Analytic Image SENSE Reconstruction for Dynamic pMRI

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Introduction: Dynamic susceptibility contrast (DSC) MRI is a commonly used technique to evaluate cerebral microcirculation. DSC MRI assesses dynamic changes in signal intensity caused by alterations in magnetic susceptibility by an intravascular contrast agent (CA). The fast passage of the CA puts high demands on the temporal resolution of the MR data collection, while reasonable spatial resolution should be maintained. This is a challenge in rodent MRI, as signal-to-noise ratio is inherently low due to the small dimensions involved. We propose an acquisition scheme that combines the benefits of the analytic image (AI) concept [1] with those of parallel data acquisition using SENSE reconstruction [2] in order to increase the acceleration factor (R) for DSC MRI perfusion measurements in rats.

Method: Image acquisition using partial *k*-space sampling can lead to image artefacts and increased noise levels in the course of the reconstruction process. The AI concept, which is a good trade-off between the acquisition speed and the quality of the reconstructed image, is based on an asymmetrical acquisition scheme. Analogous to keyhole imaging, a baseline data set with *k*-space sampling is acquired prior to the DSC MRI series. DSC data are then accelerated utilizing both partial *k*-space sampling and parallel acquisition using a 4-element phased array coil. For reconstruction, positive high spatial frequencies from the baseline *k*-space and low spatial frequencies from the DSC MRI series are combined (Fig.1) and reconstructed to a high spatial and high temporal resolution image series using the analytic image concept leading to aliased images. In a second step, two aliased images were unfolded through SENSE processing [2].

In vivo experiments were carried out on a Bruker BioSpec 94/30 (Bruker BioSpin MRI, Ettlingen, Germany) to assess the proposed reconstruction method. A linear polarized volume resonator was used for excitation and a four element phased array surface coil for signal reception. The CA Endorem (Laboratoires Guerbet SA, Roissy, Fr) was administered in the tail vein (dose: 30mg/kg, rate: 0.6ml/min) using an automatic injection pump. 128 T_2*-weighted series (temporal resolution=1s) of fully-sampled images were collected in three male Lewis rats using a FLASH sequence with the following acquisition parameters: FOV = 52 x 26 mm^2, matrix dimension =200 x 55, slice thickness = 1.5 mm, pulse angle = 10°, TE = 5ms, TR = 18.2 ms. Phase encoding lines were reduced to mimic different undersampling. For comparison, SENSE reconstruction was performed by updating the low spatial frequencies of the baseline *k*-space with the central *k*-space lines acquired in the dynamic scans. Subsequently, each image series is reconstructed independently according to the obtained *k*-space. To quantitatively evaluate the reconstruction method, the normalized mean square error values were computed as well as the relative cerebral blood volume (rCBV) values carried out in a cortical ROI. All experiments were carried out in strict adherence with the Swiss law for animal protection.

Results: First the question what values of R could be reached, for SENSE and AI_SENSE, and still provide acceptable quantitative values (NMSE and rCBV), was asked. In general, AI_SENSE provided lower error values (Table1). Both Reliable rCBV values have been obtained with SENSE for R≤4 and for AI_SENSE up to R=8. Fig.3 shows representative images reconstructed with SENSE and AI_SENSE for R=8 as compared to the fully sampled reference images (SENSE with R=1). Both reconstructed images series are of satisfactory quality and display almost identical intensity distributions. SENSE tends to have larger errors on the image edges especially after the first pass of the CA. The values of the mean rCBV and standard deviation were computed for three rats. Comparable values have been obtained for the three methods: rCBV ± Std =136.7 ± 48.2 (R=1), rCBV ± Std =121.9 ± 56.2 (SENSE, R=4), rCBV ± Std =131.8 ± 52.1 (AI_SENSE, R=4), respectively, data lying well within the range of physiological variability.

Discussion: The results demonstrate that AI_SENSE allows achieving higher acceleration of data acquisition. Combining partial *k*-space coverage (AI) with SENSE sampling strategies allows reconstructing DSC-MRI image series with a superior quality than SENSE alone for a given R-value. The proposed acquisition schema utilizes less information coming from the static part of the baseline, by the use of only a part of its positive high spatial frequencies, which may explain difference in terms of rCBV values. It furthermore yields better NMSE values than conventional SENSE and computes reasonable perfusion parameters that compare well with those derived from fully sampled data. Acceleration using AI_SENSE is attractive for perfusion studies covering large brain areas (e.g. 3D perfusion imaging).

References: [1] Yankam et al., Nucl Instr Meth Phys Res A, 1-2, pp.73-76 07. **[2]** Pruessmann et al., *MRM* 42, pp. 952-962, 99.

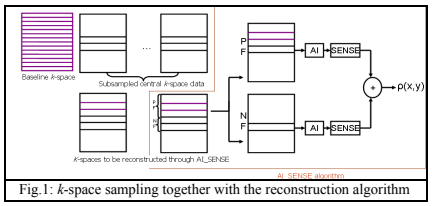

Fig.1: *k*-space sampling together with the reconstruction algorithm

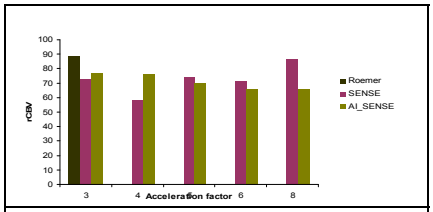

Fig.2: Relative cerebral blood volume (rCBV) values from full and reduced *k*-space reconstructions according to the acceleration factor.

R	3	4	5	6	8
SENSE	1.69xA	2.10E-05	2.37E-05	2.53E-05	3.00E-05
AI_SENSE	1.19E-05	1.35E-05	1.55E-05	1.59E-05	1.79E-05

Table1: NMSE mean values in the overall image series according to the acceleration factor.

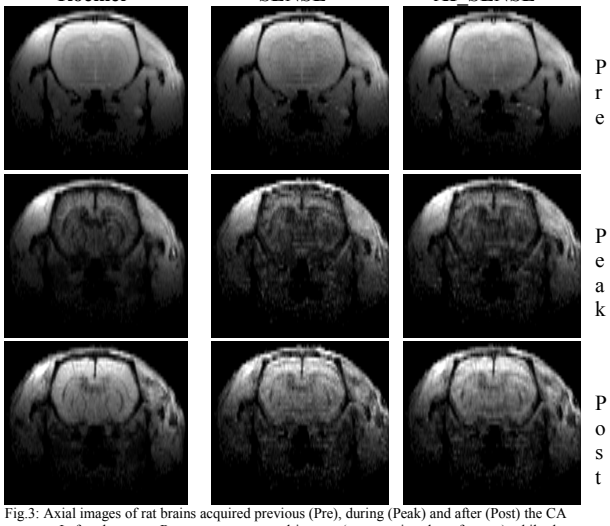

Fig.3: Axial images of rat brains acquired previous (Pre), during (Peak) and after (Post) the CA passage. Left column are Roemer reconstructed images (representing the reference) while the middle and right columns are images reconstructed with SENSE and the proposed reconstruction methods respectively. 12.5% of the full *k*-space data are kept to for SENSE and the proposed reconstruction method.