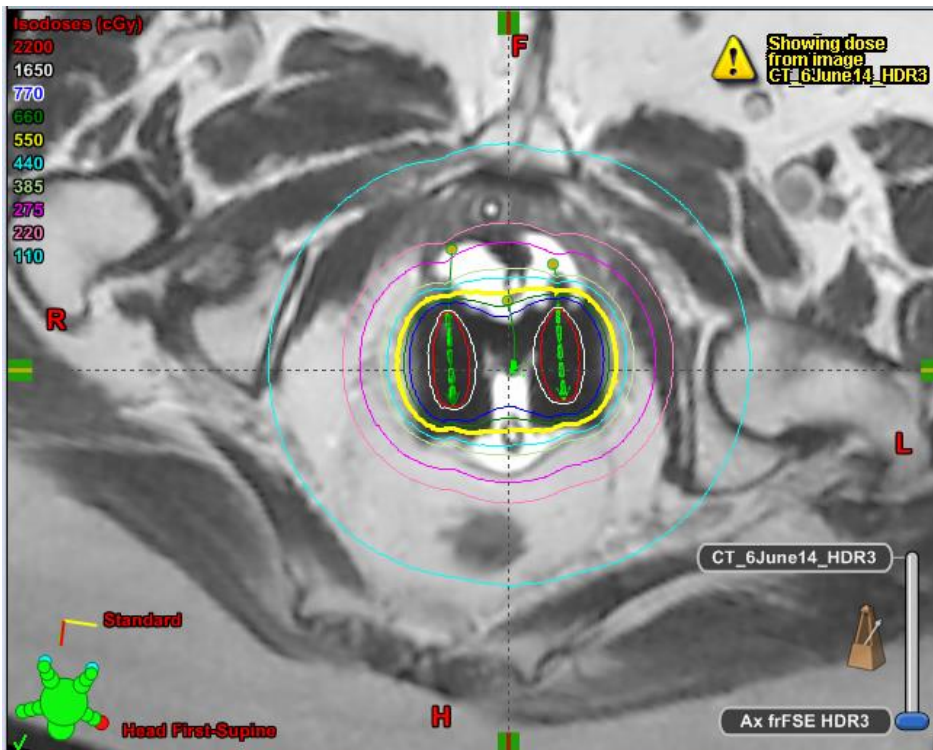




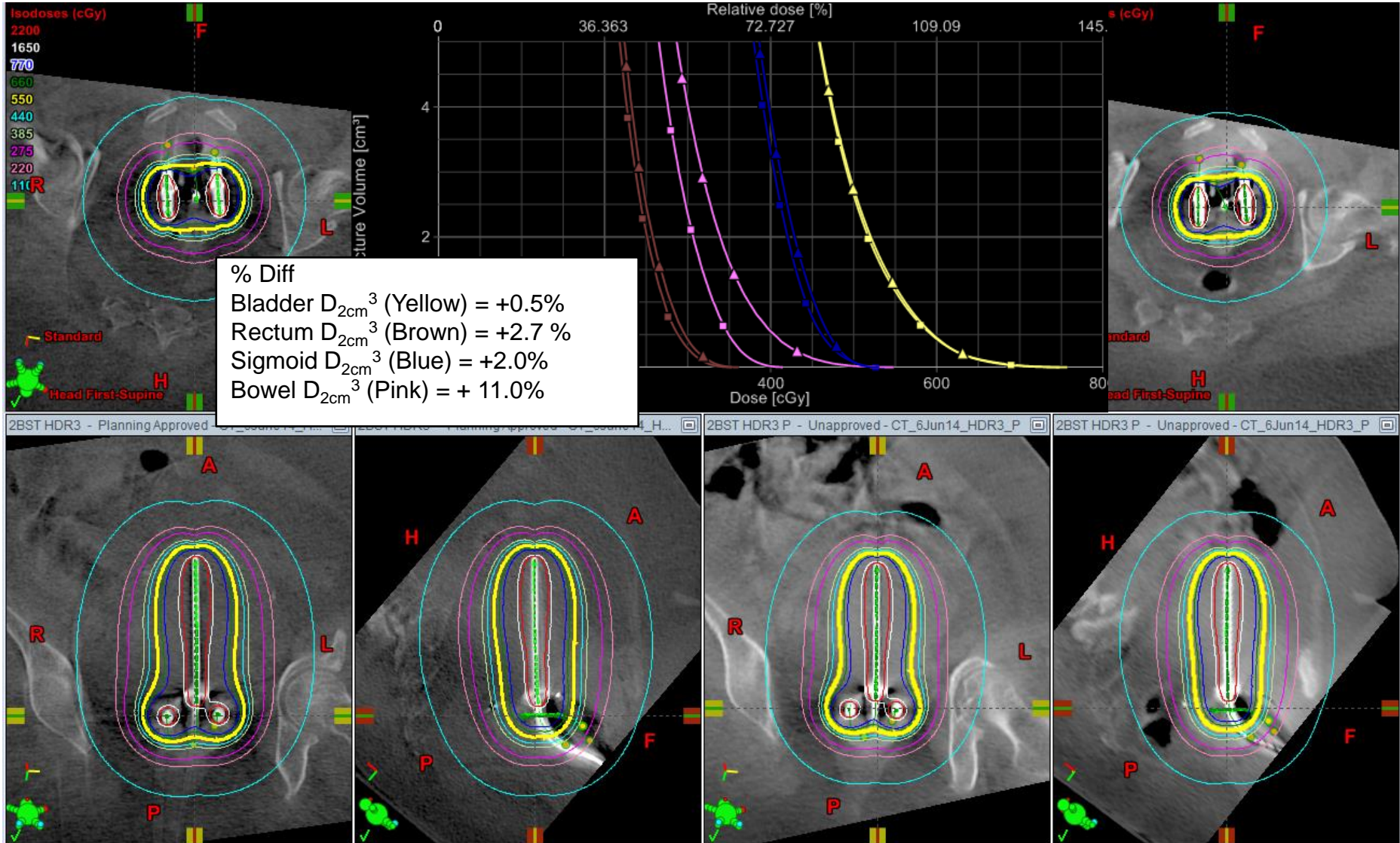
Example

**Minimal variations between
planning(MRI) and pre-TX(CBCT)**

**Implicit minimal variation between
planning MRI and planning CBCT**



T&O, Planning (Squares), Pre-TX (Triangles) MRI vs CBCT Contours





What have we learned and still learning?

- Anatomical variations in OAR between planning and Pre-TX (3-4 hrs. later) can be large so imaging before TX is recommended
- Potential large variations between MRI and CBCT planning contours
- PLANNING alone – not quite there yet...attention for when CBCT is used alone (VBT cases)
- **VERIFICATION! (+ applicator rec)**



What to do when:

- Limited Access to MRI: Hybrid Methods
 - MRI + CT
 - MRI + CBCT
- **NO access to MRI**
 - Assume uncertainties in HR CTV delineation
 - CT alone: several vs. one insertion
 - CBCT alone
 - US-based

A dosimetric evaluation of using a single treatment plan for multiple treatment fractions within a given applicator insertion in gynecologic brachytherapy

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ABSTRACT **PURPOSE:** To evaluate the dosimetric impact of using one treatment plan for multiple fractions from a single tandem and ring applicator insertion of high-dose-rate brachytherapy for cervical cancer.

METHODS AND MATERIALS: Thirteen cervical cancer patients undergoing high-dose-rate brachytherapy were followed. Patients received the total dose from a single applicator insertion in two fractions, given with at least 6 hours apart within 24 hours. The treatment plan was based on a CT scan taken before the first treatment fraction. A second CT was obtained before the second treatment fraction. The co-registered image series were used to evaluate the dosimetric impact of using a single treatment plan for both fractions. Applicator and catheters were measured to quantify interfraction displacement.

RESULTS: When the Day 1 plan was applied to the Day 2 images, high-risk clinical target volume (HR-CTV) coverage was reduced by as much as 17.4 percentage points. The mean decrease was 9.4 ± 5.0 percentage points ($p < 0.0001$). The rectum V_{75} increase was significant ($p = 0.03$), whereas the bladder V_{75} increase was not significant ($p = 0.28$). Volume changes in the HR-CTV contour from Day 1 to Day 2 were also observed ($p = 0.29$). Maximum applicator and catheter displacements of 10–30 mm were seen, from Day 1 to Day 2.

CONCLUSIONS: When the Day 1 plan was used on the Day 2, the HR-CTV coverage decreased significantly ($p < 0.0001$). Our study establishes the need for institutions to evaluate the necessity for replanning based on imaging obtained before each treatment fraction for their gynecologic brachytherapy techniques. © 2013 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: Interfraction dosimetry; HDR brachytherapy; Cervical cancer; Tandem–ring

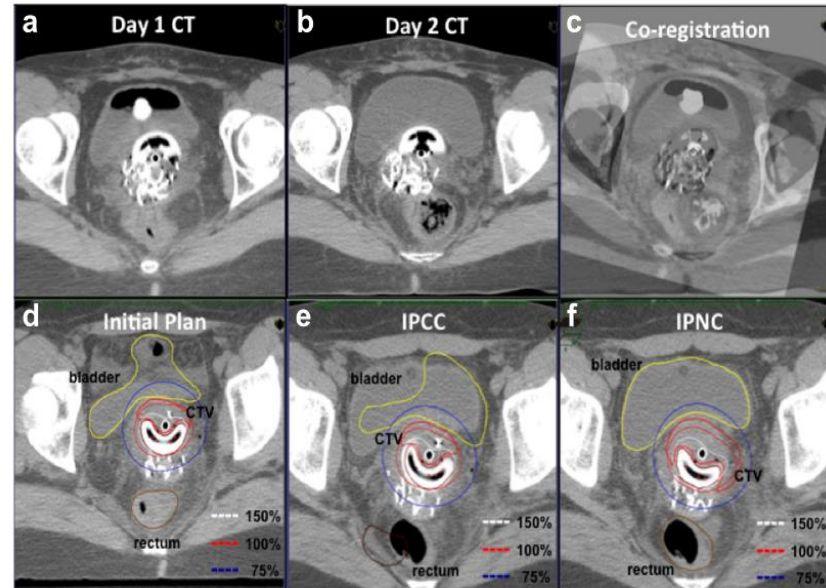


Fig. 2. (a)–(c) Image co-registration. The gray scale for the Day 2 CT data set in the co-registration is inverted. (d) Contours and isodose lines for initial Day 1 treatment plan. Data sets created by applying the Day 1 plan to the Day 2 images showing (e) contours copied from Day 1 to Day 2 images (IPCC) and (f) new contours from Day 2 (IPNC). IPCC = initial plan copied contours; IPNC = initial plan new contours; CTV = clinical target volume.



CLINICAL INVESTIGATION

Cervix

CONE BEAM CT-BASED THREE-DIMENSIONAL PLANNING IN HIGH-DOSE-RATE BRACHYTHERAPY FOR CERVICAL CANCER

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Purpose: To evaluate dose-volume histograms (DVHs) of bladder and rectum from the use of cone beam CT (CBCT)-based three-dimensional (3D) treatment planning in intracavitary high-dose-rate brachytherapy (HDRB) for cervical cancer patients and to compare these parameters with International Commission on Radiation Units and Measurements (ICRU) of rectal and bladder reference point dose measurements.

Methods and Materials: Thirteen patients with cervical cancer underwent HDRB insertions. CT-compatible tandem and ovoid applicators were used to obtain intraoperative CBCT images. The use of a rectal tube and injection of bladder contrast before scanning facilitated contouring the rectum and bladder. All patients underwent intraoperative orthogonal x-ray filming, and treatments were prescribed using standard two-dimensional planning and dosimetry. DVHs for the bladder and rectum were constructed for each treatment. The minimum dose in the most irradiated 2.0-cm³ volume of bladder (B_{D2V}) and rectum (R_{D2V}) were determined from DVHs and compared to ICRU reference point estimates of bladder (B_{ICRU}) and rectum (R_{ICRU}) doses.

Results: Twenty-six CBCT-based plans were evaluated. The median B_{ICRU} dose (347 cGy; range, 164–601 cGy) was significantly lower ($p < 0.001$) than the median B_{D2V} (594 cGy; range, 260–969 cGy). The median R_{ICRU} dose (405 cGy; range, 189–700 cGy) was also significantly lower ($p = 0.037$) than the median R_{D2V} (488 cGy; range, 227–786 cGy).

Conclusions: CBCT-based 3D planning can be used in HDRB for cervical cancer and is a convenient alternative to CT-based planning, with the advantage of minimizing applicator motion. Correlation with late effects will further define the role of CBCT-based 3D dosimetry in HDRB planning. © 2010 Elsevier Inc.

Cone beam CT, Brachytherapy, Cervical cancer, ICRU, Three-dimensional planning.



Advantage over CT (if CT not in Brachy Suite)



- Minimize applicator motion
- Limiting the patient's motion is expected to limit post insertion applicator motion, which in return leads to more accurate planning.
- No comparison with CT or MRI contours

CLINICAL INVESTIGATION

Cervix

CONFORMAL BRACHYTHERAPY PLANNING FOR CERVICAL CANCER USING TRANSABDOMINAL ULTRASOUND

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 RICHARD FISHER, M.B.B.S., PH.D.,‡ AND DAVID BERNSHAW, M.R.A.C.P., FRANZCR.†

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Purpose: To determine if transabdominal ultrasound (US) can be used for conformal brachytherapy in cervical cancer patients.

Materials and Methods: Seventy-one patients with locoregionally advanced cervix cancer treated with chemoradiation and brachytherapy were included in this study. The protocol consisted of US-assisted tandem insertion and conformal US-based planning. Orthogonal films for applicator reconstruction were also taken. A standard plan was modified to suit the US-based volume and treatment was delivered. The patient then underwent a magnetic resonance imaging (MRI) scan with the applicators *in situ*. Retrospectively, individual standard (STD), US, and MRI plans were extrapolated for five fractions and superimposed onto the two-dimensional sagittal MRI images for comparison. Doses to Point A, target volume, International Commission on Radiation Units and Measurements (ICRU) 38 bladder and rectal points, and individualized bowel points were calculated on original implant geometry on Plato for each planning method.

Results: STD (high-dose-rate) plans reported higher doses to Point A, target volume, ICRU 38 bladder and rectal points, and individualized bowel point compared with US and MRI plans. There was a statistically significant difference between standard plans and image-based plans—STD vs. US, STD vs. MRI, and STD vs. Final—having consistent ($p \leq 0.001$) respectively for target volume, Point A, ICRU 38 bladder, and bowel point. US plan assessed on two-dimensional MRI image was comparable for target volume ($p = 0.11$), rectal point ($p = 0.8$), and vaginal mucosa ($p = 0.12$). Local control was 90%. Late bowel morbidity (G3, G4) was <2%.

Conclusions: Transabdominal ultrasound offers an accurate, quick, accessible, and cost-effective method of conformal brachytherapy planning. Crown Copyright © 2009 Published by Elsevier Inc.

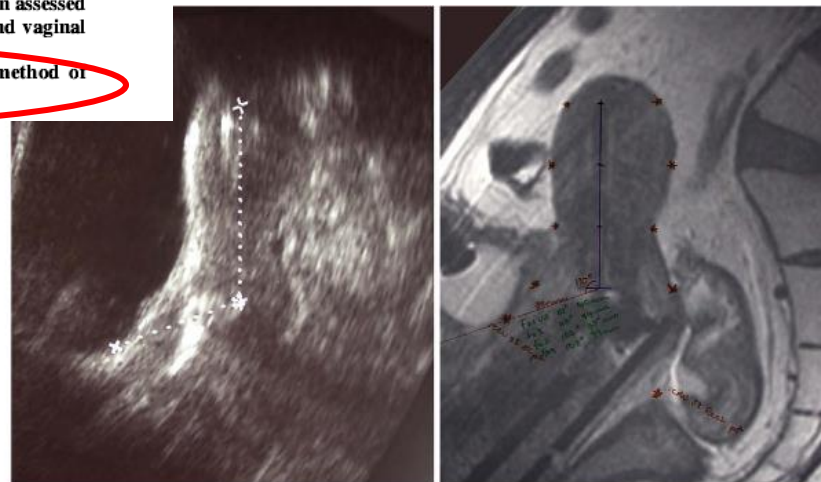


Fig. 1. Sagittal ultrasound image (left) taken at time of applicator insertion and planning and sagittal magnetic resonance imaging (right) taken after first fraction of treatment. Size and shape of cervix and uterus correlate well between the imaging methods.

Their Conclusions (2009)



- Although lacking detailed volumetric data, normal tissue doses can be limited through good insertion technique and conformal planning.
- Improvements can be made to current treatments based on standardized 2D X-ray image-based planning.
- US can identify an effective target volume.
- By using 2D US, it is possible to improve technical accuracy, visualize organ boundaries, and, with experience, plan conformal treatments that by definition spare OARs.
- Use of US allows for delivery of safe treatment in a simple approach that provides soft-tissue information not possible with 2D X-ray imaging.

Table 3. Criteria in order of importance to brachytherapy protocol in relation to imaging modalities available at our institution

	X-ray	Ultrasound	CT	PET*	MRI
Accessible for each insertion	•	•			
Ability to image intraprocedurally	•	•			
Visualize cervix uterine outline		•	•	•	•
Visualize applicator CT/MRI applicators available	•	•	•	•	•
Visualize surrounding organs	• [†]	•	•	•	•
Visualize residual tumor				• [‡]	•

Abbreviations: CT = computed tomography; MRI = magnetic resonance imaging; PET = positron emission tomography.

* In conjunction with CT (PET/CT available at our institution).

[†] Limited: can visualize vagina with addition of radiopaque gauze packing; can visualize rectum with radiopaque contrast or applicator; can visualize bladder with radiopaque contrast.

[‡] Depends on threshold image intensity percentage of peak tumor intensity.



Cervix uterine brachytherapy

Trans-abdominal ultrasound (US) and magnetic resonance imaging (MRI) correlation for conformal intracavitary brachytherapy in carcinoma of the uterine cervix

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ABSTRACT

Purpose: Trans-abdominal ultrasonography (US) is capable of determining size, shape, thickness, and diameter of uterus, cervix and disease at cervix or parametria. To assess the potential value of US for image-guided cervical cancer brachytherapy, we compared US-findings relevant for brachytherapy to the corresponding findings obtained from MR imaging.

Materials and methods: Twenty patients with biopsy proven cervical cancer undergoing definitive radiotherapy with/without concomitant Cisplatin chemotherapy and suitable for brachytherapy were invited to participate in this study. US and MR were performed in a similar reproducible patient positioning after intracavitary application. US mid-sagittal and axial image at the level of external cervical os was acquired. Reference points D1 to D9 and distances were identified with respect to central tandem and flange, to delineate cervix, central disease, and external surface of the uterus.

Results: Thirty-two applications using CT/MR compatible applicators were evaluable. The D1 and D3 reference distances which represent anterior surface had a strong correlation with $R = 0.92$ and 0.94 ($p < 0.01$). The D2 and D4 reference distances in contrast, which represent the posterior surface had a moderate (D2) and a strong (D4) correlation with $R = 0.63$ and 0.82 ($p < 0.01$). Of all, D2 reference distance showed the least correlation of MR and US. The D5 reference distance representing the fundal thickness from tandem tip had a correlation of 0.98. The reference distances for D6, D7, D8, and D9 had a correlation of 0.94, 0.82, 0.96, and 0.93, respectively.

Conclusions: Our study evaluating the use of US, suggests a reasonably strong correlation with MR in delineating uterus, cervix, and central disease for 3D conformal intracavitary brachytherapy planning.

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Their Findings (2012)

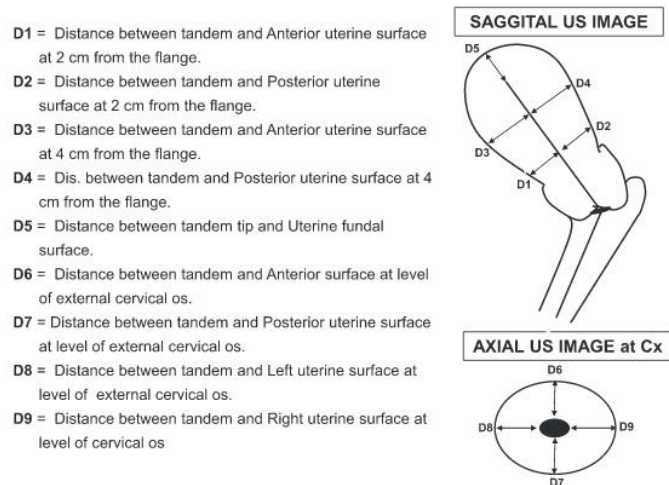
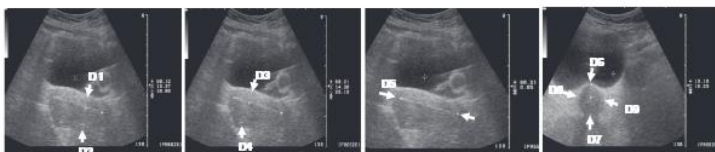
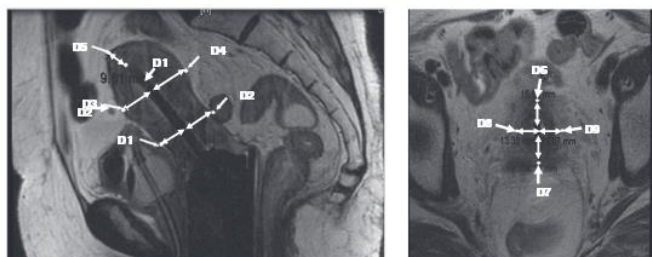


Fig. 1. Definition of reference points and distances.



(a) : Various reference points and distances on US Images



(b) : Various reference points and distances on MR Images

Fig. 2. Shows various reference points and distances on: (a) US Images and (b) MR Images.

- They outlined uterus, cervix and central disease.
- “Reasonable” correlation to MRI
- Although, posterior wall delineation showed differences >1 cm, this could be resolved with incorporation of newer US systems.
- Limitations:
 - Observer dependency
 - Presence of uterine pathologies may influence image acquisition
 - Poor delineation of posterior surface of uterus
 - Inability to define rectum, sigmoid, bowel
- Advantages
 - Universal availability
 - Cost effectiveness
 - Small learning curve
 - Advantage in developing countries

Take Home Message: Planning with Limited or NO MRI (GYN)



- **MRI + CT/CBCT**
 - good solution:
 - CT/CBCT(?) at planning and before TX Verification: a plus!!
- **MRI (FX1)+ CT/CBCT Hybrid**
 - CT: good compromise solution
 - CBCT: need more data to establish if appropriate for OARs
- **CT/CBCT alone**
 - Good for applicator
 - CT-good for OARs
 - CBCT- need more data to establish if appropriate for OARs
 - Not good for target
 - Even if one insertion, departmental evaluation necessary to decide if planning with each FX
- **US**
 - Better than 2D X-ray imaging
 - “Reasonable” correlation to MRI



Thank you!