Accelerated High-Resolution 3D Gradient Spin Echo Imaging Improves T_2 Quantification Accuracy

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Background

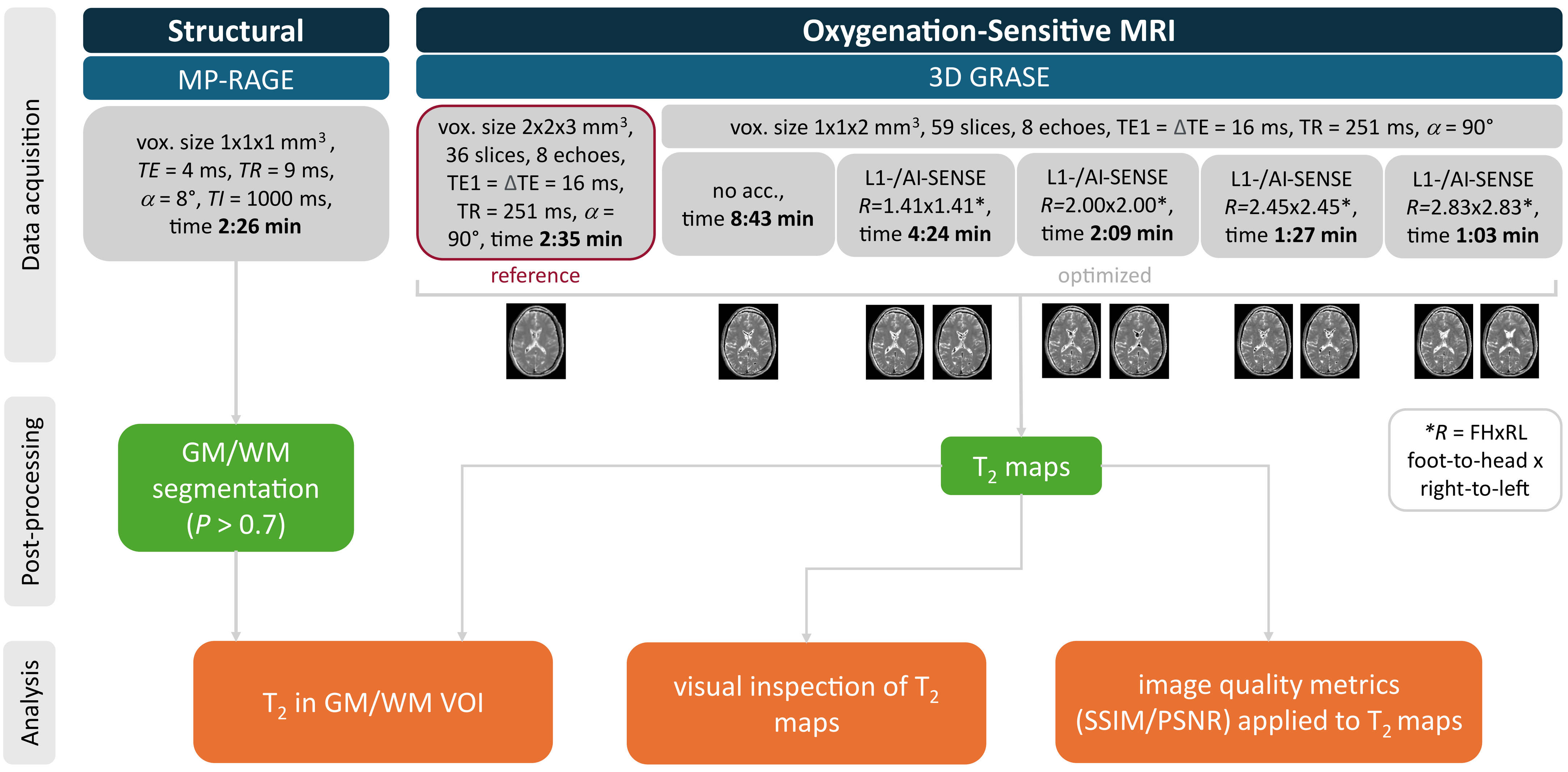
- multi-parametric quantitative blood oxygenation level dependent (mqBOLD) MRI allows to assess clinically relevant biomarkers like the oxygen extraction fraction (OEF)[1,2] and the cerebral metabolic rate of oxygen ($CMRO_2$)[3,4]
- mqBOLD requires accurate quantification of T_2, T_2*, cerebral blood flow and volume (CBF/CBV) → acquisition time beyond clinical feasibility
- modern MRI reconstruction techniques allow for high acceleration factors *R* at preserved image quality[5,6]

Hypothesis

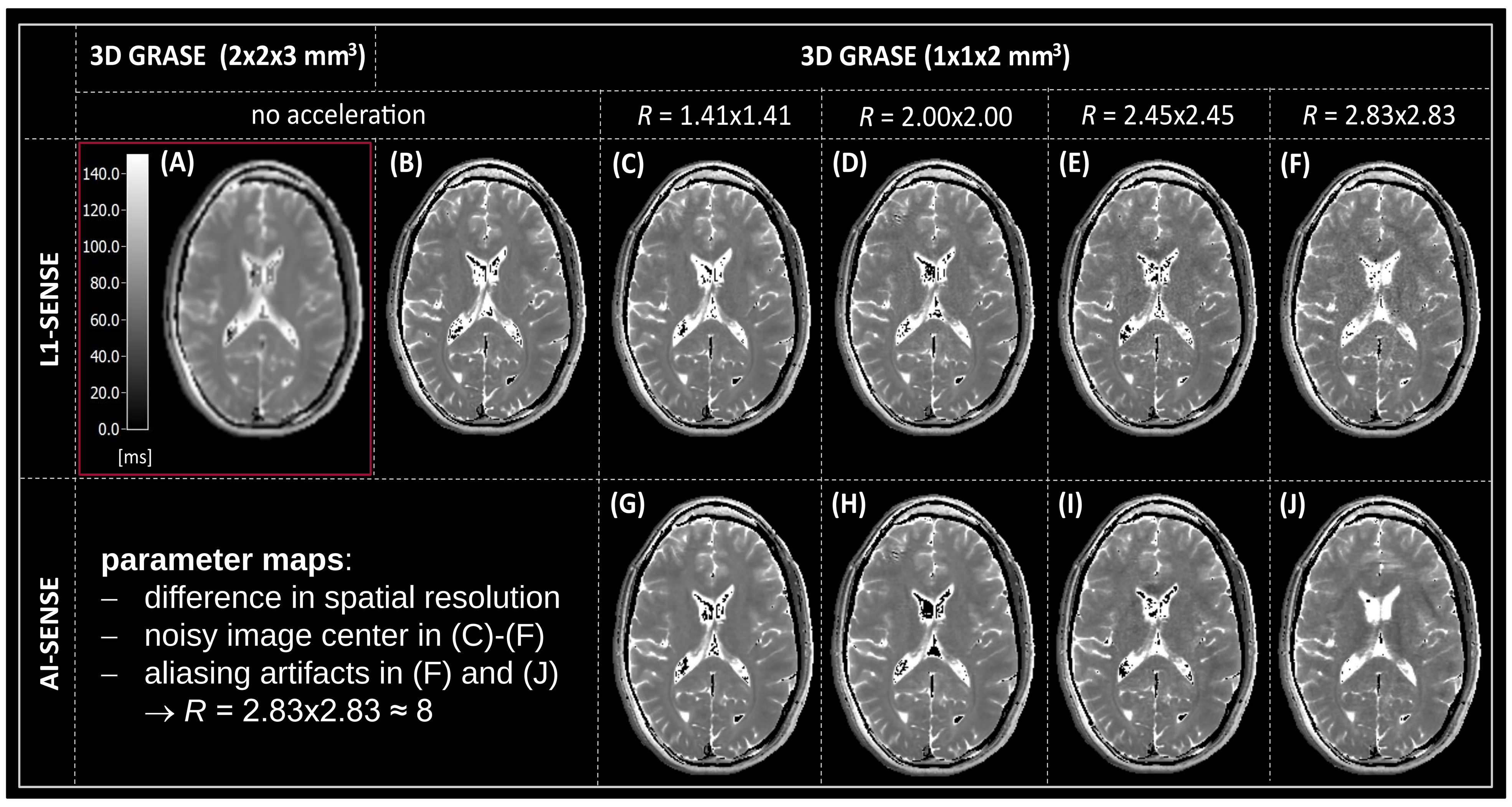
high-resolution 3D gradient spin echo (GRASE) imaging combined with an L1-regularized iterative reconstruction[5,6] enables more accurate T_2 quantification in shorter acquisition time → additional benefits from reconstruction based on adaptive intelligence[7]?

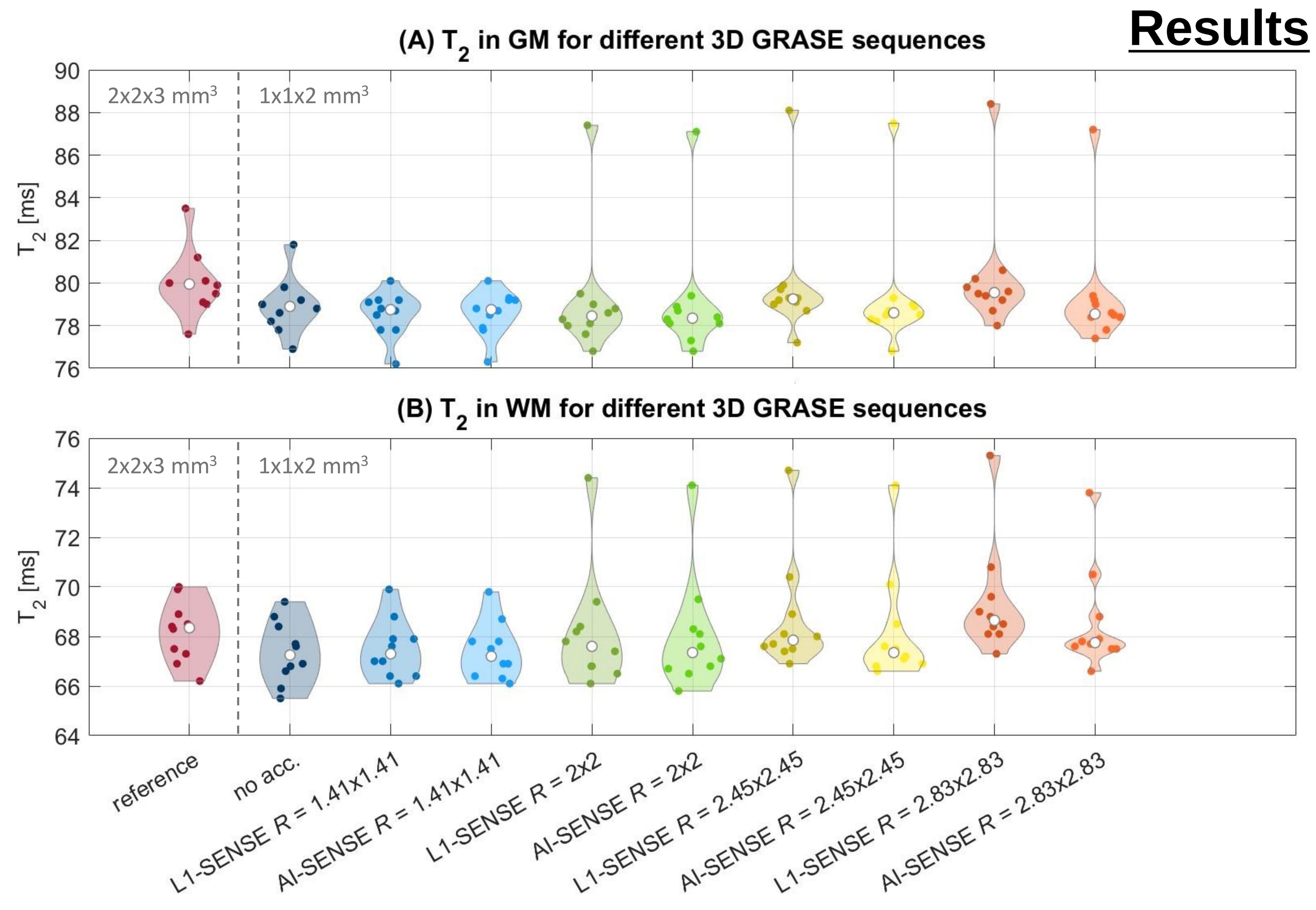
Methods

- 3T Philips Ingenia Elition X MRI scanner with a 32-channel head coil
- 10 healthy subjects aged 27.5 ± 2.9 years
- **multi-echo T2-weighted data**:
  - low- (reference) vs. high-resolution (optimized) scans
  - L1-SENSE: sensitivity-encoding-based undersampling with L1-regularized iterative reconstruction
  - AI-SENSE: undersampling with an reconstruction algorithm enhanced by adaptive intelligence
  - exponentially fitted to obtain T_2 parameter maps



Results





3D GRASE (1x1x2 mm³)	SSIM		PSNR [dB]	
	L1-SENSE	AI-SENSE	L1-SENSE	AI-SENSE
no acceleration	1.00	-	inf	-
R = 1.41x1.41	0.973 ± 0.007	0.974 ± 0.007	29.99 ± 3.22	29.67 ± 2.70
R = 2.00x2.00	0.961 ± 0.007	0.962 ± 0.007	30.86 ± 2.82	30.47 ± 2.54
R = 2.45x2.45	0.956 ± 0.006	0.956 ± 0.007	29.09 ± 4.90	28.68 ± 4.91
R = 2.83x2.83	0.953 ± 0.007	0.953 ± 0.007	28.40 ± 6.49	27.70 ± 6.06

image quality metrics (table left): mean values decrease for increasing *R*

VOI analysis (figure top right): lower median T_2 values for optimized sequences, stable in GM across *R* but slightly increasing in WM

Discussion

- optimized multi-echo 3D GRASE with voxel size 1x1x2 mm³ yielded high-resolution T_2 maps with lower median T_2 values in GM and WM (in line with literature[2,8]) across acceleration factors → improved quantification accuracy due to reduced partial volume effects at tissue borders
- denoising properties of AI-SENSE reduced *g*-factor noise[9] introduced by SENSE-based acceleration (also reflected in higher median T_2 values in WM), but could not correct for aliasing[10] at *R* = 2.83x2.83 ≈ 8

Conclusion

- **high-resolution 3D GRASE in combination with L1-SENSE acceleration up to *R* = 2.45x2.45 ≈ 6 enables faster and more accurate T_2 mapping compared to the low-resolution reference → reduction of acquisition time for the mqBOLD method**
- **image quality (*g*-factor noise) can further be improved by applying a reconstruction with adaptive intelligence (AI-SENSE)**

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data processing software:
MATLAB R2021b, The MathWorks Inc., USA
SPM12, Wellcome Centre for Human Neuroimaging

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