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Dosimetric Effects of Set-Up Errors in Volumetrically Modulated Arc (VMAT) Therapies

K. Arapi[1,2], N. Kollaros[1], G. Patatoukas[1], M. Chalkia[1], K. Zourari[1], N. Troganis[3], B. Kouloulias[3], K. Platoni[1]

1. Medical Physics Unit, 2nd Department of Radiology, School of Medicine, National and Kapodistrian University of Athens, Attikon University Hospital, Greece

2. Medical Physics Laboratory, Medical School, University of Patras, Panepistimioupoli, Rio, 26504, Achaia, Greece

3.Department of Clinical and Radiation Oncology, Medical School, National and Kapodistrian University of Athens, Attikon University Hospital, Greece

1. Background-Aim

- Set-up errors are the result of systematic and/or random errors occurring in each radiation therapy treatment session ⟶ potential reduction of tumour control & an increase in side effects.

- Image Guided Radiation Therapy corrects these displacements during the procedure, but it only minimises the geometric uncertainties (partial solution).

The purpose of this study:

- Dosimetrical quantification of the effects of set-up errors in Organs at Risk (OARs), Planning target volume (PTV) and Clinical target volume (CTV) through their statistical & clinical analysis on DVHs & patients.

2. Materials & Methods

Provided Data

- 20 treated Patients with Prostate Cancer
- 3 Phases, 3 PTVs for each patient
- Collection of Cartesian shift values through CBCT off-line data

  (Y: Posterior/Anterior, X: Right/Left Lateral,

  Z: Inferior/Superior directions)

Creation of

- Uncertainty Plans, U-Plan ($\bar{X}$, $\bar{Y}$, $\bar{Z}$ of each phase), 1 U-Plan for each patients' phase through the ''Uncertainty Plan'' tool of VARIAN
- Adjustment of the original DVHs with corresponding U-Plan' DVHs, as well as new isodose curves' distribution

2. Materials & Methods

Calculation of

- $V_{95\%}$ (PTV-50, PTV-60, PTV-70, CTV)
- D_{max} (Bladder, Rectum, Right & Left Femoral Heads) & Reduction of Dose Constraints in order to check for OARs compliance:

$$\frac{Dmax}{\sum Dmax} \cdot (index\ of\ the\ constraint\ in\ Gy\ )$$

Treatment & Uncertainty Plans, for each Patients' phase

Uncertainty Analysis

- Statistical comparison between the T-Plan & U-Plan through DVHs & CT scans (data & plots)

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Clinical Conclusions

SPSS & EXCEL Programs

3. Results

Delimitation

- The average values of coordinates (in mm) were between ±2mm (AAPM: accuracy metric), except for the Ῡ values in the 1st and 2nd phases with ***patient percentages 65% & 60% respectively.***

$V_{95\%}$ & D_{max}

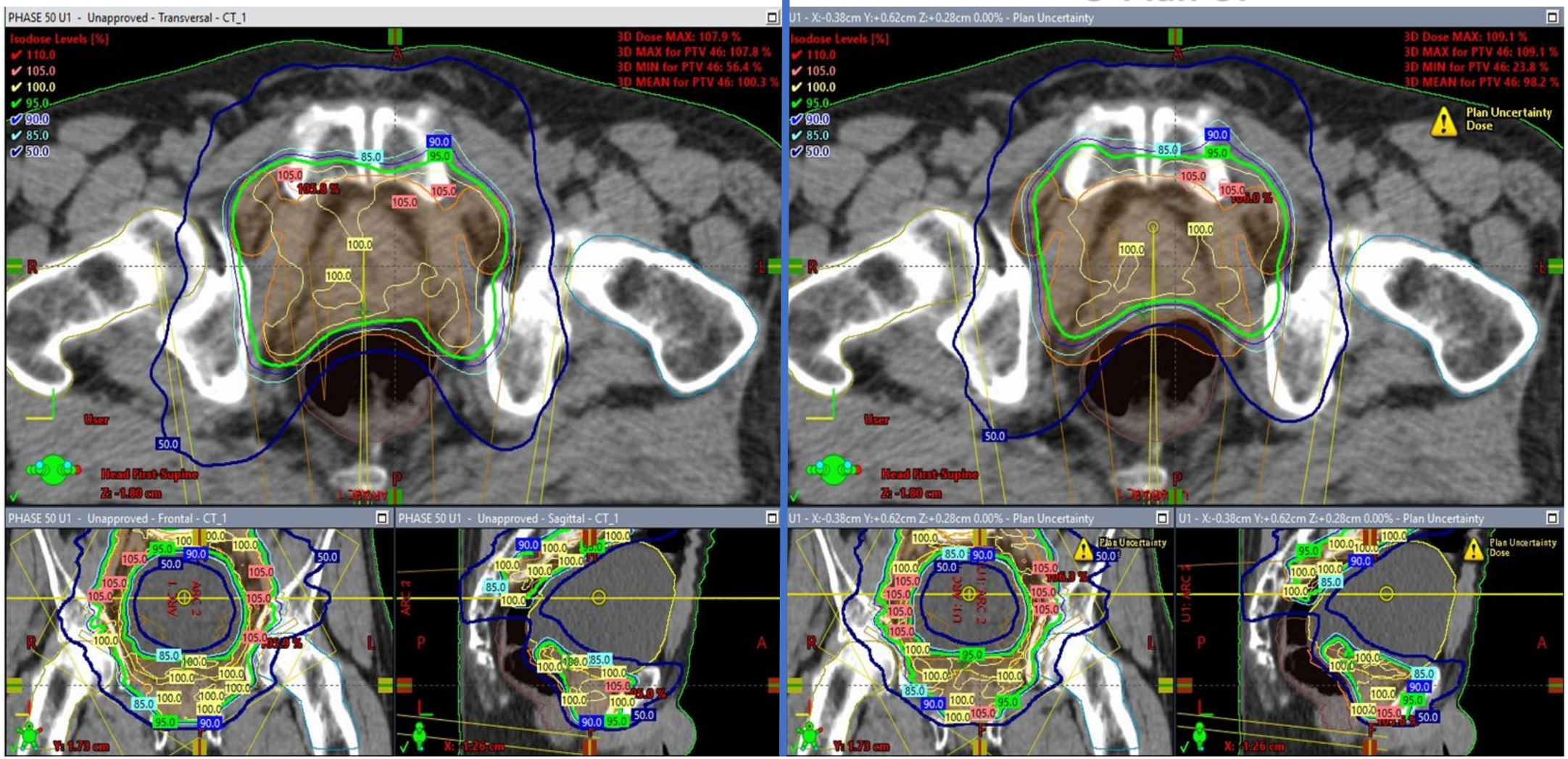
- Substantial reduction of the dosimetric coverage of PTVs (**up to 8.32%**) & Marginal reduction of the dosimetric coverage of CTVs (**up to 1.64%**).

- Bladder and Right Femoral Head were affected the most. **None OAR** exceeded any dose constraints (maintenance of the increased toxicity within acceptable limits).

4. Results-Example

The comparison of the CT scans showed how the new isodose curves would be moved and changed morphology according to the inserted set-up error values

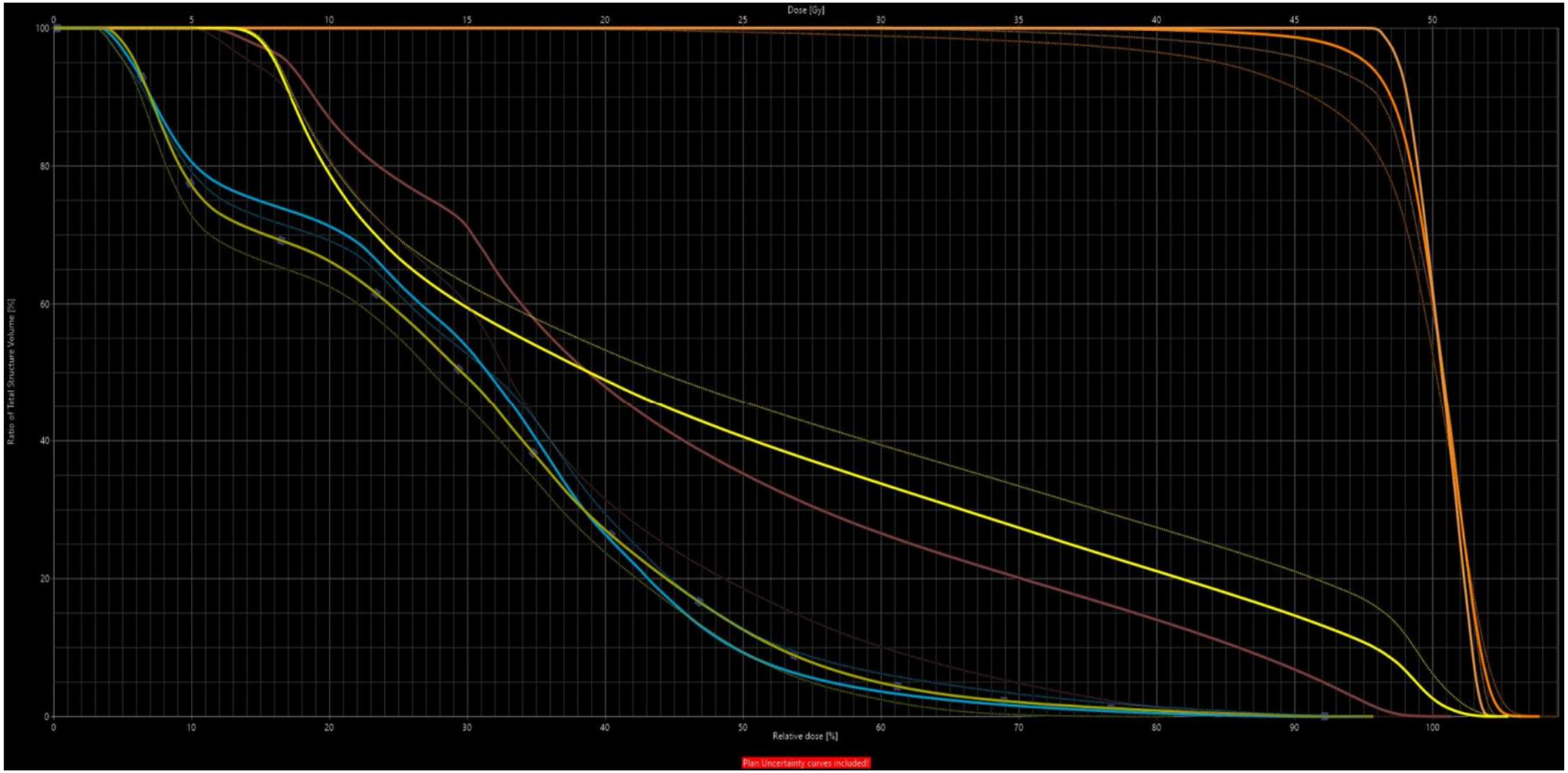
T-Plan CT | **U-Plan CT**



1st Phase, Shifts: Y=+0,62cm, X=-0,38cm, Z=+0,28cm

4. Results-Example

The comparison of the DVHs showed how the dose would be deposited to the irradiated tissues according to the inserted set-up error values



1st Phase, Shifts: Y=+0,62cm, X=-0,38cm, Z=+0,28cm

Continuous line: T-Plan

Dashed line: U-Plan

4. Conclusions

- A work based on a worst-case scenario regarding set-up errors in prostate cancer patients which showed ***strong robustness as far as CTV and OARs concerned***.

- The PTV coverage was noticeably affected.

VMAT technique is **quite sensitive** to any geometric deviations.

Proposal of an **effective method** of statistical and clinical analysis for these plans.

Every positioning uncertainty **should** be taken into serious consideration.

This research may contribute to the optimization of patient positioning, doing its bit to the assessment and minimization of these uncertainties.

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