TOF-MRA RECONSTRUCTION FROM UNDERSAMPLED DATA: COMPARISON OF THREE DIFFERENT REGULARIZATION METHODS

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TARGET AUDIENCE – Diagnostic neuroradiologist who knows high pressure for scan time in the clinical setting and who is looking for the solution for it.

PURPOSE – The purpose of this study was to evaluate the difference of the final image reconstructed from undersampled data using three different regularization method for 3D TOF-MRA by NESTA with the joint-L1 technique.

METHODS – A volunteer (age 30 y.o.) was scanned using a 3T-MR system (Vantage, TOSHIBA MEDICAL SYSTEMS CORPORATION, Otawara, Japan) with a 32-channel head coil for 3D TOF-MRA (TR/TE 21/3.4ms, FA 15, matrix size 256 x 276, in-plane resolution 0.9 x 0.8 mm, 0.5 mm-thick 160 slices) placed parallel to the AC-PC line. The k-space data was fully sampled in 480 seconds, and this full sampled data was reconstructed as the reference image. As a preconditioning step for the experiment, Fourier transformation was performed in kx-plane to reduce calculation cost. From this partially reconstructed data, a representative slice containing the circle of Willis was selected for the following experiment. Full k-space data was resampled in the ky - kz plane for 155 pattern datasets containing 10 % - 53 % data which were randomly selected based on a polynominal probability density function (more samples from the central region). Using these 155 undersampled datasets, NESTA with the joint-L1 technique was performed at off-line PC workstation with MATLAB using in-house made software. (1, 2) Parameters for NESTA were set as followings, final mu 1e-9, initial mu 1e-5, number of iterations 60, number of continuation loops 9, and estimated noise per 10% sampling data 0.065. As three different regularization methods, L1-norm, wavelet, and total variation (TV) were used in each reconstruction. Qualitative evaluation of final image was performed by visual inspection by a 16-year-experienced neuroradiologist who compared reconstructed image with the reference image for total of 465 images. For the quantitative evaluation of final images, vessel-brain-ratio (VBR) was calculated. Vessel area and brain area was extracted on the reference image and converted as a vessel mask and a brain mask. Then, VBR was calculated as follows, VBR = (mean signal intensity of vessel area) / (mean signal intensity of brain area). VBR of the reference image was calculated and VBR of each reconstruction set was divided by this value for a ratio of VBR (rVBR, rVBR more than 1.0 was considered as a sufficient result). As another quantitative evaluation, normalized mean square error (NMSE) of final image was calculated in each reconstruction set. Statistical analysis was performed using ANOVA and $p < 0.05$ was considered as significant.

RESULTS – By the qualitative visual inspection of final images, appearance of final image was different among different regularization methods. Final images reconstructed from data which contains less than 30% showed visually apparent image degradation. (Fig. 1) On quantitative evaluation by rVBR, L1-norm showed the statistically significantly higher rVBR than other two methods and wavelet showed higher rVBR than TV. (Fig. 2) Undersampling ratio of 30 % was sufficient for the value of rVBR. NMSE analysis showed that wavelet showed the statistically significantly smaller NMSE than other two methods and L1-norm showed the largest NMSE. (Fig. 3)

DISCUSSION – In this study, TOF-MRA images were reconstructed from 10% - 53% undersampled data and final images were evaluated qualitatively and quantitatively. As a regularization method, L1-norm showed the highest rVBR, however, L1-norm showed the largest NMSE of final images among three regularization methods. Obtaining images from undersampled data is one of the methods of reducing scan time and enables TOF-MRA acquisition in a short time. Various image reconstruction methods from undersampled data have been proposed and NESTA method is reportedly the most accurate and efficient. NESTA can be performed with various regularization methods, such as L1-norm, wavelet or TV. In this experiment, 30 % undersampled data was sufficient for the almost equivalent image with the full sampled image both qualitatively and quantitatively in the context of visual evaluation and rVBR. Larger NMSE might come from noisy appearance of L1-norm method and might be overcome with fine parameter tuning.

CONCLUSION – In conclusion, 30 % undersampled data is sufficient for TOF-MRA and L1-norm method shows the best image quality in NESTA compared to wavelet and TV.

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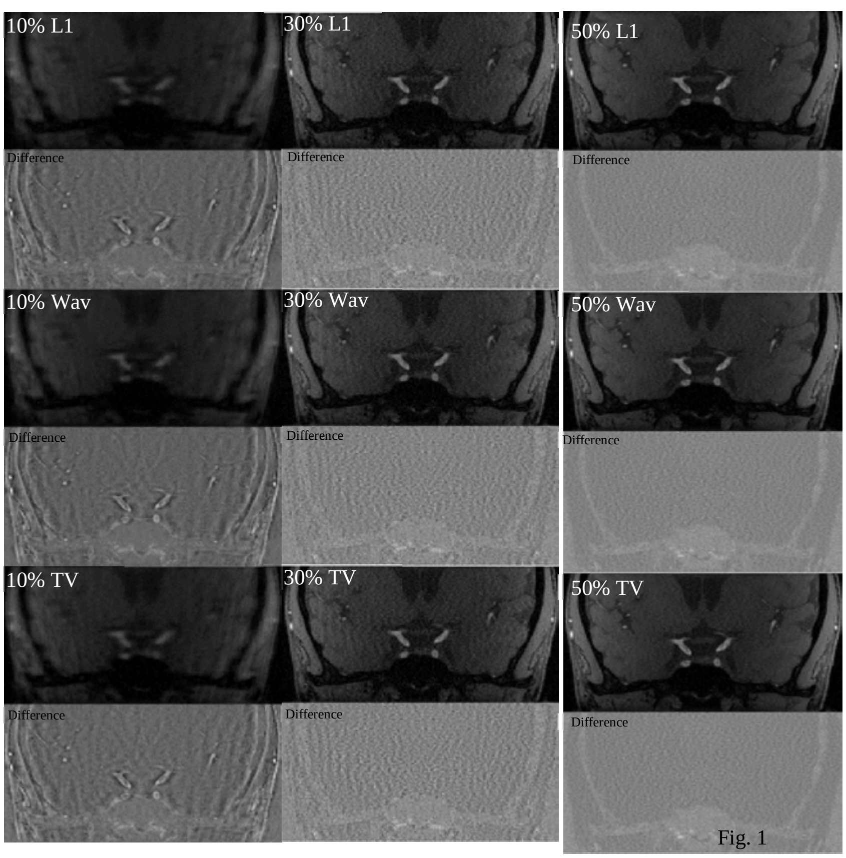

Fig. 1

Fig. 2
rVBR

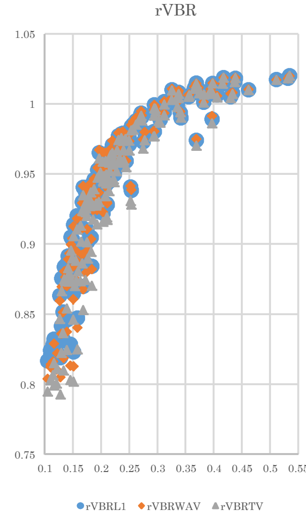

Fig. 3
NMSE