Development of voxel-by-voxel based Synthetic CT generation method using a Flexible UTE sequence (FUSE) in a porcine model

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ABSTRACT

Purpose:
To evaluate the feasibility of implementing FUSE for future voxel-based synthetic CT generation.

Methods:
A porcine head was scanned with high-resolution CT to assess bone, soft-tissue, and air-cavity anatomy. FUSE was implemented on a clinical 3T MRI system, and a steak sample was scanned using T2-weighted MRI and FUSE for preliminary comparison.

Results:
The porcine-head CT demonstrated suitable anatomy for future FUSE evaluation. FUSE was successfully implemented, and spatially registered steak images showed improved cortical-bone conspicuity with FUSE compared with T2-weighted MRI.

Conclusion:
FUSE implementation was feasible. Future work will include sequence optimization, porcine MRI acquisition, and integration of FUSE-derived information into the voxel-wise sCT framework.

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Introduction:

- In conventional MRI, both bone and air appear as signal voids and cannot be easily distinguished.
- This limitation remains a major challenge for synthetic CT (sCT) generation in MRI-based radiotherapy.
- Although AI-based methods have shown promising results, their performance in complex anatomical regions, particularly at bone–air interfaces, remains limited and highly dependent on training datasets (7-11).
- This study investigated the feasibility of implementing a new Flexible Ultra-Short Echo Time (FUSE) pulse sequence and its potential integration into a voxel-based framework for future sCT generation.

Materials and Methods:

- A porcine head was selected because its bone, soft-tissue, and air-cavity anatomy closely resembles that of the human head (12). High-resolution CT was acquired to characterize its anatomical structures (Figure 1).
- The FUSE sequence described by Cui et al. (13) was implemented in Siemens IDEA. Following successful compilation, the RF and gradient waveforms were verified in POET (Figure 2), and the sequence was deployed on a 3T MRI scanner.
- As a preliminary ex vivo test, a steak sample containing cortical bone, soft tissue, and air interfaces was scanned using T2-weighted MRI and FUSE (Figure 4).
- A voxel-based sCT framework was developed using the available non-FUSE images (Figure 3). FUSE-derived information will be incorporated after successful acquisition in the porcine model.

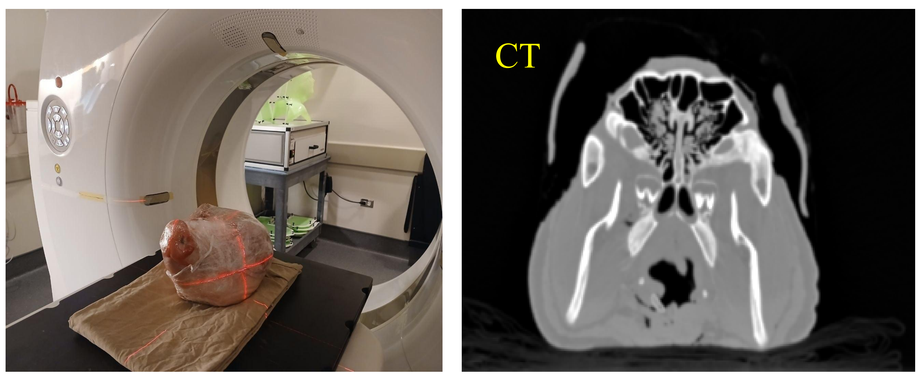

Figure 1. Porcine-head experimental setup and high-resolution CT image showing bone, soft tissue, and air cavities

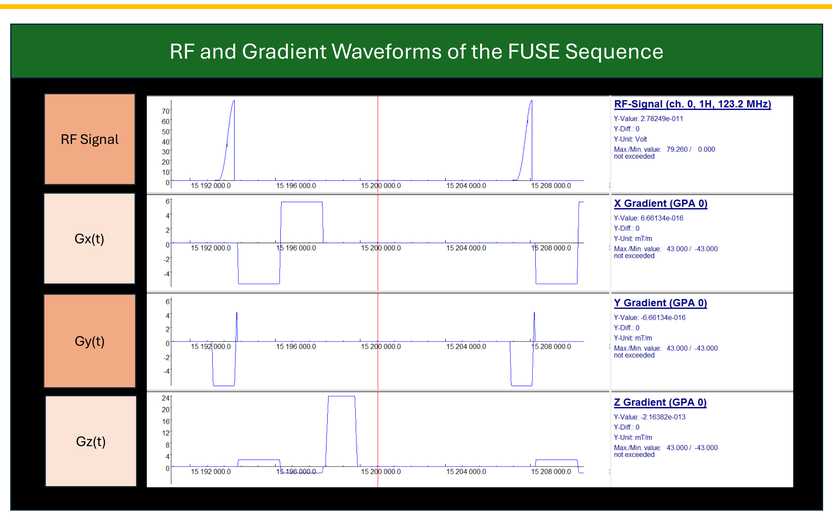

Figure 2. RF excitation and gradient waveforms (Gx, Gy, and Gz) of the implemented Flexible Ultra-Short Echo Time (FUSE) sequence, displayed in Siemens POET.

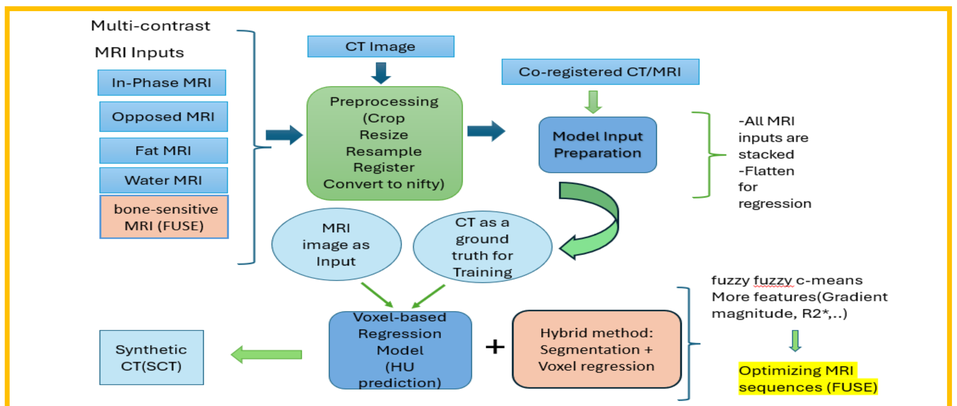

Figure 3. Proposed voxel-wise sCT framework with future FUSE integration.

Results:

- Porcine-head CT demonstrated complex bone, soft-tissue, and air-cavity anatomy.
- FUSE was successfully implemented and executed on a 3T MRI scanner.
- Preliminary steak imaging showed improved cortical-bone conspicuity with FUSE compared with T2-weighted MRI, where cortical bone appeared as a signal void (Figure 4).
- A voxel-wise sCT framework was developed; FUSE integration will follow sequence optimization and porcine acquisition.

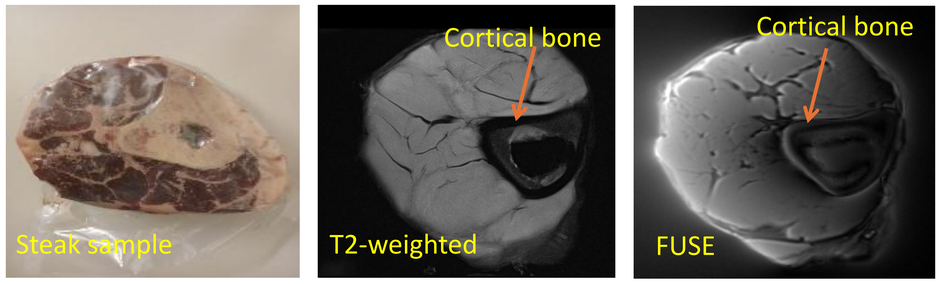

Figure 4. Spatially registered T2-weighted and FUSE images of the steak sample. FUSE provided improved cortical-bone conspicuity compared with T2-weighted MRI, in which cortical bone appeared as a signal void.

Discussion:

- Porcine-head CT confirmed complex bone, soft-tissue, and air-cavity anatomy suitable for future FUSE evaluation.
- Preliminary steak results showed improved cortical bone visualization with FUSE compared with T2-weighted MRI.
- Future work will optimize FUSE, acquire porcine data, and integrate FUSE-derived information into the voxel-wise sCT framework.

Conclusion:

- Porcine-head CT confirmed its suitability for future MRI-based sCT evaluation.
- FUSE was successfully implemented on a 3T MRI scanner and showed improved cortical bone visualization in the preliminary steak experiment.
- Future work will optimize FUSE, acquire porcine MRI data, and integrate FUSE-derived information into the voxel-wise sCT framework.

References:

1. Edmund et al. (2017); 2. Owrangi et al. (2018); 3. Kazemifar et al. (2019); 4. Spadea et al. (2021); 5. Huijben et al. (2024); 6. Bird et al. (2021); 7. Johnstone et al. (2018); 8. Stanescu et al. (2008); 9. Dowling et al. (2012); 10. Hsu et al. (2013); 11. Lui et al. (2021); 12. Kyllar et al. (2014); 13. Cui et al. (2023)