The next snapshot CEST for fast 3D APTw imaging at 3T

Patrick Liebig,[1] Maria Sedykh[2], Kai Herz[3], Moritz Fabian[2], Angelika Mennecke[2], Manuel Schmidt[2], Arnd Dörfler[2], and Moritz Zaiss[2, 3*]

[1] Siemens Healthcare GmbH, Erlangen, Germany
[2] Neuroradiologie, Universitätsklinikum Erlangen, Friedrich-Alexander Universität Erlangen Nürnberg, Germany
[3] Magnetic resonance center, Max-Planck-Institute for biological cybernetics, Tübingen, Germany
* moritz.zaiss@uk-erlangen.de

Introduction

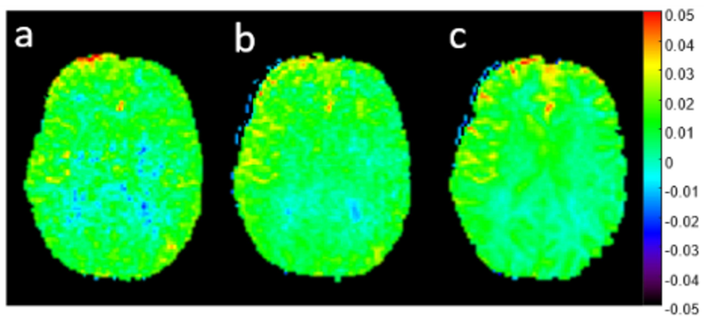
CEST MRI suffers from long preparation times and consequently long acquisition times (~5 mins)[1]. To reduce acquisition time, the snapshot CEST approach has been suggested[2], as a way to acquire the entire 3D volume after only one preparation block. This reduces the acquisition time to an absolute minimum. Furthermore, snapshot CEST completely disentangles the preparation from the readout block, giving the freedom to optimally design the preparation block for the contrast desired. Herein, we show an optimized sequence and protocol for snapshot APTw CEST imaging. By using compressed sensing (CS), we could extend the volume and resolution of the snapshot GRE CEST to whole brain acquisition, which is currently limited to a smaller slab.

Methods

All MRI scans were performed at a Siemens PRISMA scanner (3T) with a 64 channel head coil after written informed consent of the healthy volunteers and patients.
The snapshot CEST sequence consist of an APTw preparation phase following the pulseq-cest.github.io[3] standard **APTw_001**[4] with a pulsed rf irradiation of 2 s duration at 90% rf duty cycle and a B1rms of 2 µT, followed by a 3D GRE readout (2x2x5mm, FA=8°, TE/TR = 2ms/4ms), with 8-fold undersampled acquisition following a variable density poisson disk centric-out in the two phase encoding directions. A 4D coupled reconstruction with L1 regularisation was running on GPU. The regularisation factor along the offset dimension is set to 0. Coil sensitivities were estimated using ESPIRiT. Reconstruction times are 3- 5 minutes depending on the matrix size as well as the number of offsets. Different number of offsets between 30 for full Z-spectrum acquisition and 6 offsets around 3.5ppm were used. Minimal possible acquisition time was ~1min. APTw contrast was achieved by asymmetry analysis evaluate at 3.5 ppm.

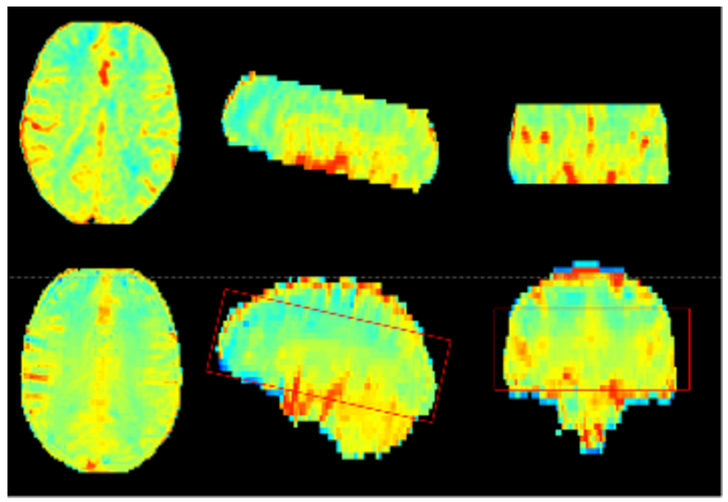
Results

In a first step an APT protocol has been optimized

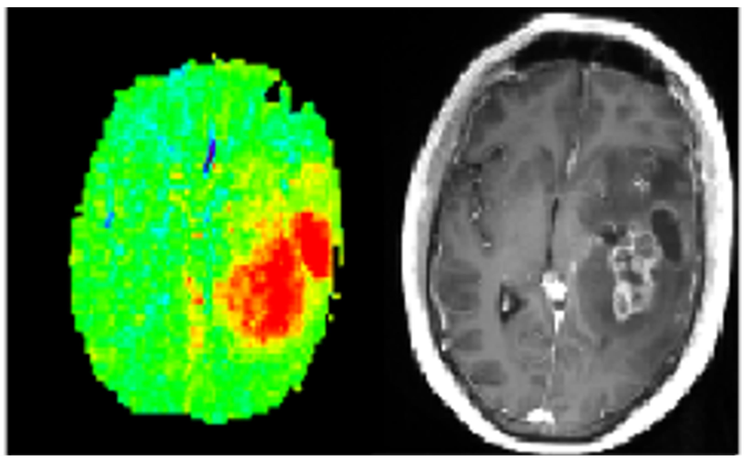


It is shown that increasing the Flip angle (from 6° (a) to 7° (b)) as well as decreasing the inplane resolution to 2 mm (c) from 1.7mm (a nd b) increases the CNR.

In the next step it is shown that the CS Whole Brain protocol gives similar results as the slab selective one



At last, one patient with a high-grade glioblastoma could be scanned with this optimized protocol. Good contrast between the tumor and the surrounding tissue can be achieved.



Discussion

SnapshotCEST can be readily applied to APT CEST at 3T, where SNR is the limiting factor. Optimizing the flip angle as well as the voxel size helps in alleviating that issue.
Employing CS allows the snapshot CEST approach to be applied for whole brain measurementsThe acquisition time for this whole-brain APT weighted protocol could be reduced to just below 1 minute. In comparison TSE-based methods with comparable coverage and resolution take about 5-10 minutes. Echo-Planar-Imaging on the other hand is the fastest way to acquire CEST spectra[6]. However, EPI based methods come with a high sensitivity to B0, resulting in distortions and/or signal dropout and making it difficult to be applied in other organs. CS-GRE based methods provide a way of overcoming the artefacts from an EPI based Readout without sacrificing too much of the acquisition time.
The whole CEST pipeline including B0 map acquisition + reconstruction, CS image reconstruction, as well as CEST evaluation is implemented online within the scanner software. Thus, APTw images are directly provided at the scanner console making this protocol a push button tool for clinical researchers. Furthermore, it was shown that a reliable contrast in a patient can be achieved.
Future work will include to further push the resolution and changing the undersampling mask per offset to exploit the offset dimension as additional dimension inside the CS reconstruction

References

1. Zhou J, et al. *J Magn Reson Imaging*. 2019;50(2):347-364. doi:10.1002/jmri.26645
2. Zaiss M, et al. NMR Biomed. 2018 Apr;31(4):e3879. doi: 10.1002/nbm.3879.
3. Herz et al. Pulseq-CEST: T *Magn Reson Med*. 2021; 00: 1– 14. https://doi.org/10.1002/mrm.28825
4. .https://github.com/kherz/pulseq-cest-library/tree/master/seq-library/APTw_3T_001_2uT_36SincGauss_DC90_2s_braintumor
5. Herz et al. *Magn Reson Med*. 2019; 82: 1832–1847. https://doi.org/10.1002/mrm.27857
6. Mueller et. Al. Magn Reson Med. 2020 Nov;84(5):2469-2483. doi: 10.1002/mrm.28298.