

A multi-phase cross-modality deformable bio-tissue phantom for deformable image registration validation

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INTRODUCTION

- f-MRI techniques, like DWI and DCE, have demonstrated their utility in tumor response assessment in Head&Neck cancer, glioblastoma, and in liver and cognitive function assessment during and after radiation therapy.
- With MR-Linac, potentially daily/weekly f-MRI images can be collected for longitudinal evaluation
- Quantitative analysis of longitudinal f-MRI will heavily depend on the accuracy of MR-MR deformable image registration

AIM

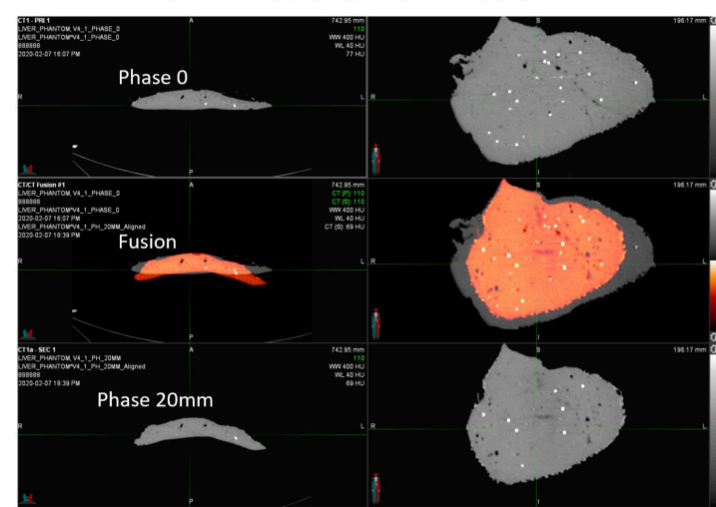
- To develop a bio-tissue phantom with landmarks for deformable image registration (DIR) on multi-modality images
- To demonstrate the effectiveness of the phantom on DIR on multiple MR sequences

METHOD

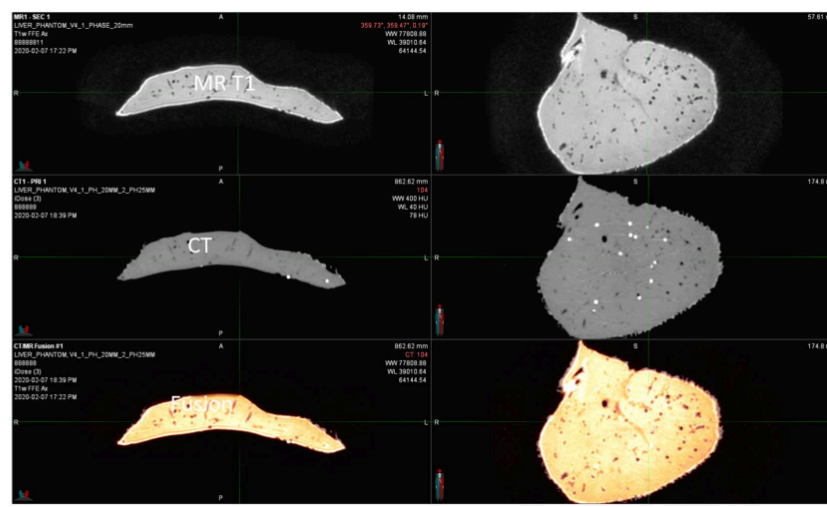
- Fresh pork liver lobe embedded in the deformable foam
- 40+ Golden seeds were implanted in liver as landmark
- Five deformation/shrinkage states
 - Deformations: Phase 1-4 (10mm, 20mm, 25mm, cross-direction 20 cm)
 - Shrinkage: Phase 5 (Steamed)
- Imaging
 - CT
 - MR: T1, T2, BTFE

RESULTS

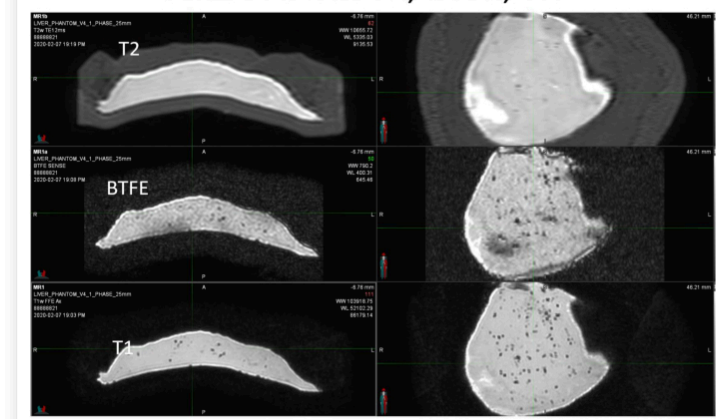
CT: Phase 0 VS Phase 2



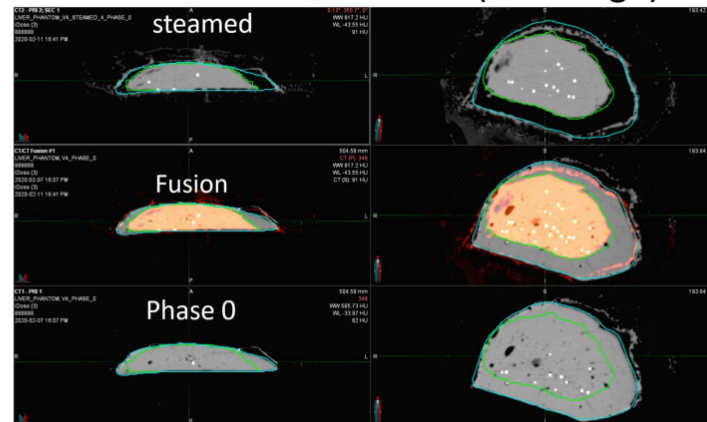
Phase 2: MR T1 VS CT



Phase 2: MR T2, BTFE, T1

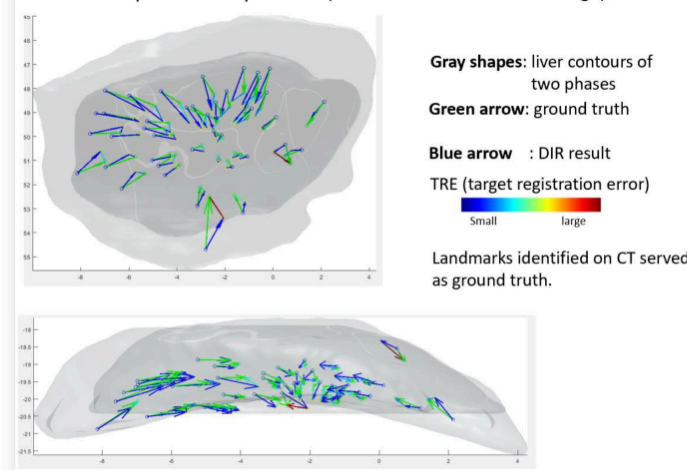


CT: Phase 0 vs Phase 5(shrinkage)



Liver volume shrinks from 200 cc to 113cc (56.5%)

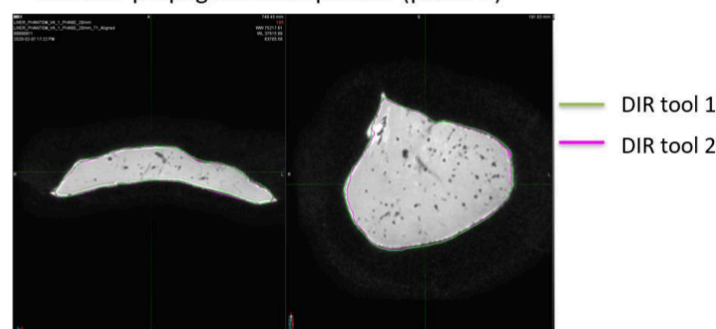
CT phase 2 to phase 5 (both deformation and shrinkage)



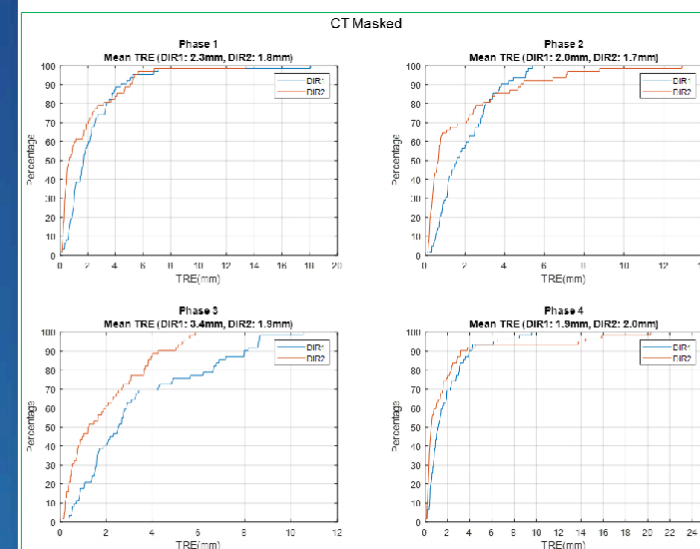
- Two commercial DIR tools were evaluated

- DIR between Phase 0 and phase 1-5

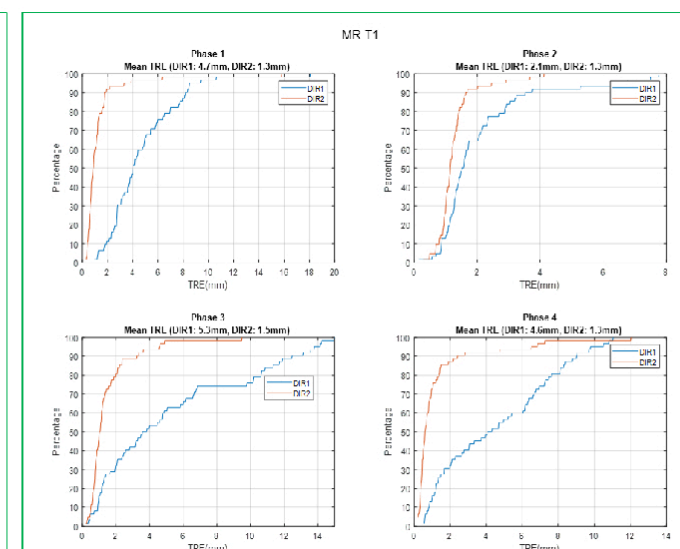
Contour propagation comparison (phase 2)



CT (marks digitally removed) phase 1-4

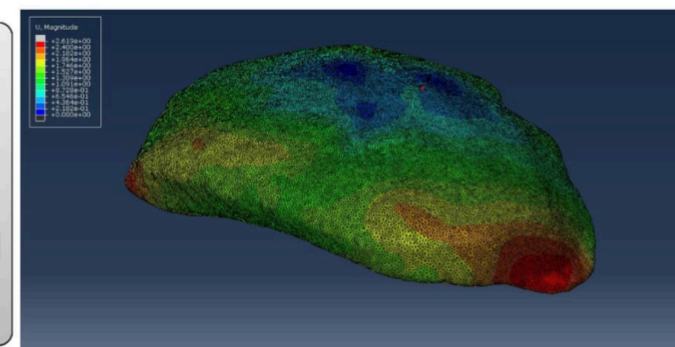
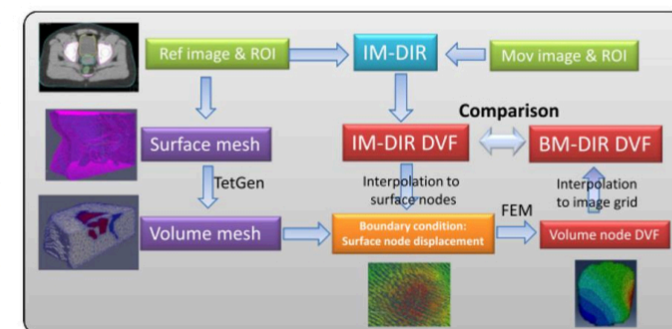


MR T1, phase 1-4



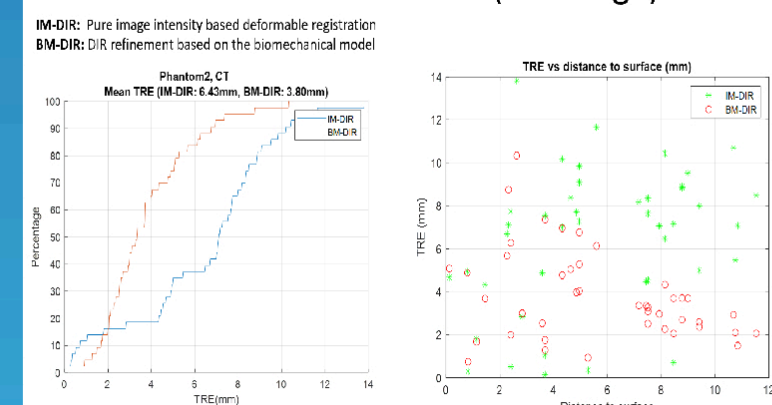
Biomechanical-model based DIR refinement*

(Recover physically-plausible deformation based on initial IM-DIR)



*Qin A, Ionascu D, Liang J, Han X, Connell NO, Yan D. The evaluation of a hybrid biomechanical deformable registration method on a multistage physical phantom with reproducible deformation. Radiation Oncology, 2018

CT: Ph0 to Ph5 DIR (shrinkage)



CONCLUSIONS

- A bio-tissue phantom was developed to validate deformable image registration accuracy on both MR and CT
- For two DIR tools with similar contour propagation accuracy, the internal DVF quality evaluated by the implanted landmarks could be very different, depending on the imaging modality and degree of deformation.
- The Bio-mechanical model has shown the potential to further improve pure image-based DIR accuracy.

Phantom development process

