Clinical Implementation and Evaluation of an MRI-Only Workflow for Interstitial High-Dose-Rate Brachytherapy In Gynecologic Cancer

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PURPOSE

MRI-only treatment planning (MRTP) for interstitial high-dose-rate (HDR) gynecologic brachytherapy has been limited by poor catheter visibility on conventional anatomical MRI.

To address this challenge, we proposed an MRTP workflow based on a **Pointwise Encoding Time Reduction with Radial Acquisition (PETRA)** sequence[1,2] and **applicator pointset-guided reconstruction**. Geometric and dosimetric quality were compared to conventional CT/MRI-based planning (CTP).

METHODS

Patients with gynecologic cancer (n = 28)

Characteristics	Median (range)
Age (years)	70 (28, 86)
HDR fx size (Gy)	5 (3.5, 7)
HDR fx (#)	5 (2, 5)
Interstitial needles (#)	15 (11, 25)

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Helical CT

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3T MAGNETOM Vida (Siemens)

Parameters	T_2 SPACE	PETRA
TR (ms)	1800	3.32
TE (ms)	167	0.07
FA (deg)	120	4
FOV (mm^2)	300×300	373×373
Resolution (mm)	1.0	0.9
Scan time (min)	11	6

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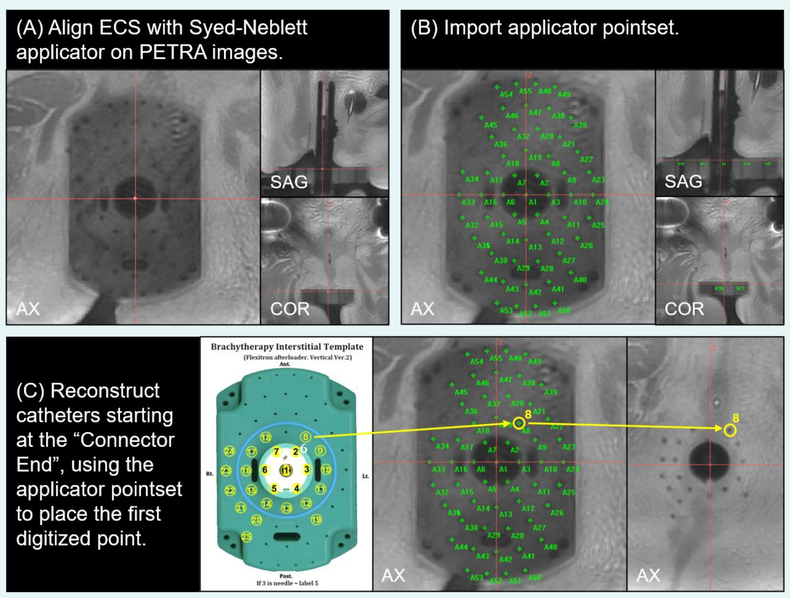
MRTP catheter reconstruction



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Analysis

- Geometry: Target registration error (**TRE**); mean signed error (**MSE**)
- Dosimetry: **DVH** and **EQD2** metrics for **CTV D_{90}** and **OAR D_{2cc}**; dice similarity coefficient (**DSC**)
- Multiple comparisons corrected with Sidak's post hoc test

RESULTS

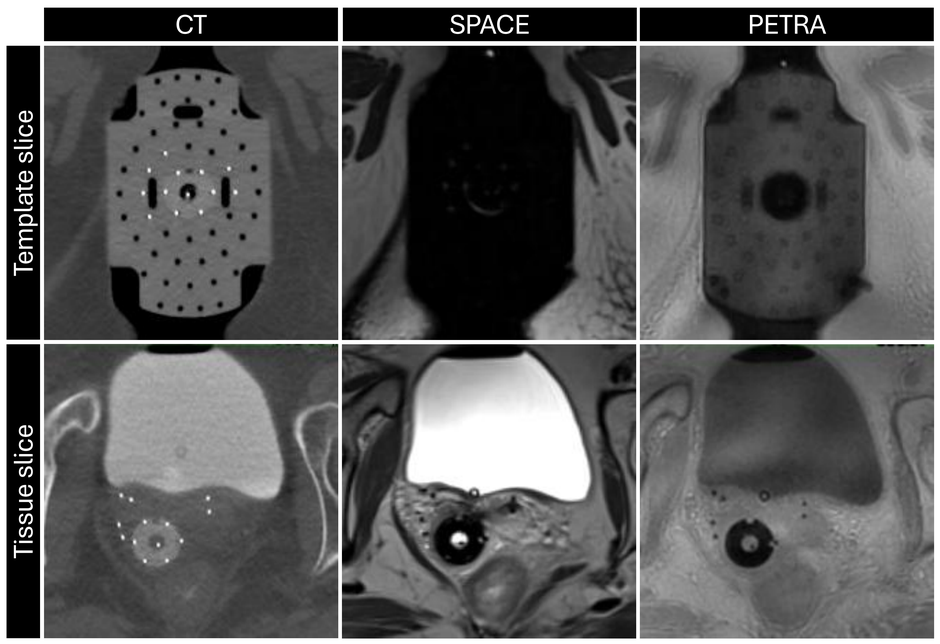

Fig. 1: Representative images of a 54-year-old patient with recurrent endometrial cancer and 13 catheter insertions.

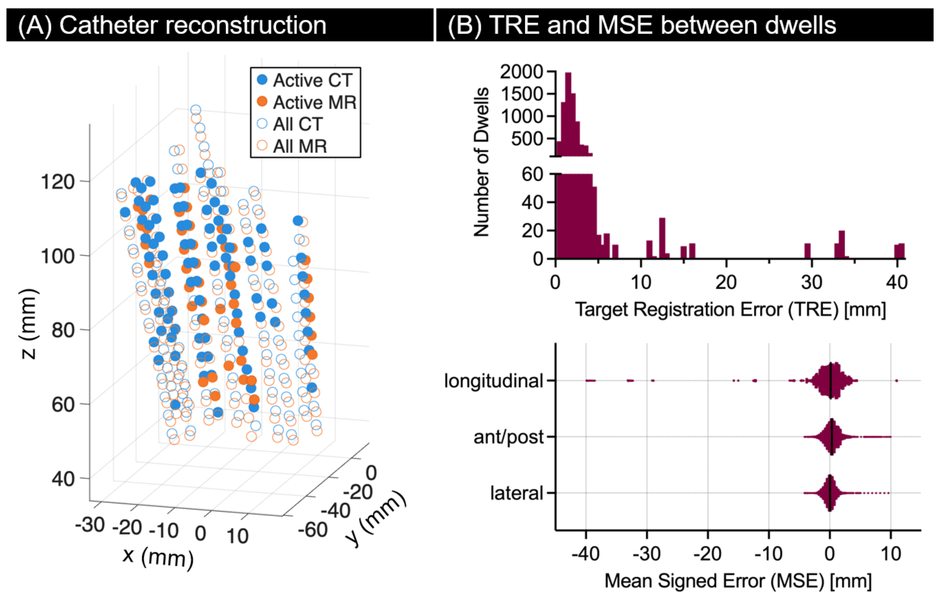

Fig. 2: (A) Overlay of 13 catheters reconstructed by CTP (blue) and MRTP (orange) approaches, comparing activated (filled) and inactivated (open) dwell positions. (B) The median **TRE was 1.7 mm** (range [0.065 mm, 41 mm]). The median **MSE was 0.024 mm** [-4.2 mm, 9.6 mm] in the lateral, 0.35 mm [-4.1 mm, 10 mm] in the anterior/posterior (ant/post), and 0.15 mm [-40 mm, 11 mm] in the longitudinal directions.

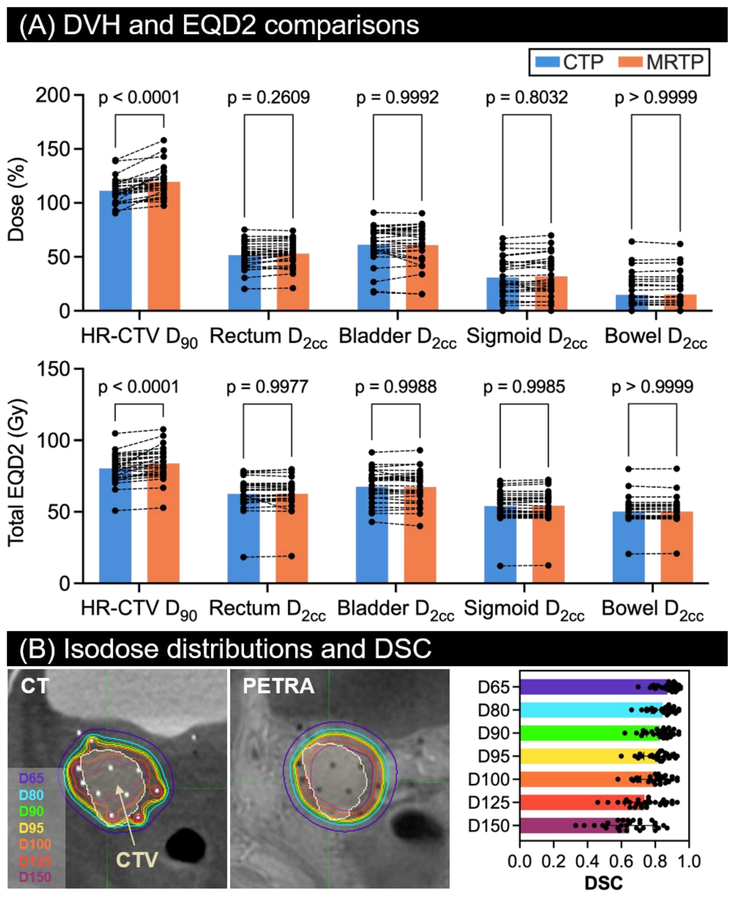

Fig. 3: (A) MRTP achieved **higher HR-CTV D_{90}** doses (ΔDVH = 8.3%, 95% CI [6.2%, 10%], p < 0.0001; ΔEQD2 = 3.6 Gy, 95% CI [2.3 Gy, 4.8 Gy], p < 0.0001) and **similar OAR D_{2cc}** doses (|ΔDVH| < 1.6%, p > 0.05; |ΔEQD2| < 0.2 Gy, p > 0.05) compared to CTP.
(B) Strong spatial agreement was demonstrated across the 65% to 125% isodose levels (**DSC > 0.74**).

DISCUSSION & CONCLUSIONS

- Geometric differences were within acceptable limits (**TRE ± 2 mm**)[3]. Outliers were measured in cases in which needle identification was ambiguous on PETRA images and will be further investigated.
- Dosimetric differences were within acceptable limits (**DVH metrics ± 10%**)[4]. Improved HR-CTV D_{90} coverage with MRTP may reflect differences in planning conditions (e.g., retrospective bias, no clinical time constraint).
- Future work will assess the operational impact of MRTP vs. CTP on clinical workflow (e.g., total treatment planning time, training requirements) in a prospective, multi-institutional, multi-planner study employing a larger patient population.
- These findings support PETRA-based MRTP for gynecologic brachytherapy, mitigating uncertainties related to image fusion and applicator shifts in CTP.

REFERENCES

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