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Feasibility of Low-Field 0.55T MRI-Based Synthetic CT for Simulation-Free Adaptive Stereotactic Prostate Radiotherapy on Ethos with HyperSight

Noora H. Ba Sunbul, PhD[1]; **Marissa Gilbert, BSBME[1]**; Payton Dolan, BSBME[1]; Joshua P. Kim, PhD[1]; Yimei Huang, PhD[1]; Anthony J. Doemer, MS[1]; Aharon Feldman, MD[1]; Kundan Thind, PhD[1]
[1]Henry Ford Health

ABSTRACT

Purpose/Objectives
The 0.55T MRI offers potential advantages including reduced susceptibility artifacts and improved accessibility. Separately, HyperSight cone-beam CT on the Ethos enables direct dose calculation during adaptive radiotherapy. This study evaluates the feasibility of integrating 0.55T MRI-based synthetic CT (SynCT) into a simulation-free workflow for stereotactic prostate adaptive radiotherapy on Ethos (SPARE), with daily adaptive replanning performed on HyperSight CBCTs.

Materials/Methods
Fourteen subjects were included in this retrospective study. Five initial subjects were used to optimize the MRI protocol for SynCT generation. Nine subsequent subjects underwent workflow validation and dosimetric comparison.

Reference treatment plans were generated on MRI-based SynCT using the Ethos 2.0 Emulator. For each subject, five adaptive sessions were simulated with the Emulator using their daily HyperSight CBCTs. Emulator-generated adaptive plans were then compared with clinically delivered sessions. Dosimetric endpoints included target coverage (D99%, D95%, Dmax) and organ-at-risk (OAR) dose constraints.

Results
Forty-five treatment fractions were successfully simulated using this proposed workflow. Adaptive plan selection matched clinical sessions in all Forty-five fractions. Target coverage variability (D99%\D95%) was 1.3%±1.5% across all target structures. OAR constraint differences averaged 0.38 ± 0.72Gy with Dmax differences of 0.07 ± 0.07Gy for the bladder, 0.13 ± 0.22Gy for the rectum, and 0.06 ± 0.04Gy for the urethra.

Conclusions
Simulation-free SPARE using 0.55T MRI-based SynCT for reference plan generation and Ethos HyperSight for daily adaptation is deemed feasible. Adaptive plan quality remained robust despite reference plans generated without conventional CT sim.

This workflow may streamline the treatment pathway while maintaining dosimetric accuracy for SPARE.

CONTACT

Marissa Gilbert
Henry Ford Health
2800 West Grand Blvd, Detroit MI 48202
mgilber6@hfhs.org
313-556-8314

INTRODUCTION

Simulation-free ART may improve clinical efficiency by eliminating the need for a dedicated CT simulation (sim) while maintaining high-quality treatment planning. 0.55T MRI enables SynCT generation with reduced susceptibility artifacts and improved accessibility compared with conventional MRI, while the Varian HyperSight system on the Ethos platform[1] provides improved CBCT image quality, enabling AI informed, on-couch adaptive replanning directly from the daily CBCT [2-4].

We hypothesized that treatment plans generated using a sim-free ART workflow with 0.55T MRI-derived SynCT for planning and daily HyperSight CBCT for adaptation would achieve plan quality comparable to conventional CT sim-based planning, supporting a more efficient, cost-effective treatment workflow.

METHODS AND MATERIALS

Fourteen subjects were included in this retrospective study. The first five subjects were used to optimize the 0.55T MRI protocol for SynCT generation. The remaining nine patients underwent workflow validation and dosimetric comparison.

MRI-based SynCTs were generated using a research-only version of the Siemens SynCT generation algorithm (not FDA approved for 0.55T). Reference treatment plans were then created on the SynCTs using the Ethos 2.0 Emulator using the proposed workflow (Figure 1).

For each validation subject, five treatment sessions were simulated using the corresponding daily HyperSight CBCTs, and the resulting adaptive plans were compared with the clinically delivered adaptive plans. Dosimetric endpoints included target coverage (D99%, D95%, and Dmax) and OAR dose constraints.

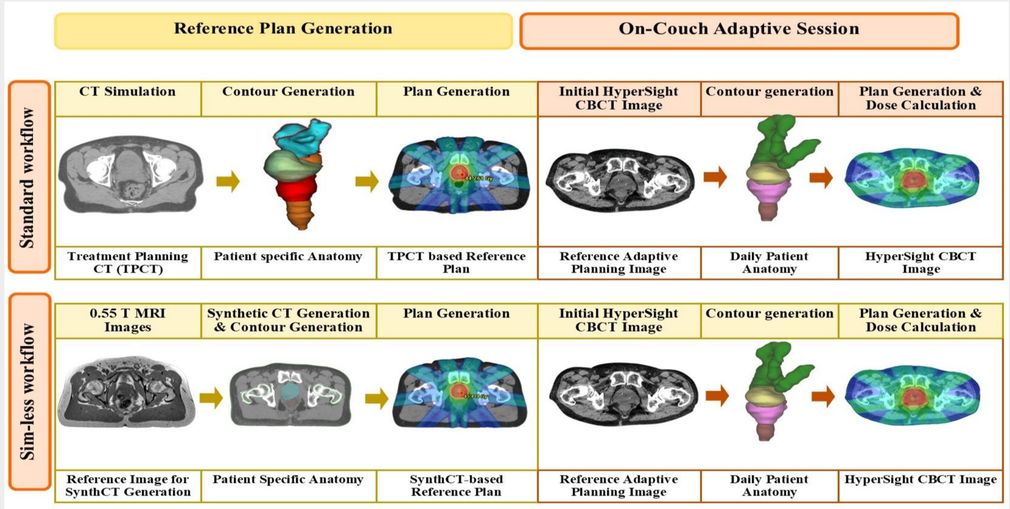

Figure 1: The Standard and the Sim-free workflow for CT-guided SPARE. The proposed CT Sim-free workflow allows for reference plan generation on the SynCT generated from the 0.55T MRI.

RESULTS

The dosimetric effect of SynCT Hounsfield unit (HU) values on plan quality is shown in Figure 2, which compares each subject's clinical reference plan generated on the planning CT with the same plan recalculated on the SynCT using physician approved contours.

Per-fraction dosimetric variability in target coverage and OAR dose constraints during ART is summarized in Figure 3.

Across all 45 delivered fractions, the Emulator selected the same treatment plan as the clinical workflow, with adaptive plans chosen in 34 fractions and the scheduled plan delivered in the remaining 11 fractions.

REFERENCES

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DISCUSSION

The highest variability in dose between plans calculated on the TPCT and SynCT was observed for the bladder D50% constraint (Figure 2), likely due to differences in bladder filling, as the TPCT and MRI were acquired approximately 1 hour apart. This finding highlights the sensitivity of bladder dose metrics to anatomical variation when imaging is performed at different time points.

Dosimetric differences between the clinical and Emulator sessions were small (Figure 3). Mean OAR dose differences were within 0.38 ± 0.72Gy, with Dmax differences of 0.07 ± 0.07Gy for the bladder, 0.13 ± 0.22Gy for the rectum, and 0.06 ± 0.04Gy for the urethra. Mean target coverage differences (D99%/D95%) remained within 1.3% ± 1.5% across all target volumes.

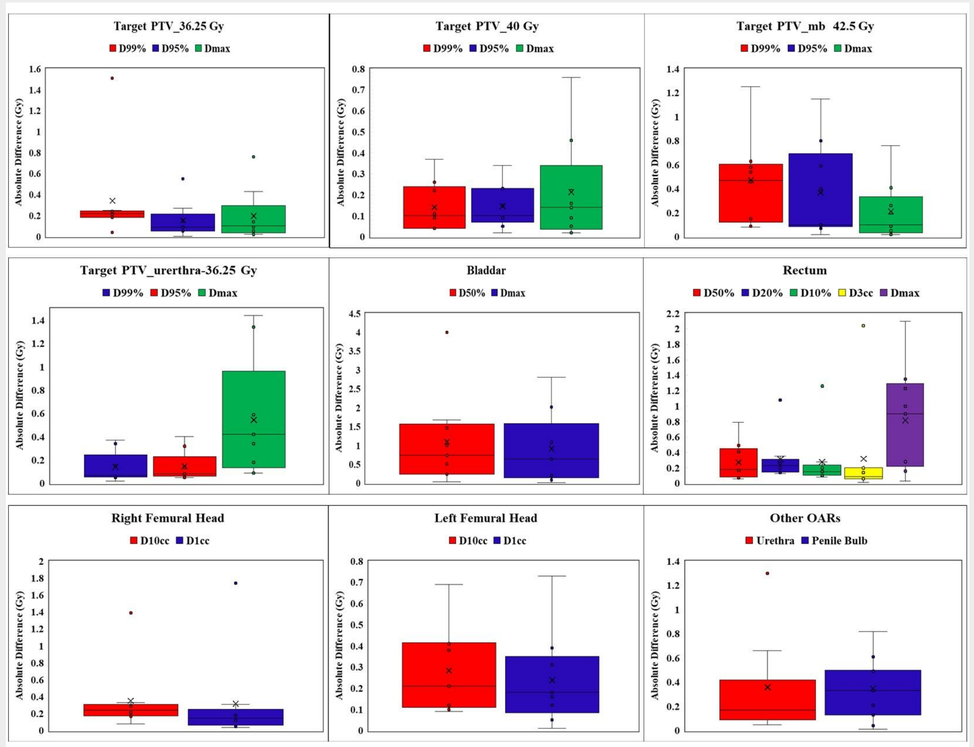

Figure 2: Dosimetric comparison between the reference TPCT based clinical plan and the same plan recalculated on SynCT in Eclipse v16.1. Recalculating the clinical plans on the SynCT isolated the dosimetric impact of SynCT HU differences.

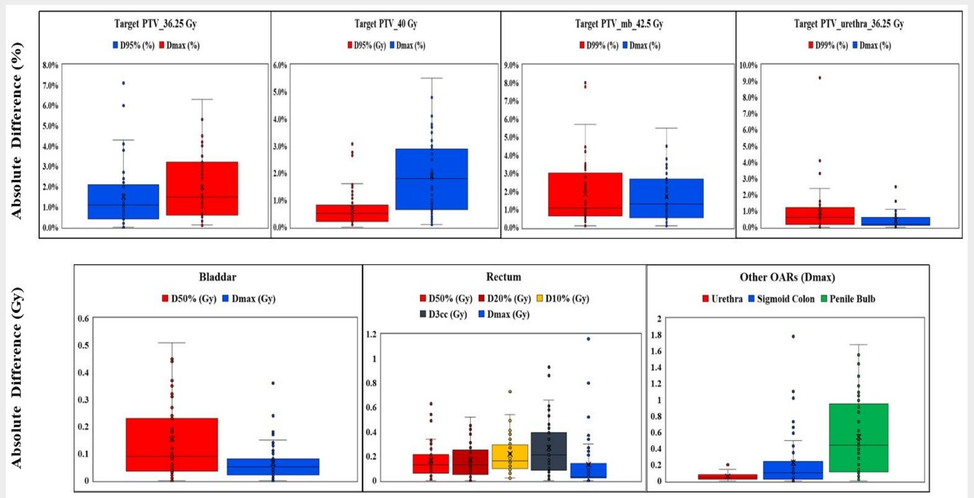

Figure 3: Dosimetric differences between clinically delivered ART plans (TPCT-based reference plan) and Emulator-generated ART plans (SynCT-based reference plan) across all treatment sessions.

CONCLUSION

Simulation-free SPARE using 0.55T MRI-based SynCT for reference plan generation and Ethos HyperSight for daily adaptation is deemed feasible.

This study concludes that adaptive plan quality remained robust despite reference plans generated without conventional CT sim. This proposed workflow may streamline the treatment pathway while maintaining dosimetric accuracy for CT-guided SPARE.