Synthetic Inversion Image Generation Using MP2RAGE T1 Mapping for DBS Targeting

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CONFLICT OF INTEREST

- Dr. Middlebrooks: Research support from Varian Medical Systems, Inc. and Boston Scientific Corp; institutional research support from Mayo Clinic and as a Site PI, Co-I, and consultant on NIH supported grants unrelated to the current study.

BACKGROUND

- Advances in MRI technology have increased interest in direct targeting for DBS.
- Various imaging sequences enhance contrast for common DBS targets, including:
  - Fast Gray Matter Acquisition T1 Inversion Recovery (**FGATIR**) → prelemniscal radiations/dentato-rubro-thalamic tract, ANT and mammillothalmic tract
  - Edge-Enhancing Gradient Echo (**EDGE**) → CM and parafascicular nuclei

BACKGROUND

- The increase in the number of necessary sequences has led to an increase in imaging time
- Precise inversion pulse timing may result in suboptimal contrast, especially in ultra-high field MRI due to B1+ field inhomogeneity causing significant contrast variability.

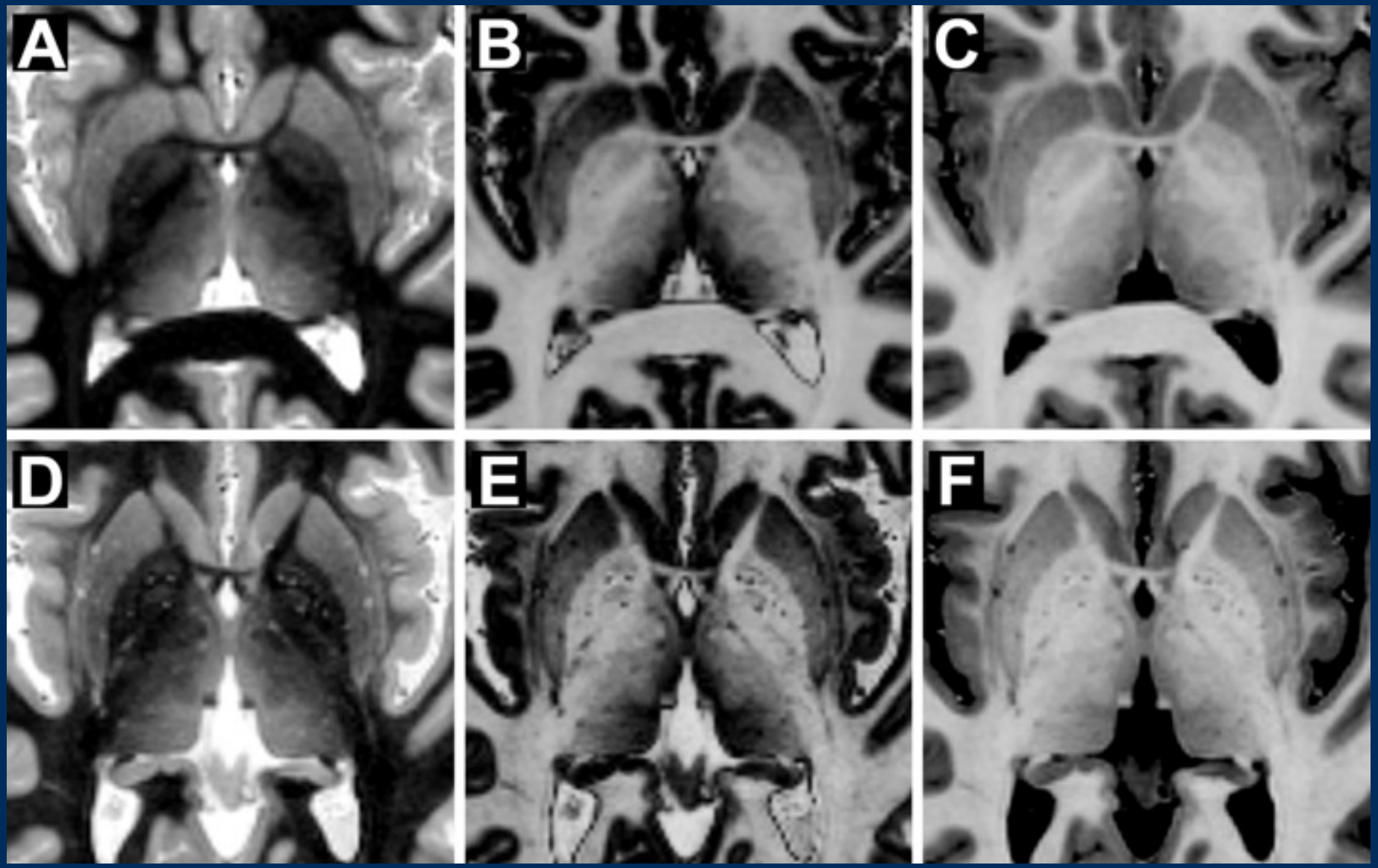
STUDY PURPOSE

We used 3D MP2RAGE-based T1 maps to retrospectively synthesize images of any desired inversion time, including T1-weighted, FGATIR, and EDGE contrasts, to visualize specific DBS targets at both 3T and 7T.

METHODS

- The T1 maps were generated from the MP2RAGE sequence.
- Using a systematic sequence optimization framework, we modified two MP2RAGE product sequences for optimal T1 mapping at 7T and 3T.
- Sequence parameters were balanced to achieve optimal image resolution/sharpness, signal-to-noise ratio (SNR), image uniformity, and scan time.
- Synthetic image contrasts were generated across a full range of inversion times (TIs) at 3T and 7T.

[Middlebrooks et al, 2023]

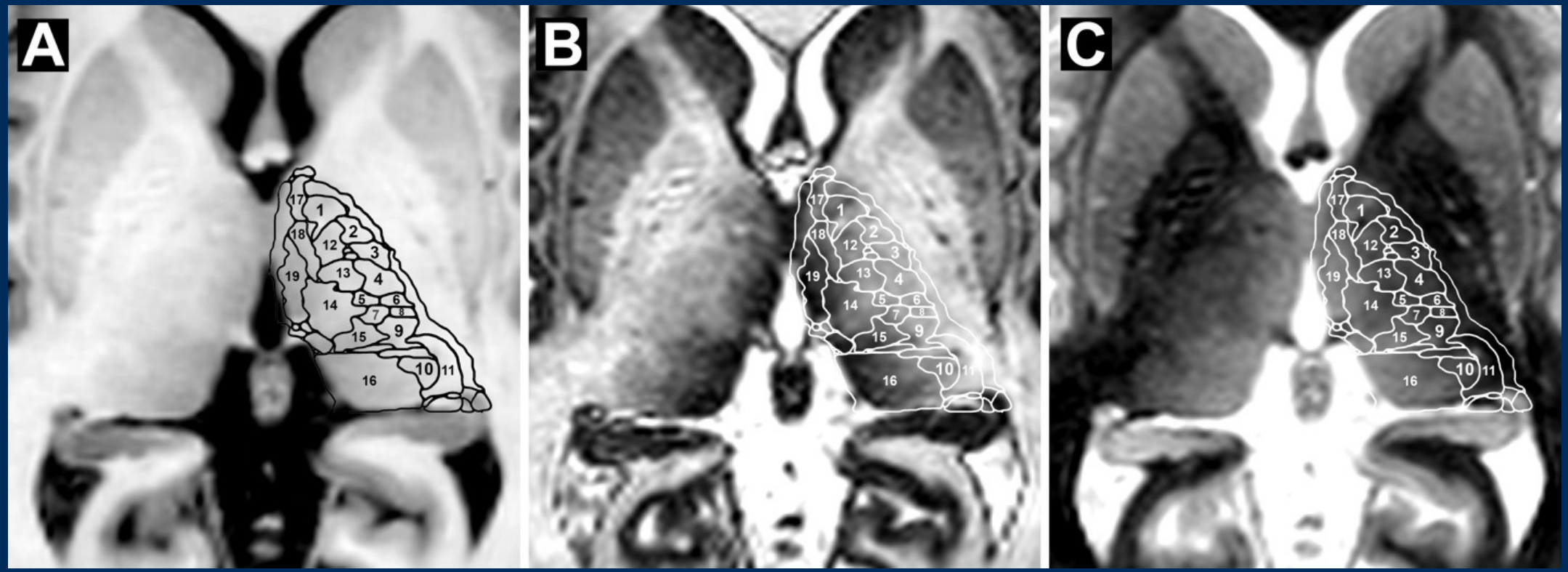


Synthetic 3T inversion images representing common contrasts used in DBS targeting, including (A) FGATIR, (B) EDGE, and (C) T1-weighted images.

Synthetic 7T inversion images for (D) FGATIR, (E) EDGE, and (F) T1-weighted contrasts.

[Middlebrooks et al, 2023]

The intra-thalamic contrast allowed visualization of thalamic microstructure with many key nuclei delineated



Example synthetic 7T inversion images for (A) T1-weighted, (B) EDGE, and (C) FGATIR contrasts with atlas overlay of the DBS Intrinsic Template AtLas (DISTAL).

[Middlebrooks et al, 2023]

- The standard acquisition 3T EDGE-MICRA image (A) acquired in a total of 24 minutes of scan time showed the location of the CM nucleus.
- Synthetic EDGE images for both 3T (B) and 7T (C) acquired in only 12 minutes showed similar or improved SNR and contrast with the delineation of the CM nucleus.

CONCLUSION

Our MP2RAGE T1 mapping approach:

1. Offers the benefit of producing numerous contrasts of interest for DBS targeting from a single acquisition
2. Enables post-acquisition image contrast adjustment for specific DBS target enhancement compared to single inversion methods like FGATIR or EDGE.
3. It is particularly advantageous at 7T to mitigate variations in B1+ inhomogeneity for optimal contrasts.

LIMITATIONS

1. Physics Simplification: Our modified equation simplifies image calculations without major contrast effects from tissue proton density variations, optimizing surgical planning.
2. Sequence Adaptation: Synthetic image generation utilizes a common sequence, although facilities without it would need adaptation.
3. T1 Map Challenges: Despite shorter scan times, T1 map acquisition might be problematic for motion-prone patients. Future techniques like compressed sensing and deep learning could improve efficiency.

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QUESTIONS

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