CBCT-Guided Online Adaptive Radiotherapy in the Treatment of Cervical Cancers

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

Background: External beam radiotherapy (EBRT) for cervical cancer targets the cervix, uterus, parametrium, upper vagina, and pelvic lymph nodes. Uterine motion due to bladder and rectal filling is highly patient-specific and difficult to predict. Large margins are usually applied to the uterus to keep the radiation plan robust to changes in position. Tailoring a plan daily to the current uterus position with online adaptive radiotherapy (oART) enables more precise targeting.

Objectives: Compare oART and EBRT dosimetry on daily anatomy and evaluate the impact of intrafraction motion during the time required to plan oART.

METHODS AND MATERIALS

10 cervical cancer patients

- 6 sessions/patient included (#1, 5, 10, 15, 20, 25)
- All treated with oART (Varian Ethos)
  - ITV (internal target volume) = Uterus + 7 mm sup, 5 mm post
  - PTV (planning target volume) = ITV + 7 mm

oART vs. conventional EBRT dosimetry:

- EBRT plans created in Eclipse (Varian) (Fig. 1)
- Contours based on CT-SIM: full (FB) & empty (EB) bladder scans
  - **Basic IGRT**: ITV = Uterus + 1 cm, 0.5 cm lat, PTV = ITV + 7 mm
  - **Intermediate IGRT**: ITV = $Uterus_{FB}$ + $Uterus_{EB}$, PTV = ITV + 7 mm
- EBRT plans applied to daily oART contours & dosimetry compared

Impact of intrafraction motion during oART:

- Targets & OAR re-contoured on verification scan (Fig. 2)
- oART plan recalculated on verification scan
- Changes in dosimetry evaluated

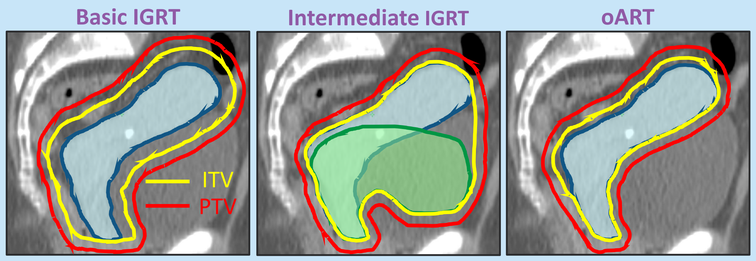


Figure 1. IGRT and oART treatment volumes. Blue: $Uterus_{FB}$; Green: $Uterus_{EB}$

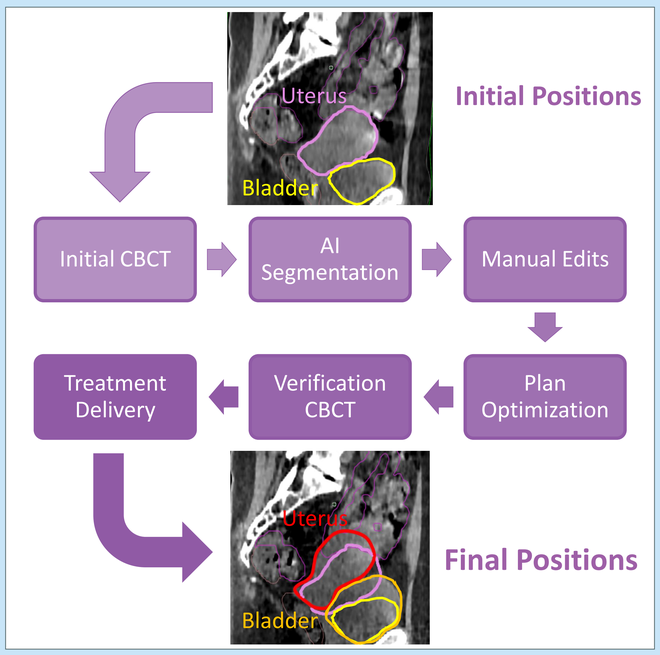


Figure 2. The oART process. Uterine position can change between planning scan & treatment delivery due to changes in OAR filling.

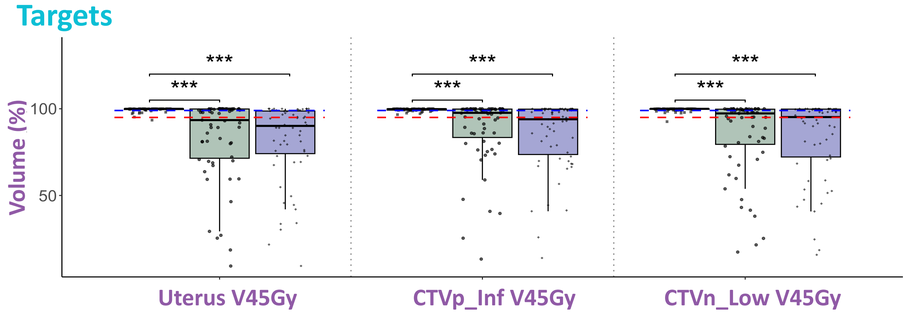
RESULTS

Adaptive vs. Conventional Dosimetry

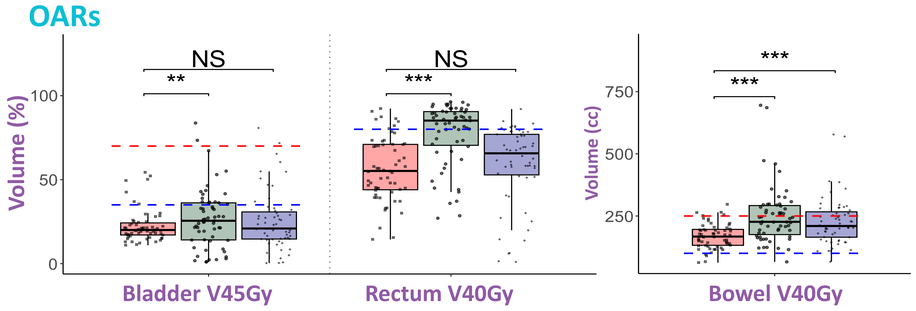
oART:

- ↑ **target coverage** by an average of **7.5%**
- ↓ **dose received** by evaluated OARs
- ↓ **variability** of DVH metrics.
- ↑ **probability** of meeting **clinical goals** by up to **76.6%.**

Targets



OARs



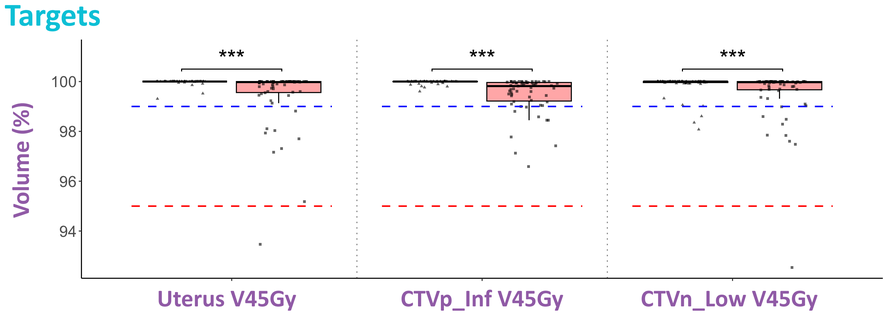
= oART = Basic IGRT = Intermediate IGRT
NS = Not Significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
= Standard Clinical Goal
= Acceptable Clinical Goal

Figure 3. Dosimetric comparison of oART versus conventional EBRT. CTVp_Inf includes the parametrium, cervix and upper vagina. CTVn_Low includes the pelvic lymph nodes. Vx refers to the volume receiving dose x (Gy).

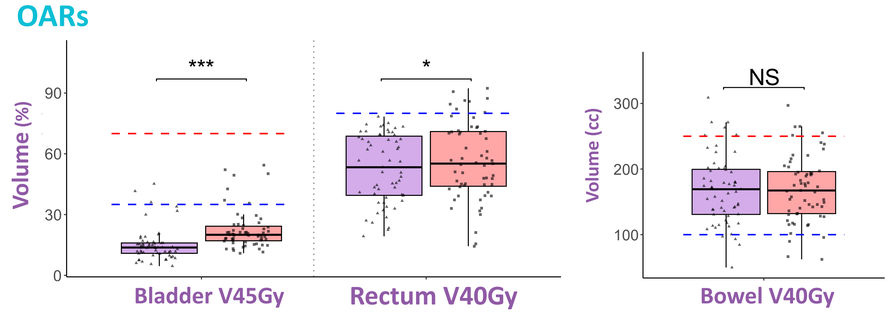
Impact of Intrafraction Motion

- Intrafraction motion ↓ **target coverage** and ↑ **OAR doses**
- Average **oART treatment time: 21.2** ± 8.2 **min.**

Targets



OARs



= Initial Scan = Verification Scan
NS = Not Significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
= Standard Clinical Goal
= Acceptable Clinical Goal

Figure 4. Dosimetric impact of intrafraction anatomical motion on targets and OAR.

DISCUSSION

Adaptive vs. Conventional Methods

- Unpredictable interfraction changes (e.g., tumour shrinkage, weight gain/loss, reduced bladder capacity) compromise conventional EBRT techniques
- oART accounts for interfraction changes:
  - Improves target coverage (may enhance tumour control)
  - Reduces dose to OARs (may reduce side effects)
- oART requires increased time & resources (may limit widespread adoption)

Impact of Intrafraction Motion

- Intrafraction changes (e.g., bladder/rectal filling, uterine motion) led to statistically significant dosimetric changes
  - Most changes remained within clinical acceptability limits
- Population-based ITV margins overestimate uterine motion for most patients
  - Personalized ITV margins may reduce dose to OARs while maintaining target coverage
- 7 mm PTV margins may overcompensate for treatment-related uncertainties (e.g., intra/interobserver contouring errors, patient movement during treatment)
  - Daily replanning accounts for patient setup differences
- The oART workflow should be streamlined to minimize intrafraction motion & improve patient comfort

Limitations

- Limited sample size (10 total patients)
- Soft tissue delineation is subjective on CBCT images
  - Contours validated by experienced medical physicists routinely involved in oART to reduce subjectivity

Future Works

- Derive appropriate ITV margins for intrafraction uterine motion & PTV margins for treatment uncertainties
- Evaluate importance of manual edits to AI-generated contours & their dosimetric impact
- Develop open-source application to train clinicians in oART treatment planning

CONCLUSIONS

- oART is dosimetrically superior to conventional cervical cancer EBRT treatment techniques in terms of:
  - ✓ Target coverage
  - ✓ OAR dose sparing
  - ✓ DVH metric consistency
  - ✓ Clinical goal pass rates
- oART should be used for cervix cancer EBRT when feasible

REFERENCES

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