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Iterative Multi-Slice Compressed Sensing Reconstruction for Peripheral MRA

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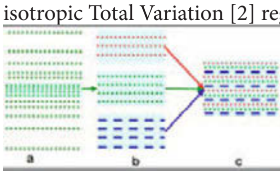
Purpose/Introduction: The combination of parallel MRI and Compressed Sensing (CS) [1] promises accelerated acquisition while maintaining image quality. Non-contrast-enhanced MR angiography, such as Time-Of-Flight (TOF), is an attractive application as it suffers from long acquisition times. Here, we present a multi-slice CS reconstruction for TOF in the peripheral arteries, where vascular continuity across slices can be exploited. Multi-slice reconstruction, sampling patterns and different regularization terms are evaluated.

Subjects and Methods: Volunteer data was acquired on a clinical 3T scanner (MAGNETOM Trio, Siemens Healthcare, Erlangen, Germany). A matrix of 448 x 168 was fully sampled over 448 x 168 mm and retrospectively undersampled using 29 of 168 phase-encoding steps in each slice. Further parameters include: slice thickness 2 mm, TR/TE=34.7/5 ms, flip angle 70°.

The data was partitioned into slabs of N_s slices and image volumes **x** were reconstructed from the slabs **y** by optimizing the objective function f(**x**) (Eq.1), consisting of the data fidelity term (containing the sampling patterns **P**, Fourier Coefficients **F** and Coil Sensitivities **C**). TV-L2 as well as anisotropic and isotropic Total Variation [2] regularization was applied.



Eq. 1: $f(\mathbf{x}) = \sum_{j}^{N_s} \|\mathbf{PFC}^j\mathbf{x} - \mathbf{y}^j\|_2^2 + \lambda_1 TVL_2(\mathbf{x}) + \lambda_2 TV(\mathbf{x})$

Eq. 2: $CNR = \frac{\bar{V} - \bar{T}}{\sigma_B}$ Eq. 3: $RMSE = \sqrt{\frac{\|\mathbf{x}^R - \mathbf{x}^I\|_2^2}{N}}$

Fig.1: Varying pattern and joint coil sensitivity estimation.
a) k-space pattern slice i, b) Shifted k-space central regions slice i-1, i+1
c) joint k-space center used for the calculation of coil sensitivities C_i

As shown in Fig.1, the sampling pattern **P** is interleaved between slices. By sharing k-space data across slices, full sampling in the center is achieved, which allows the estimation of coil sensitivity profiles without an external reference scan. The influence of the weighting terms λ_r, slab size N_s and the varying pattern was studied. Quantitative comparison against the fully sampled reference included the Contrast-To-Noise-Ratio (CNR) and the Root-Mean-Square-Error (RMSE) (Eq.2-3). In addition, Maximum-Intensity-Projections (MIPs) were calculated for visual assessment.

Results: Fig.2 shows CNR and RMSE for the TV-L2 regularization for N_s=5 (2a) and N_s=15 (2b). Increasing λ_1 leads to higher CNR and lower RMSE, but can cause staircase artifacts and artificial straightening of the vessels especially for N_s=5, as illustrated in Fig.3. Interleaving the sampling patterns significantly increases CNR, as evident in Fig.4. As shown in Fig.5, with isotropic TV a higher CNR is achieved than with anisotropic TV.

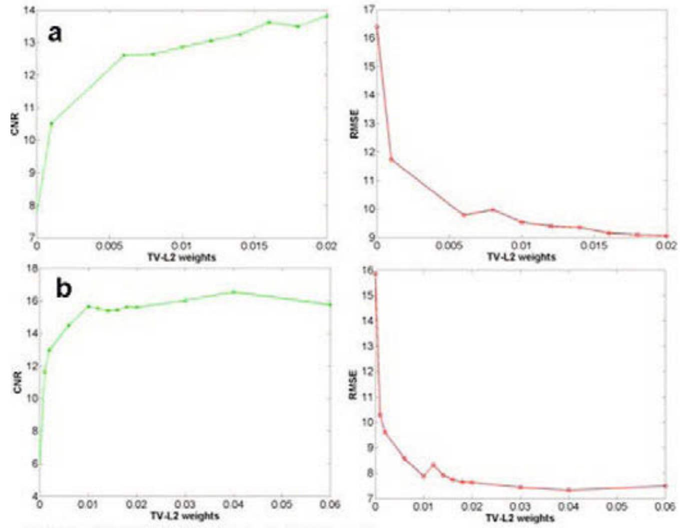


Fig.2: CNR / RMSE: a) N_s=5, b) N_s=15

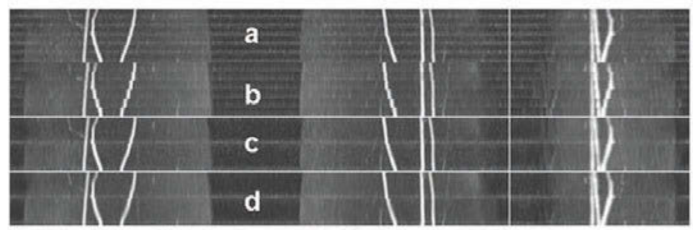


Fig.3: MIPs: a) N_s=5, λ_1=0.006 b) N_s=5, λ_1=0.06 c) N_s=15, λ_1=0.006 d) N_s=15, λ_1=0.06

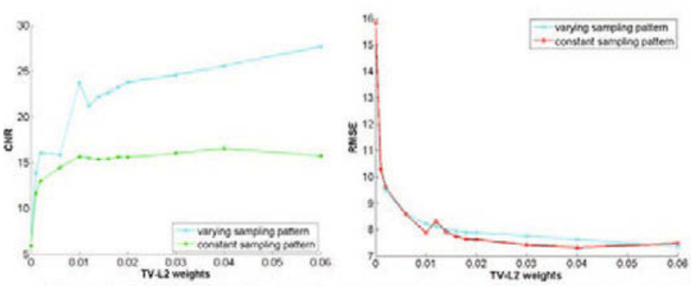


Fig.4: CNR / RMSE for TV-L_2 with constant / varying sampling pattern N_s=15

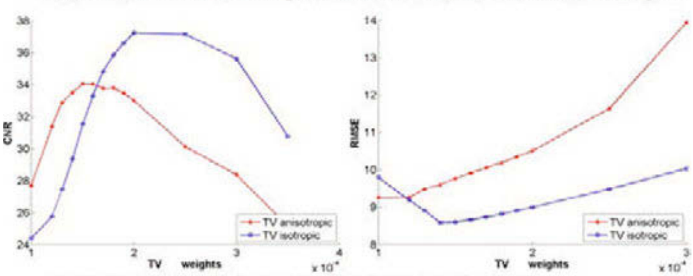


Fig.5: CNR / RMSE for anisotropic and isotropic TV, N_s=15

Discussion/Conclusion: A multi-slice CS algorithm for TOF in peripheral arteries was proposed and evaluated. The combination of a varying pattern and iterative reconstruction using isotropic TV and TV-L2 allows a significant acceleration (17% of the data, no external reference scan) while maintaining a high CNR and a low RMSE. Further studies will be carried out on patient data and include additional regularization techniques such as multi-slice Wavelet.