Klinikum rechts der Isar
Technische Universität München

5612 Technical Challenges in Measuring Adipose Tissue T2*

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Session: **Contrast Mechanisms: Relaxation & More**
Computer No.: **81**
Time: **14:15 – 15:15**
Date: **Thursday, June 21, 2018**

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[2] Philips Research Laboratory, Hamburg

Declaration of Financial Interests or Relationships

Speaker Name: Maximilian N. Diefenbach

I have the following financial interest or relationship to disclose with regard to the subject matter of this presentation:

Company Name: Philips Healthcare

Type of Relationship: Grant Support

Introduction

- Recent interest in imaging brown adipose tissue (BAT) "brown fat" [1,2]
- Differentiation of BAT and white adipose tissue based on the proton density fat fraction and T2* [2,3]
- Fairly broad range of reported T2* values in fatty tissues [1–4]

Purpose

To investigate systematic errors in T2* mapping with gradient-echo based water–fat imaging techniques in human brown adipose tissue to develop a reliable T2* mapping technique.

[1] McCallister et al., Magnetic Resonance in Medicine, 78(5), 1922–1932 (2017). http://dx.doi.org/10.1002/mrm.26589
[2] Gifford et al., Endocrinology And Metabolism, 311(1), 95–104 (2016). http://dx.doi.org/10.1152/ajpendo.00482.2015
[3] Hui et al., Journal of Magnetic Resonance Imaging, 46(3), 758–768 (2017). http://dx.doi.org/10.1002/jmri.25632
[4] Hu et al., Journal of Magnetic Resonance Imaging, 38(4), 885–896 (2013). http://dx.doi.org/10.1002/jmri.24053

Introduction

State-of-the-art:

- single-R2* water–fat signal model [5]
- complex-based water–fat separation [5]
- initialized by “intermediate field map” estimated with voxel neighborhood information [6,7]
- spectral complexity of fat signal [5]

Problem:

- offset between true and pre-calibrated fat spectrum
- one pre-calibrated fat spectrum, tissue specific fatty acid composition → systematic offset in some voxels

Previous work:

- correction of phase errors [8]
- optimization of echo time selection[9]
- characterization of biases [10]

[5] Yu et al., Magnetic Resonance in Medicine, 66(1), 199–206 (2011). doi:10.1002/mrm.22840
[6] Berglund et al., Magnetic Resonance in Medicine, 63(6), 1659–1668 (2010). doi:10.1002/mrm.22385
[7] Hernando et al., Magnetic Resonance in Medicine, 63(1), (2009). doi:10.1002/mrm.22177
[8] Ruschke et al., Magnetic Resonance in Medicine, 78(3), 984–996 (2016). doi:10.1002/mrm.26485
[9] Pineda et al., Magnetic Resonance in Medicine, 54(3), 625–635 (2005). doi:10.1002/mrm.20623
[10] Wang et al., Magnetic Resonance in Medicine, 75(2), 845–851 (2015). doi:10.1002/mrm.25681

→ Focus on proton density fat fraction PDFF, not R2*/T2*

Methods

Parametrization:

water fat field map

$$s_n = (W + c_n F)\, e^{(i2\pi f_B - R_2^*)t_n}$$

complex signal, nth echo

$$c_n = \sum_{p=1}^{N} a_p e^{i2\pi \Delta f_p t_n}$$

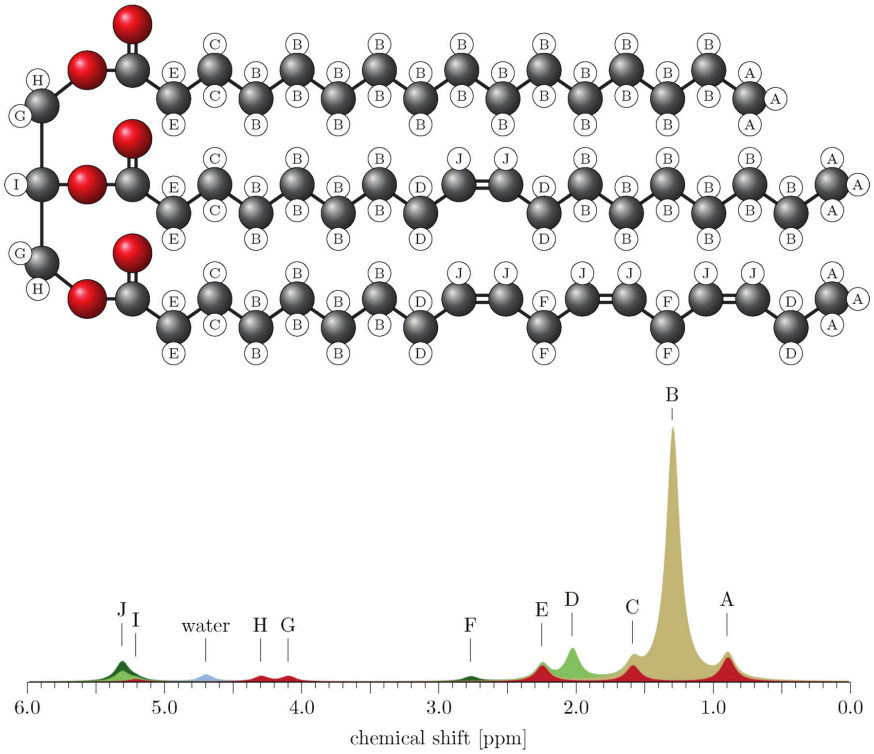
relative amplitudes

chemical shifts

$$a_p = [9,$$
$$6(\mathrm{cl} - 4) - 8\,\mathrm{ndb} + 2\,\mathrm{nmidb},$$
$$6,$$
$$4(\mathrm{ndb} - \mathrm{nmidb}),$$
$$6,$$
$$2\,\mathrm{nmidb},$$
$$2,$$
$$2,$$
$$1,$$
$$2\,\mathrm{ndb}]$$

Chain length: cl,
Number of double bounds: ndb
Number of methylene-interrupted double bounds: nmidb

Methods



Parametrization:

$$s_n = (W + c_n F)\, e^{(i2\pi f_B - R_2^*)t_n}$$

$$c_n = \sum_{p=1}^{N} a_p e^{i2\pi \Delta f_p t_n}$$

Figure from

[11] Berglund et al., Magnetic Resonance in Medicine, 68(6), 1815–1827 (2012). doi:/10.1002/mrm.24196

$$a_p = [9, 6(\mathrm{cl}-4) - 8\,\mathrm{ndb} + 2\,\mathrm{nmidb}, 6, 4(\mathrm{ndb} - \mathrm{nmidb}), 6, 2\,\mathrm{nmidb}, 2, 2, 1, 2\,\mathrm{ndb}]$$

Methods

Numerical Analysis:

- Computation of the Cramér-Rao lower bound
- Monte-Carlo simulation of systematic biases in parameters estimated by T2*-IDEAL algorithm

Ground truth:

- fat fraction = 95 %,
- cl = 17.5,
- ndb = 2.83,
- nmidb = 0.74,
- field map = 10 Hz
- T2* = 45 s,
- number of fat peaks=10,
- peak locations characterized in superficial subcutaneous fat

Simulation:

- ndb $\in$ [2.83-0.2, 2.83+0.2]
- nmidb $\in$ [0.74-0.2, 0.74+0.2]
- No noise
- TE1 = 1.22 ms
- dTE = 1 ms
- Varying # of TE

Methods

Clinical in vivo study:

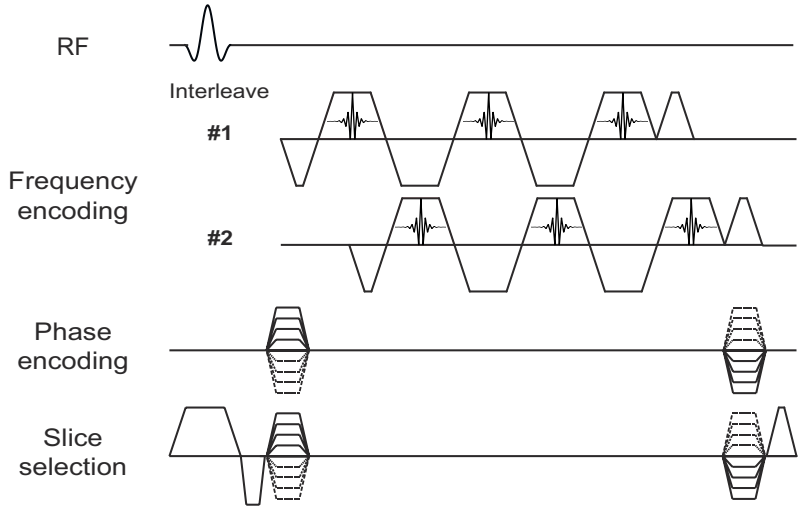
Time-interleaved multi-gradient echo

TR/TE1/dTE = 24/1.5/1.0 ms
FOV = 400 x 296 x140 mm^3
voxel size = 2 x 2 x 2 mm^3
flip angle = 5 deg
SENSE R = 2.5
scan time = 3:08 min
orientation = axial

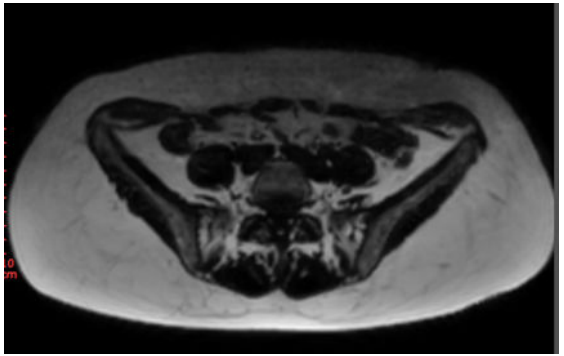
gluteal region 16 healthy volunteers

single-R2* IDEAl with two fat spectra of
ndb1 = 2.83 and ndb2 = 2.76

semi-automatic segmentation algorithm
→ two ROIs per dataset in gluteal fat

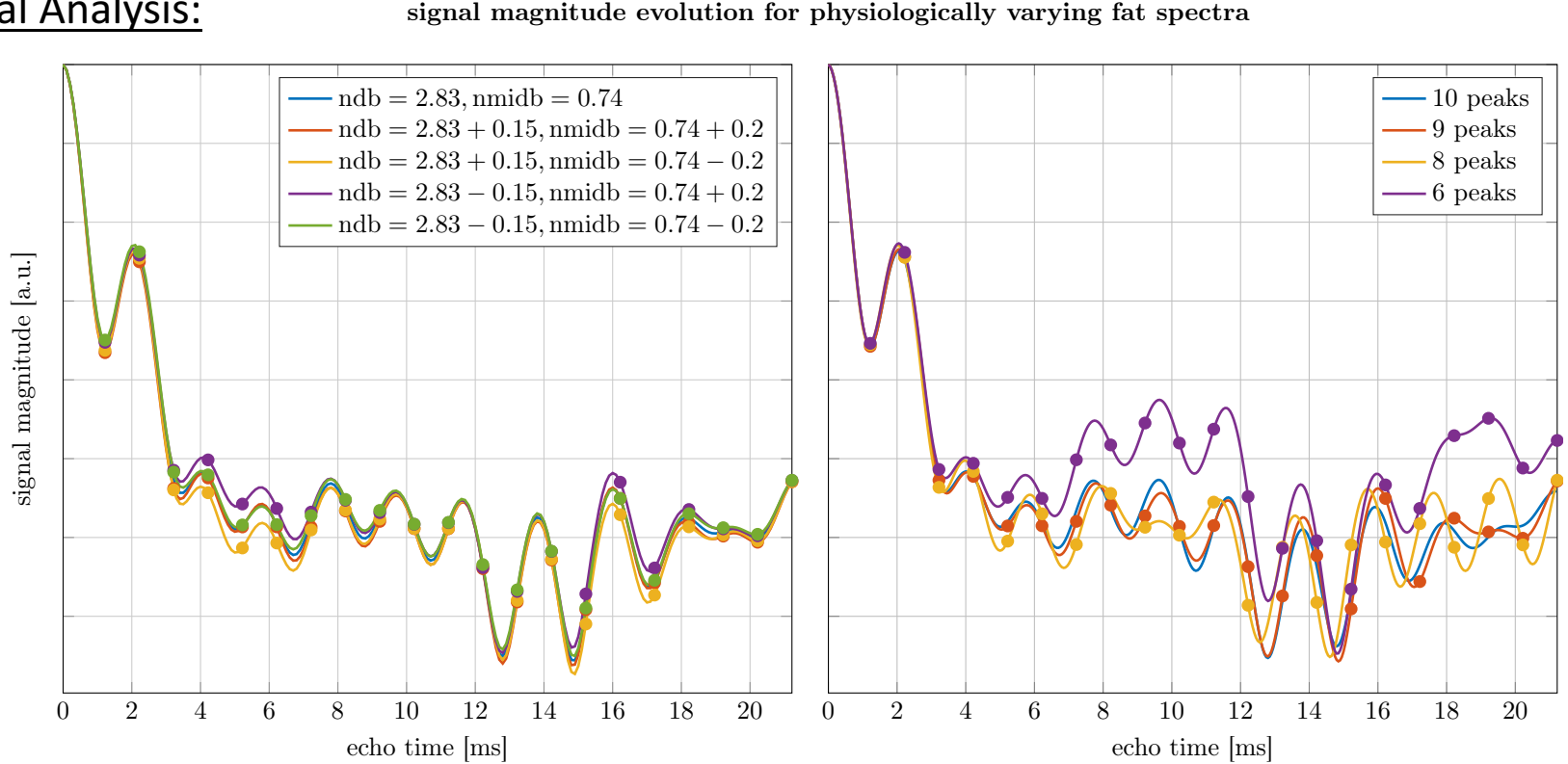


[[8] Ruschke et al., Magnetic Resonance in Medicine, 78(3), 984–996 (2016). doi:10.1002/mrm.26485



Results

Numerical Analysis:

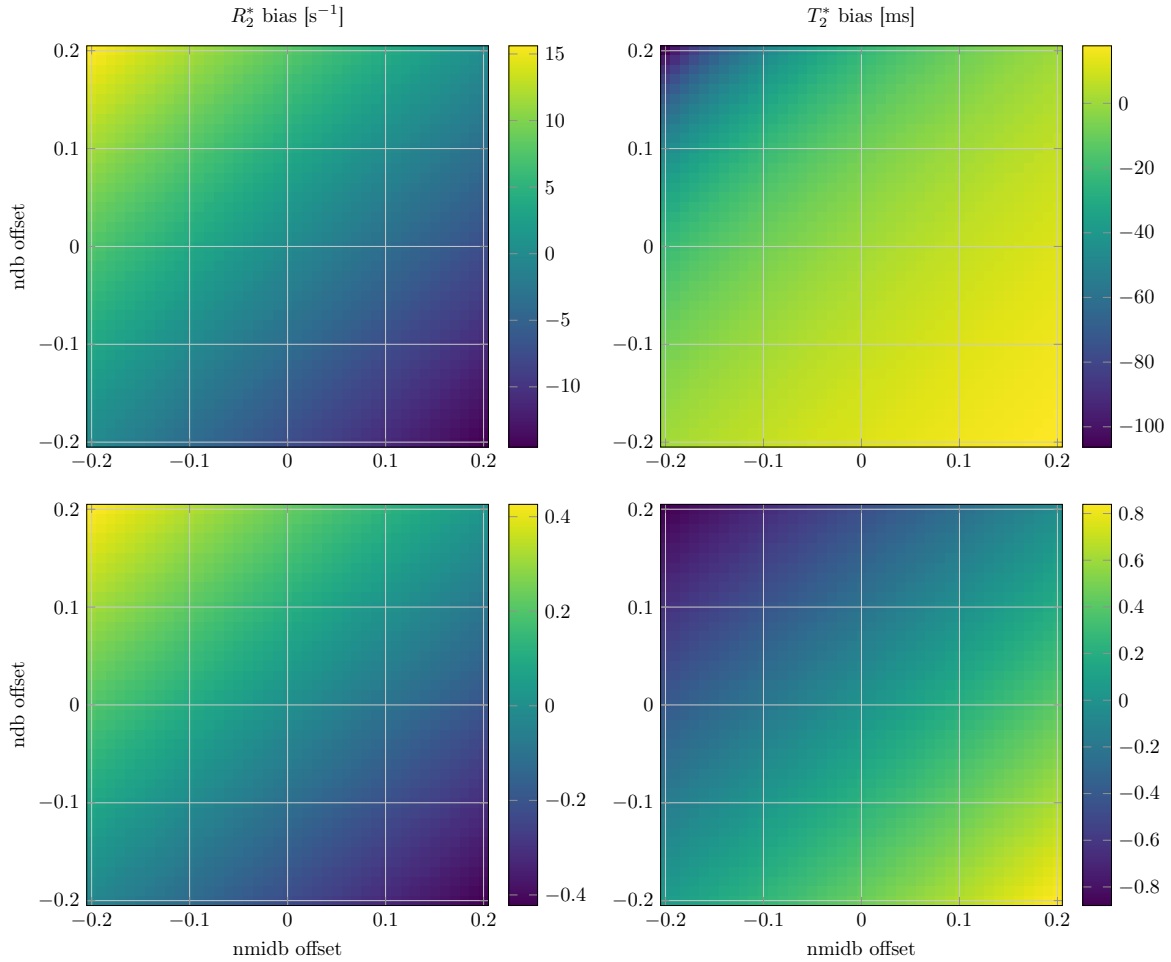


MR signal of fat varies noticeably with assumed fat spectrum.

Results

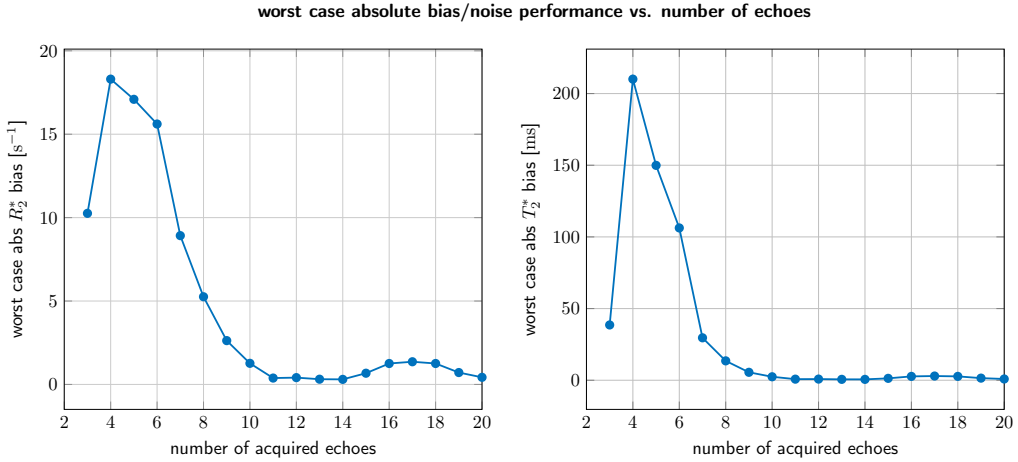
Numerical Analysis:

Worst-case bias for R2*/T2* can be large for only small fat spectrum variations

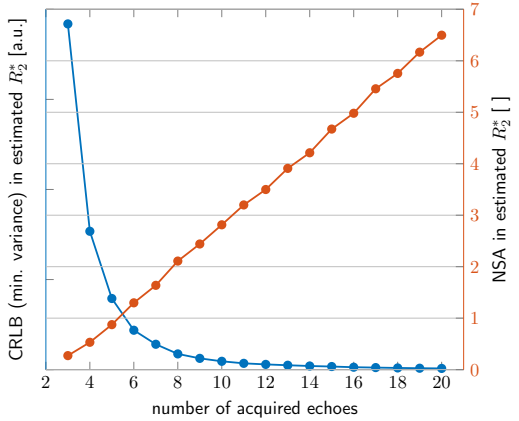


Results

Numerical Analysis:

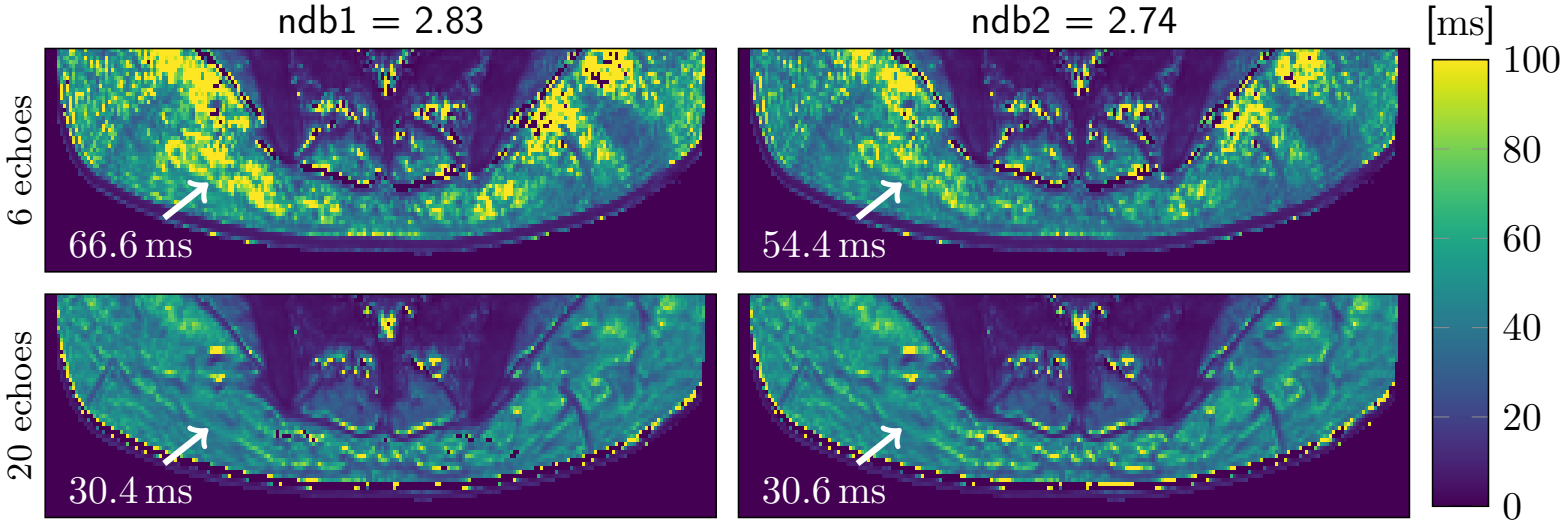


- Strong bias-decrease towards parameter estimations using more echoes.
- The increased accuracy for 20 echo estimations is accompanied by an increase in precision



Results

In vivo scans:

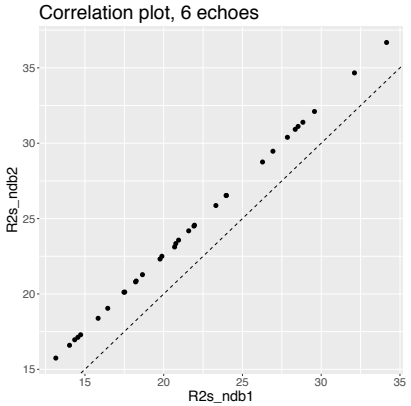


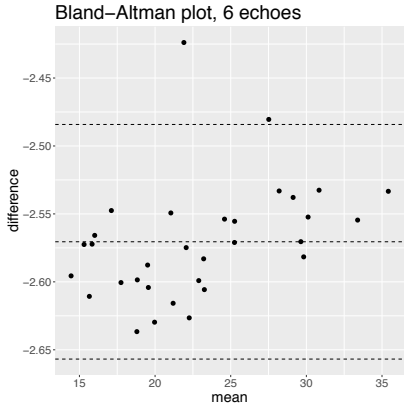
20 echo T2*-maps show less noice, more homogenous appearance and greater robustness w.r.t. fat spectrum variations

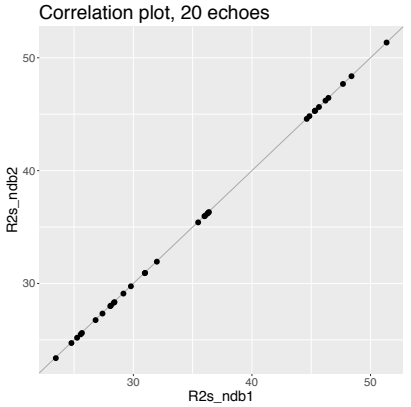
Results

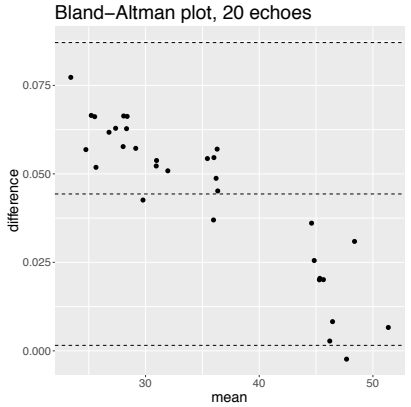
In vivo scans:

The fat spectrum difference between ndb1 and ndb2 translates into a systematic T2*-offset.







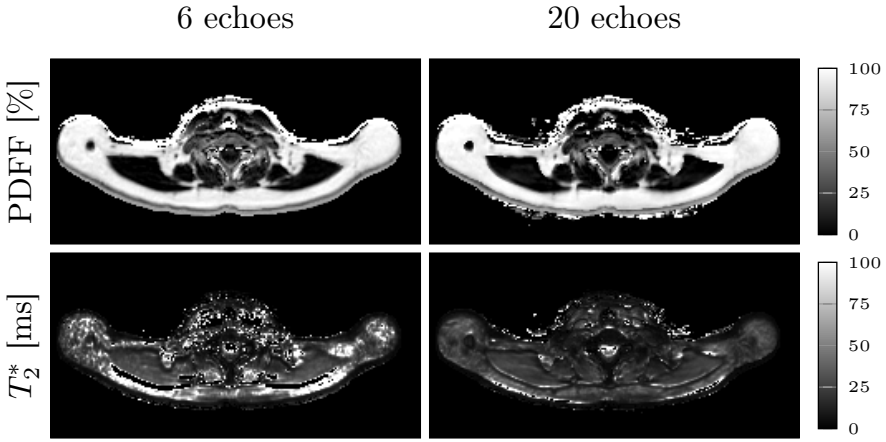


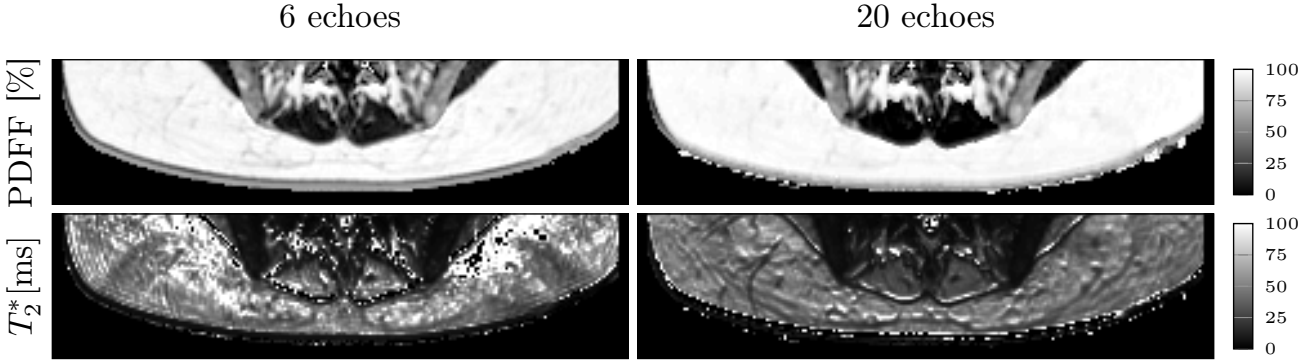
Results

In vivo application:

Differentiating supraclavicular from gluteal adipose tissue based on simultaneous PDFF and T2* mapping using a twenty-echo gradient echo acquisition

Author: Franz Daniela, Weidlich Dominik, Syväri Jan, Diefenbach Maximilian, Rummeny Ernst, Hauner Hans, Karampinos Dimitrios, Ruschke Stefan
Session Type: Traditional Poster
Session Date: Wednesday, 20 June 2018
Session Time: 16:15
Session: Body: Fat Imaging
Program Number: 2498





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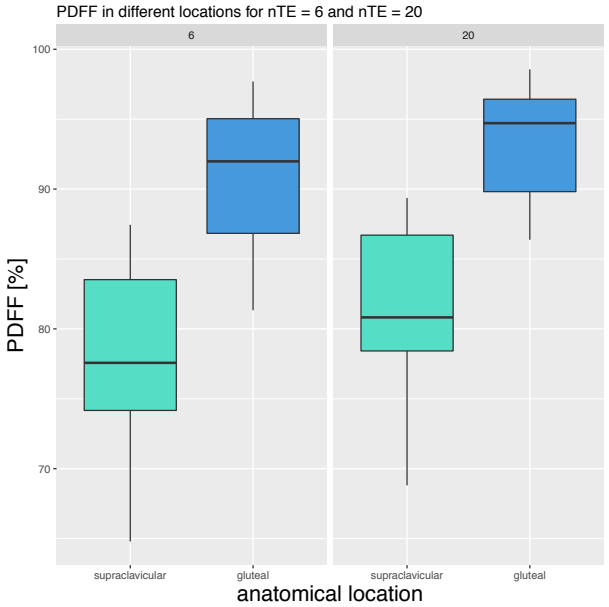

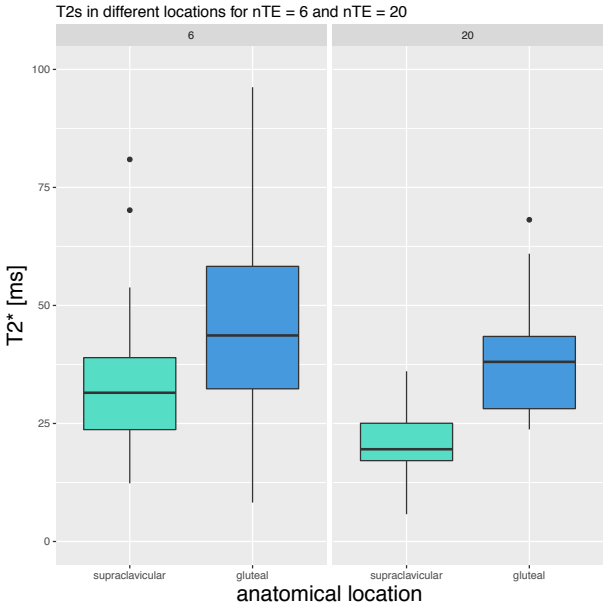

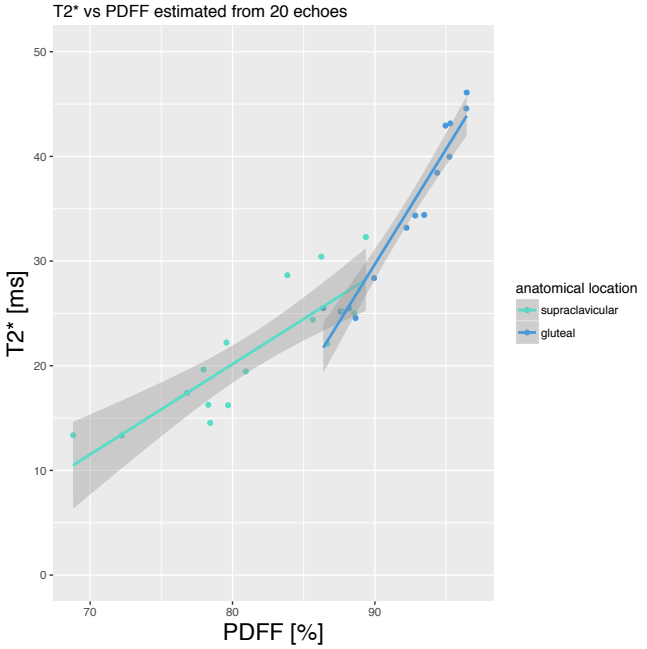

Discussion/Conclusion

T2* in fatty tissues heavily depend:

- on the assumed *a priori* fat spectrum and
- selected echo times

Mismatch between true and assumed fat spectrum
can lead to high inaccuracies in T2*

Simulations show that a higher number of echoes results in estimated T2* more robust to fat spectrum missmatches

In vivo the higher number of echos lead to noise-mitigated T2*-maps

Acknowledgements

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