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Yale

5023

Reducing T2-related bias in mq-BOLD derived maps of Oxygen Extraction Fraction by 3D acquisition

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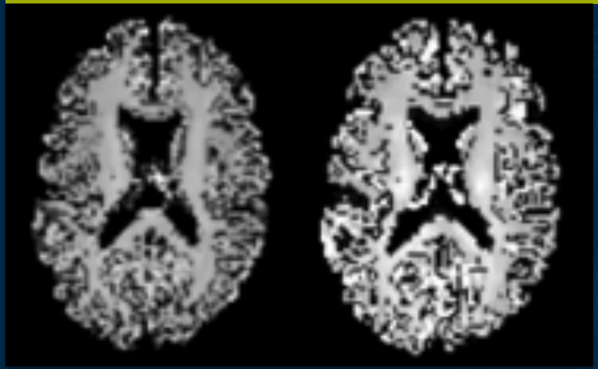
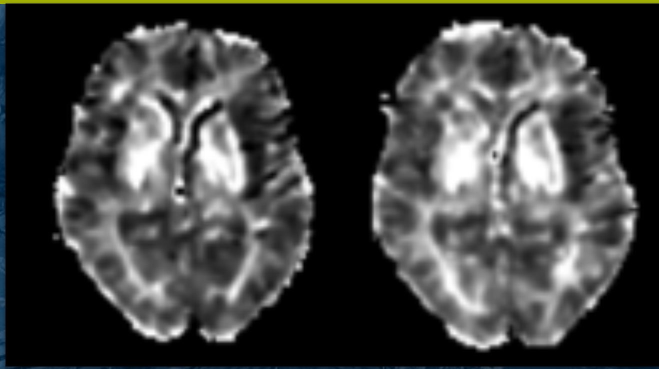


Session: **Physiological Techniques**
Room: **Exhibition Hall**
Time: **4:15pm – 5:15 pm**
Date: **Wednesday, June 20, 2018**



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Declaration of Financial Interests or Relationships

Speaker Name: Stephan Kaczmarz

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Motivation

Background

Oxygen extraction fraction (OEF) is a fundamental marker of brain function

Relative OEF (rOEF) can be measured by multiparametric quantitative BOLD (mq-BOLD) with 3 separate measurements of T_2, T_2* & rCBV

mq-BOLD was successfully applied in stroke, tumor and cerebrovascular disease

Issue

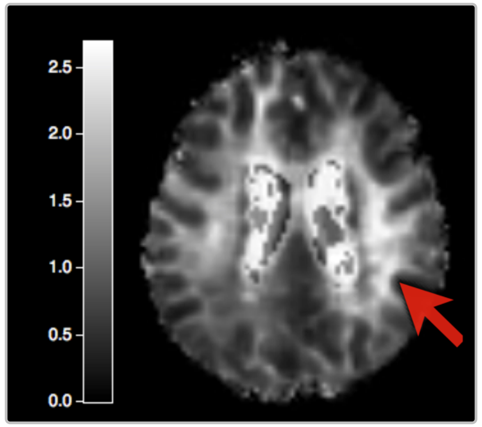
However, rOEF values systematically elevated

Hypothesis

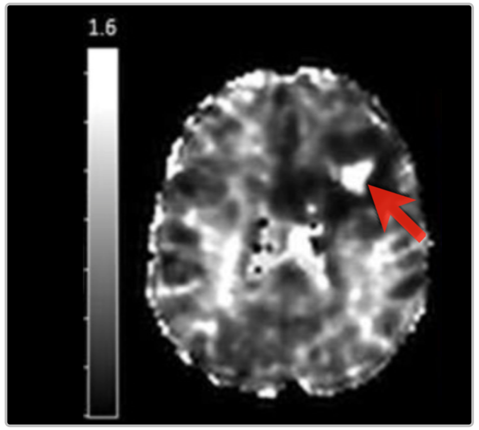
rOEF elevations caused by T_2 elevations

rOEF elevations can be reduced by 3D GraSE T_2 acquisition

rOEF in ICAS



rOEF in Glioma



From Preibisch et al. In NMR BioMed 30(11) (2017):3775.

Material & Methods

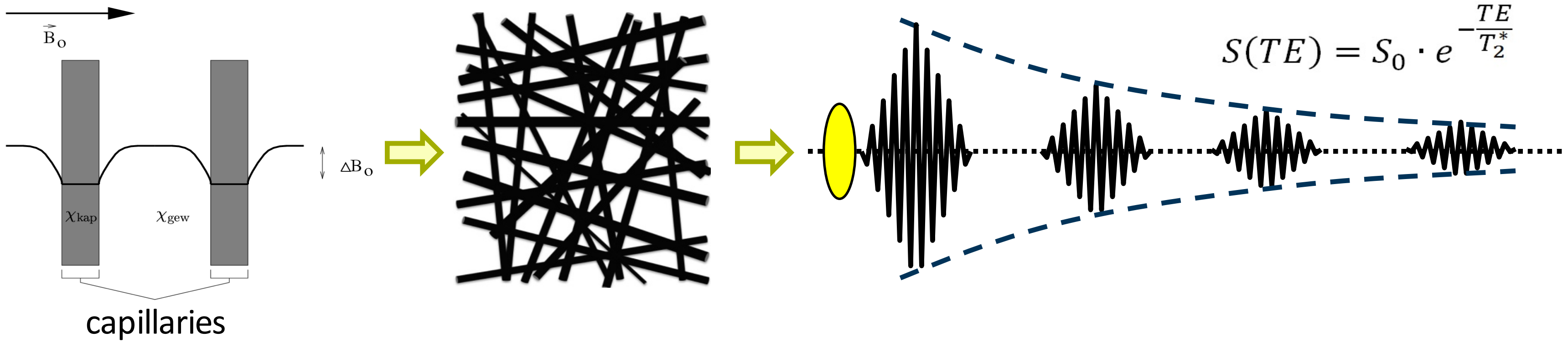
Multi-parametric **q**uantitative **BOLD** (mq-BOLD)

Idea

Model vasculature by randomly oriented cylinders with infinite length

Estimate deoxygenated blood volume by total relative cerebral blood volume

Model



rOEF

$$rOEF = \frac{R_2'}{c \cdot rCBV} \quad \text{with} \quad R_2' = \frac{1}{T_2^*} - \frac{1}{T_2}$$

rCBV: relative cerebral blood volume

$c = 4/3 \cdot \gamma \cdot \pi \cdot \Delta\chi \cdot B_0 \approx 317$ Hz @3T

According to: Yablonskiy & Haacke, MRM 32(6) (1994); 749-763. Tóth et al. In J Neurooncol. 115 (2013): 197-207 ; Hirsch et al. in NMR Biomed, 27 (2014): 853-862 ; Christen et al. in MRM 68(3) (2012): 905-911.

Material & Methods

Participants

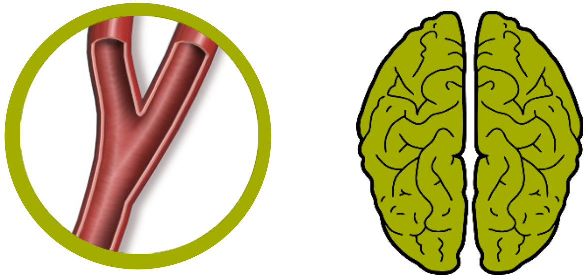
- 3T Philips Ingenia
- Software release 5.1.8
- 32 channel head coil
- Custom patches

1

Phantom

2

Young healthy controls (YHC)



3

Elderly healthy controls (EHC)

4

Internal carotid artery stenosis (ICAS)

Material & Methods

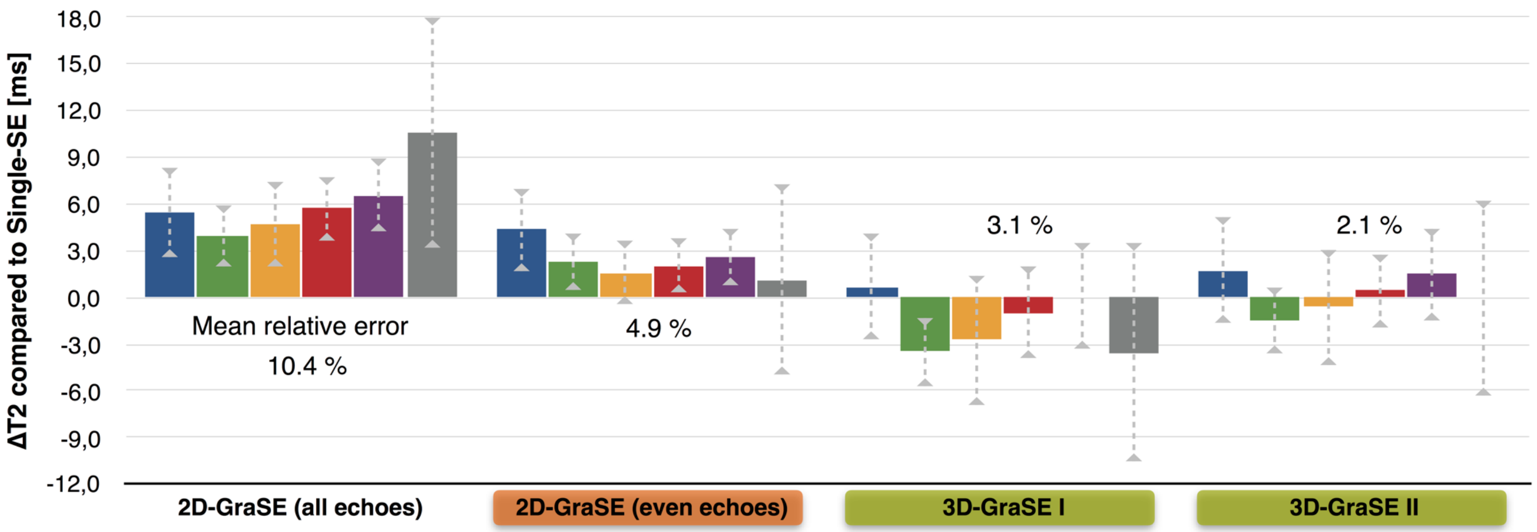
MR Sequences

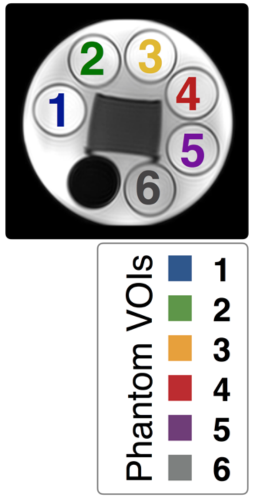
Subjects		T_2 mapping				T_2*	DSC	Main parameter
		Single-SE	2D-GraSE	3D-GraSE I	3D GraSE II	multi GRE	GE-EPI	
Stage 1	**Phantom** 6 different VOI's	✅	✅	✅	✅			T_2
Stage 2	**10 YHC** age: 28.4 ± 4.1 y	(Literature)	✅	✅	✅	✅		R_2'
Stage 3	**8 EHC** age: 69.5 ± 4.8 y		✅		✅	✅	✅	rOEF
Stage 4	**3 ICAS** age: 63.0 ± 9.6 y		✅		✅	✅	✅	rOEF
		TE = 60, 70, 80, 100, 120, 140, 160 ms	*$TE_1 = \Delta TE$ = 16 ms*	*$TE_1 = \Delta TE$ = 16 ms*	*$TE_1 = \Delta TE$ = 10 ms*	*$TE_1 = \Delta TE$ = 5 ms*	*TE = 30 ms*	
		7 echoes	*8/4 echoes*	*8 echoes*	*16 echoes*	*12 echoes*	*1 echo*	
		TR=3000 ms	*TR=8596 ms*	*TR=251 ms*	*TR=487 ms*	*TR=1950 ms*	*TR=1513 ms*	
		3.5x4x4 mm³	*2x2x3 mm³*	*2x2x3 mm³*	*2x2x3 mm³*	*2x2x3 mm³*	*2x2x3.5 mm³*	
		5 slices	*30 slices*	*30 slices*	*30 slices*	*30 slices*	*26 slices*	
		each 2:36 min	*2:23 min*	*2:09 min*	*4:09 min*	*6:08 min*	*2:01 min*	

Results

Stage 1: Phantom T_2

Sequence		T₂ in phantom volumes of interest [ms]					
		1	2	3	4	5	6
Single-SE		32,4 ± 1,7	48,6 ± 0,7	61,1 ± 0,9	62,6 ± 1,0	61,9 ± 0,9	105,1 ± 2,7
2D-GraSE	all echoes	37,9 ± 1,2	52,5 ± 1,2	65,8 ± 1,8	68,3 ± 1,0	68,5 ± 1,4	115,7 ± 4,7
	even echoes	36,7 ± 0,9	50,9 ± 1,0	62,8 ± 1,0	64,7 ± 0,8	64,5 ± 1,0	106,2 ± 3,4
3D-GraSE I		33,1 ± 1,7	45,1 ± 1,5	58,4 ± 3,3	61,6 ± 1,9	62,0 ± 2,6	101,6 ± 4,3
3D-GraSE II		34,1 ± 1,6	47,1 ± 1,4	60,5 ± 2,7	63,1 ± 1,4	63,4 ± 2,1	105,1 ± 3,6





As expected, less stimulated echoes bias by even echo fitting of 2D-GraSE

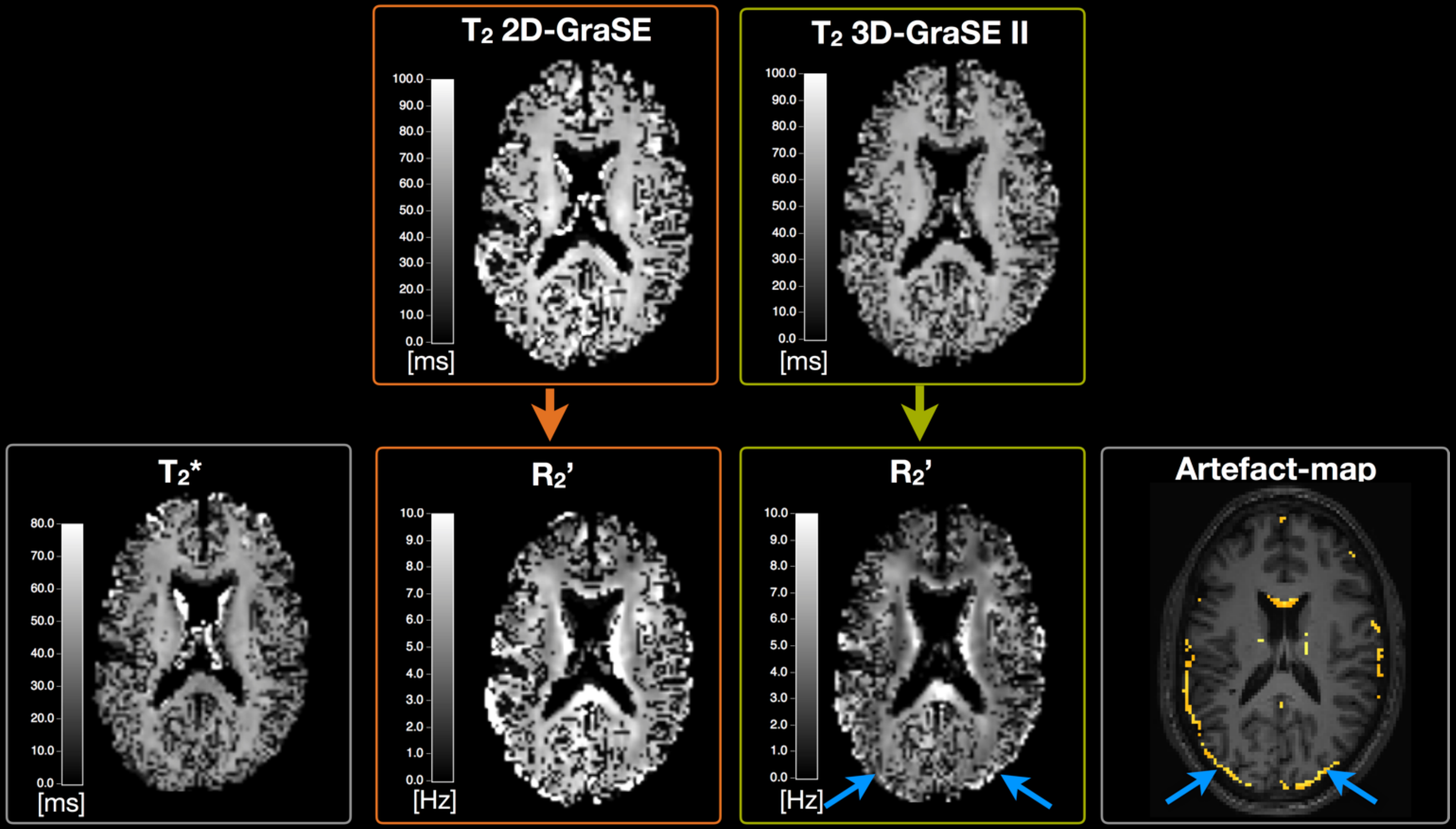
3D-GraSE I better than 2D-GraSE

3D-GraSE II closest to reference

30y, male

Results

Stage 2: YHC examplary data



Globally decreased T_2 & R_2' by 3D-GraSE II

Results

GM & WM mean of all YHC

Stage 2: YHC R_2'

	GRE	2D-GraSE	3D-GraSE I	3D-GraSE II
	T_2* [ms]	T_2 [ms]	T_2 [ms]	T_2 [ms]
GM	53.9 ± 1.7	83.9 ± 1.1	76.5 ± 1.2	78.2 ± 1.1
WM	50.3 ± 0.9	75.4 ± 1.0	66.6 ± 0.9	69.1 ± 1.0
Fit-error [‰/echo]	1.6 ± 0.2	3.4 ± 0.2	3.3 ± 0.2	1.7 ± 0.1

Literature*	2D-GraSE	Single SE
	T_2 [ms]	T_2 [ms]
	84.9 ± 3.5	73.5 ± 2.4
	73.5 ± 2.4	68.2 ± 2.2

	2D-GraSE	3D-GraSE I	3D-GraSE II
	R2' [1/s]	R2' [1/s]	R2' [1/s]
GM	8.3 ± 0.4	6.9 ± 0.3	7.2 ± 0.4
WM	7.3 ± 0.3	5.4 ± 0.3	6.0 ± 0.3

Artefact exclusion by R_2' and fit-errors

	3D-GraSE II
	R2' [1/s]
GM	6.2 ± 0.2
WM	5.7 ± 0.2

- 3D-GraSE I & II closer to reference
- 3D-GraSE II with less fit-errors
- Artefact exclusion further decreases R_2'

* from Hirsch et al. in NMR Biomed, 27 (2014): 853-862

Results

GM & WM mean of all EHC

Stage 3: EHC rOEF

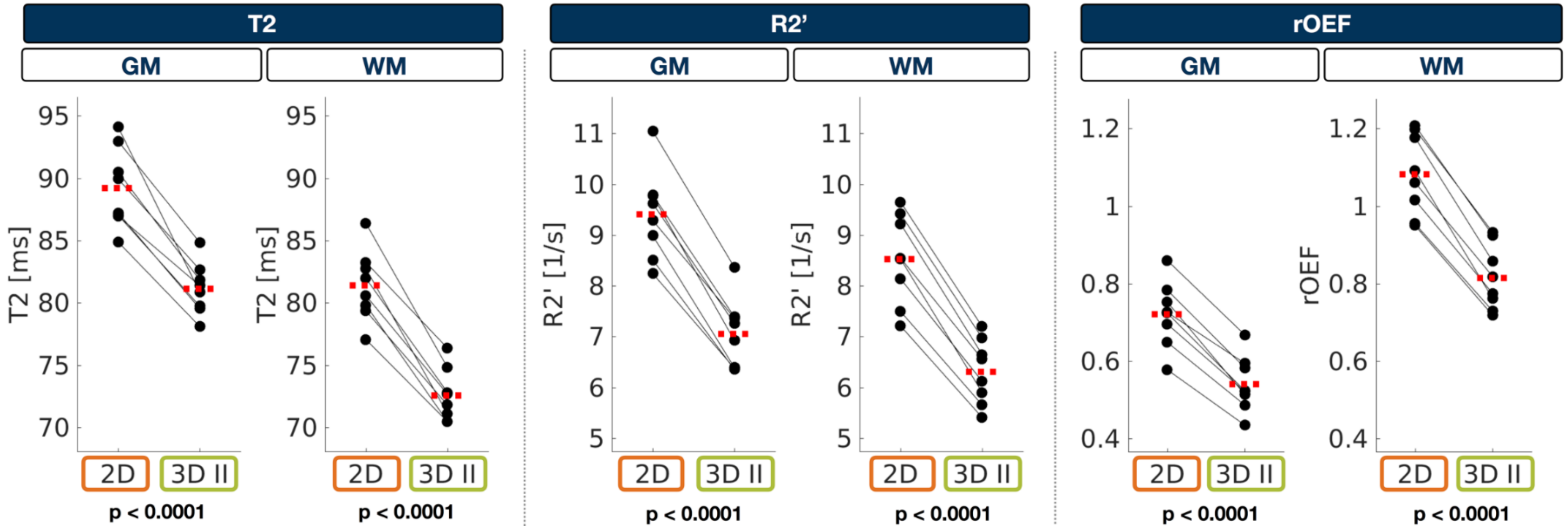
	GRE T2* T_2^* [ms]	2D-GraSE * T_2 [ms]	3D-GraSE II * T_2 [ms]	DSC rCBV [%]
GM	55.1 ± 4.1	89.2 ± 3.2	81.4 ± 2.0	4.7 ± 0.4
WM	50.7 ± 2.6	81.4 ± 2.8	72.3 ± 2.1	2.7 ± 0.1

	R2' [1/s] *	R2' [1/s]
GM	9.4 ± 0.9	8.2 ± 0.9
WM	8.5 ± 0.9	6.8 ± 0.7

	rOEF *	rOEF
GM	0.72 ± 0.08	0.61 ± 0.09
WM	1.08 ± 0.10	0.85 ± 0.09

Artefact exclusion by R_2' and fit-errors

	* rOEF
GM	0.54 ± 0.07
WM	0.81 ± 0.08

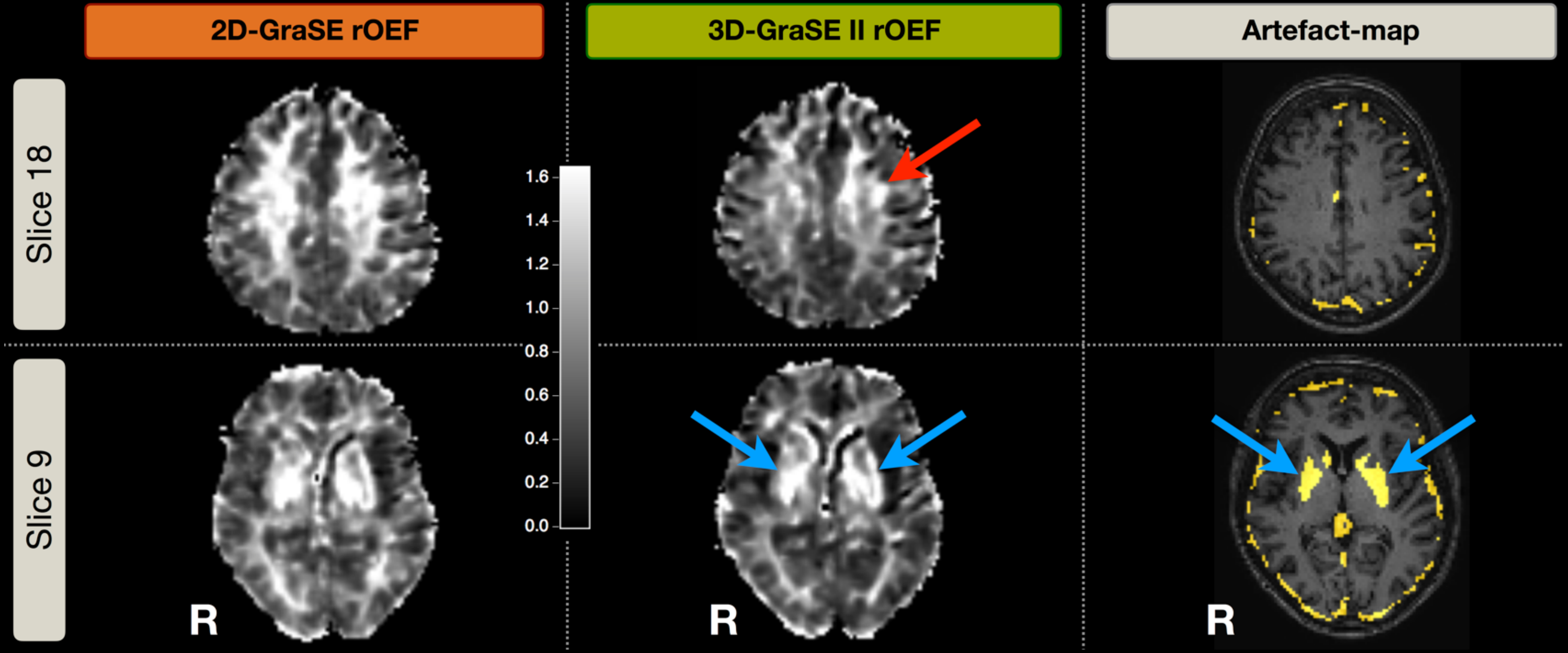


3D-GraSE II with significant decrease of T_2, R_2' & rOEF

Results

High-grade left sided unilateral ICAS
69y, female

Stage 4: ICAS examplary data



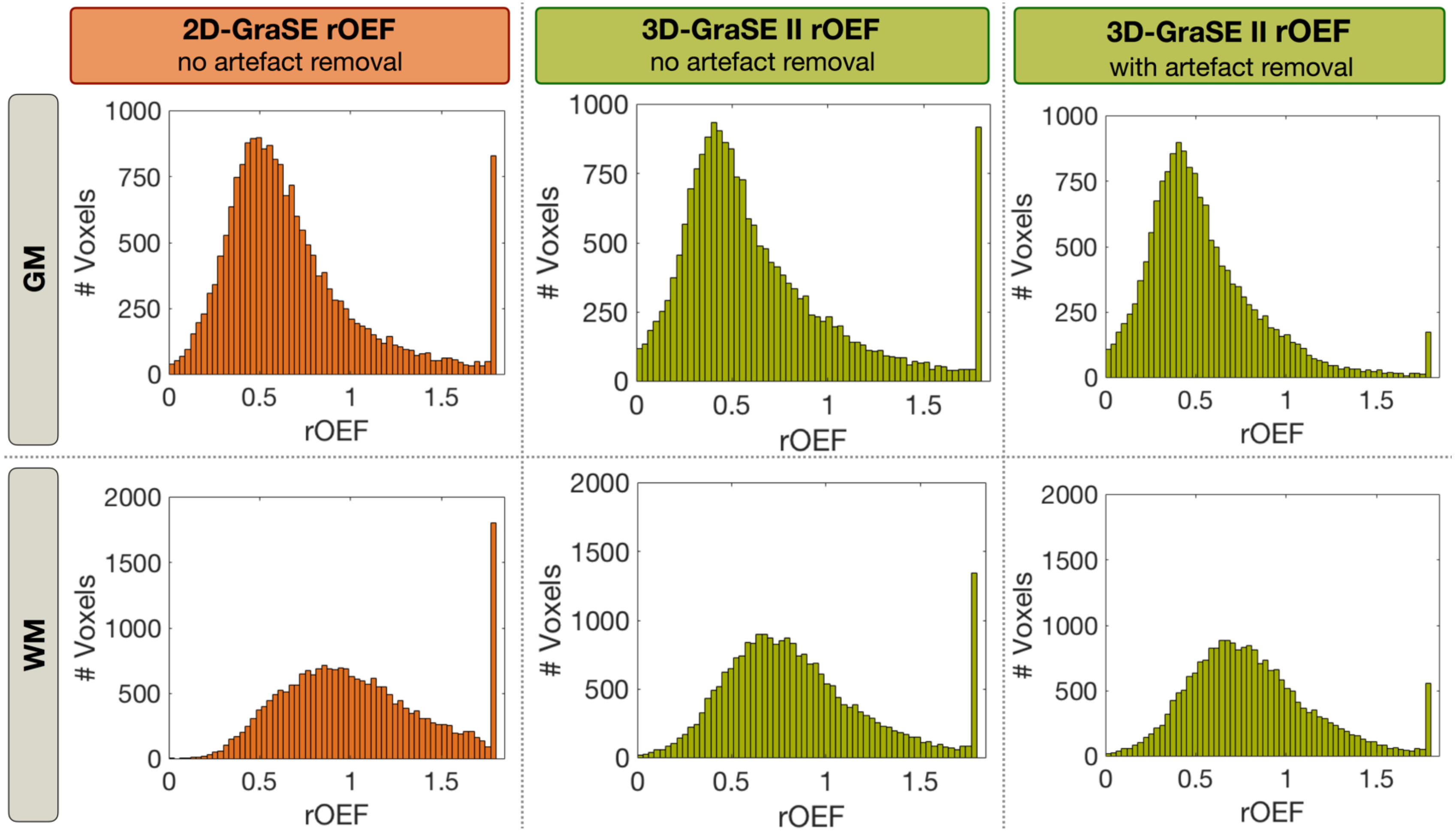
ICAS induced ipsilateral rOEF increase only visible in 3D-GraSE II

Putamen (high iron content) masked in artefact-map and corresponds to maximum rOEF values

Results

High-grade left sided unilateral ICAS
69y, female

Stage 4: ICAS rOEF



Strong clipping for 2D-GraSE

Lower rOEF peak position by 3D-GraSE II

Artefact removal reduces clipping

Summary

Systematically elevated rOEF values biased by elevated T_2

3D-GraSE I significantly reduces T_2 and shortens scan time

3D-GraSE II with increased echo sampling (10ms) and prolonged echo train (160 ms) shows even better results

rOEF significantly decreased (to 0.81 in WM & 0.54 in GM) & focal hyperintensities become visible

Remaining bias requires further analysis, e.g. by CSF induced partial volume effects

3D-GraSE T_2-mapping further improves mq-BOLD by lowering rOEF-values closer to physiological values

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