Dosimetric Evaluation of MRI-Only Hybrid Applicator Reconstruction: The Use of MR Marker Catheters and Dedicated CISS MR Protocols.

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Introduction

- The study focus on the utility of C4 Orion MRI markers with 3D Constructive Interference in Steady State MRI sequence for MRI based brachytherapy for hybrid gynecological applicators.

Aim

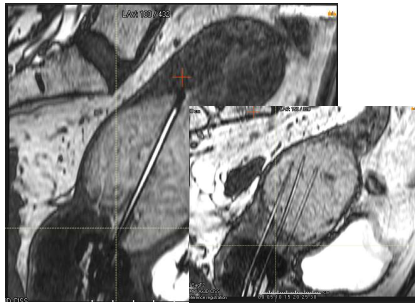
- Quantitative evaluation of source reconstruction accuracy using C4 MRI markers for needles using 3T 3D-CISS MRI-CT fusion .
- Dosimetric implications of C4 Orion marker-based MRI-only workflow versus CT-based workflows for hybrid gynecological brachytherapy

Method

- 10 HDR/PDR brachytherapy patients using Geneva-Venezia applicators with ProGuide needles (3 to 10 per case).
- Post-implant CT (Siemens Somatom, Airo® TruCT) with x-ray catheters and CT markers in intracavitary (IC) channels and needles, followed by CISS MRI (Siemens Magnetom 3T Vida, 1.5T Sola) using Elekta MRI markers for IC channels and Orion MRI markers for needles.
- MDACC workflow includes CT-MRI registration with HR-CTV delineation on CISS MRI and OAR contouring on CT, followed by CT-based planning in Oncentra v4.2.
- Applicator based CT-MRI registration, distal dwell positions of the needles were reconstructed on 3D CISS MRI using C4 line marker contrast and compared to corresponding CT marker positions from post-operative CT (Oncentra) to quantify reconstruction discrepancies.
- Retrospective MRI-guided planning using Elekta MRI Marker (3D Applicator Model) and C4 Orion MRI line markers with CISS MRI sequence.
- Dosimetric comparison assessed relative mean differences in HR-CTV coverage (D90, D98) and OAR dose (D2cc) between MRI and CT-guided plans

RESULTS

(Top) C4 MRI line marker shown with its locking cap. (bottom) The C4 Orion marker secured within a 6G, 294 mm ProGuide sharp needle



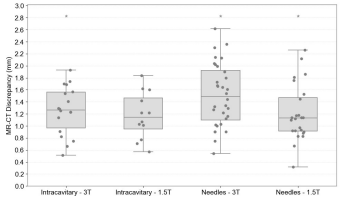
Sagittal CISS MRI of a gynecological patient with Geneva tandem with Elekta MRI line markers (left), and sagittal CISS MRI showing ProGuide needles with C4 Orion MRI markers (right).

Patient-Specific Reconstruction Accuracy for Needles:

- 3T MRI median needle accuracy ranging from 0.95 - 2.2 mm across 6 patients.
- 1.5T MRI needle reconstruction accuracy within 1.0–2.0 mm across 4 patients

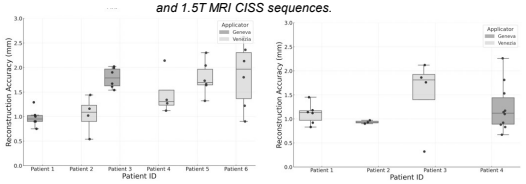
Percentage Dose Differences (HR-CTV)

- Mean percentage difference in HR-CTV D90 was +1.9% (1.5% - +5.8%) and in HR-CTV D98 was –1.8% (–4.1% - +1.3%).
- No statistically significant differences found for D90 (p = 0.11) or D98 (p = 0.09), indicating dosimetric agreement between MRI & CT

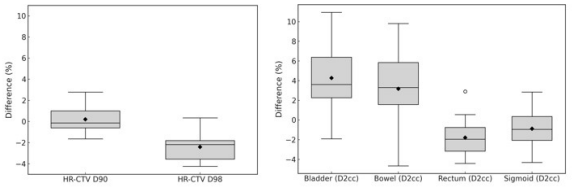


Reconstruction accuracy of IC channels with Elekta MRI markers and ProGuide needles with C4 Orion markers using Siemens 3T and 1.5T MRI CISS sequences.

Reconstruction accuracy per patient for ProGuide needles with C4 Orion markers using Geneva and Venezia applicators. Left: Six patients imaged with Siemens 3T MRI. Right: Four patients imaged with Siemens 1.5T MRI. Both applicators showed comparable reconstruction accuracy across patients



RESULTS



(Left)Mean percentage dose difference for HR-CTV D90 and D98 across 10 clinical cases, comparing MR guided treatment plan to conventional CT guided treatment plan. (Right) the mean percentage dose difference for D2cc in OAR's (bladder, bowel, rectum, and sigmoid).

Conclusions

- The Orion MRI markers and Elekta MRI markers generated strong signal in CISS MRI image for catheter visualization and accurate digitization.
- Achieves submillimeter precision in needle reconstruction (1.5T & 3T MRI) with median errors <1.1 mm, strong correlation between MRI-based and CT-based treatment plans for HR-CTV D90 and D98 coverage.
- Integration of C4 MRI line markers eliminates the need for post-operative CT scans, reduces treatment planning times, minimizes registration errors, ensuring greater accuracy in treatment planning.

References

Ning MS et al. Clinical utility and value contribution of an MRI-positive line marker for image-guided brachytherapy in gynecologic malignancies. Brachytherapy. 2020 May-Jun;19(3):305-315

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