High-Resolution 3D Volumetric Nerve-Sheath Weighted RARE Imaging (3D SHINKEI)

M. Yoneyama[1], M. Nakamura[1], T. Okuaki[1], T. Tabuchi[1], A. Takemura[2], M. Obara[2], and J. Ogura[1]
[1]Medical Satellite Yaesu Clinic, Tokyo, Japan, [2]Philips Electronics Japan, Tokyo, Japan

Introduction:

Magnetic resonance neurography (MRN) **[1]** is a useful technique with which to evaluate abnormal conditions of entire nerves and nerve bundles, and it has been used successfully in patients with tumors, trauma, and neuritis **[2,3]**. In former presented MRN techniques are fat-suppressed T2-weighted imaging **[4.5]**, diffusion-weighted imaging (DWI) **[6,7]**, and 3D diffusion-weighted steady-state free precession imaging (3D DW-SSFP) **[8-10]**. Although these techniques can produce excellent-quality images, they have limitations. T2-weighted spin-echo techniques cannot image smaller nerves in the periphery because the nerves cannot be distinguished from blood vessels on T2-weighted images. DWI sequences have limited spatial resolution or low signal-to-noise ratio and often produce severe image distortion. Furthermore, 3D DW-SSFP technique requires long scan duration.

In this study, we propose a new scheme of 3D-RARE (Turbo Spin-Echo: TSE) based fast high-resolution volumetric peripheral nerve-sheath images using 3D improved Motion Sensitized Driven Equilibrium (iMSDE) **[11]** prepared 3D variable refocusing flip angle-TSE sequences.
(3D nerve-**SH**eath signal increased with **INK**ed rest-tissue RAR**E** **I**maging : 3D **SHINKEI**)

Methods:

Theory: 3D SHINKEI technique combines fat-suppression pre-pulse (SPectral Attenuated Inversion Recovery: SPAIR) for uniform fat signal suppression, iMSDE preparation for signal suppression from vessels, and 3D variable refocusing flip-angle RARE readout segments for contrast-efficient T2-weighted images. Furthermore, iMSDE pre-pulse was based on T2-preparation (T2-prep) pulse and therefore T2-contrast is affected by preparation duration (iMSDE-prep). We attempted to use the pre-pulse for muscle (and short T2-value tissues) signal suppression. Consequently, 3D-SHINKEI technique will be made possible to nerve-sheath depiction **[Fig.1]**.

Experiments: All experiments were acquired by 3D SHINKEI using a 3.0 Tesla whole-body clinical imager (Achieva, Philips Healthcare). The study was approved by local-IRB, 10 healthy volunteers and 2 patients were examined in this study. The study was parameter optimization of 3D SHINKEI sequences and to prospectively evaluate its feasibility in brachial plexus, lumbosacral plexus, and cranial nerves by using optimal 3D SHINKEI sequences.

Imaging parameters (include examined parameters) were: TR=2500ms, effective-TE=61 or 102ms, ETL=100, echo spacing=4.0ms, VRFA modulation= low-constant **[12]** or TRAPS **[13]** or tissue-specific modulation **[14,15]**, iMSDE gradient-strength (velocity-encoding (Venc : cm/s))= 0 or 5 or 1cm/s, iMSDE preparation duration (iMSDE-prep)=18 (shortest value) or 50 or 100ms, voxel-size= 1x1x1mm, scan duration=4:57~5:47.

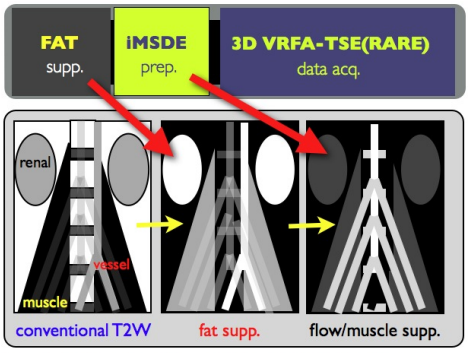

Fig. 1 A concept of nerve-sheath weighted imaging. Fat, flow, and muscle signal suppressed T2-weighted images thus will be possible to nerve-sheath depiction.

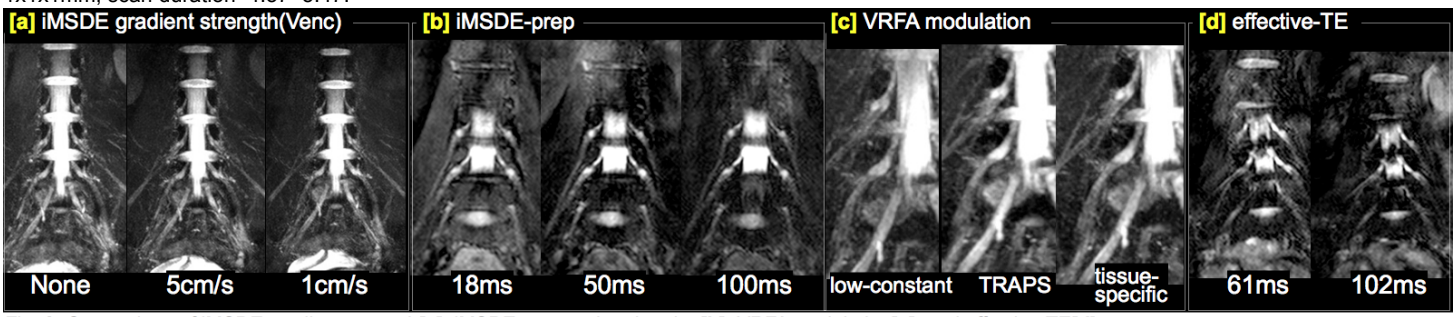

Fig. 2 Comparison of iMSDE gradient strength**[a]**, iMSDE preparation duration**[b]**, VRFA modulation**[c]**, and effective-TE**[d]**.

Results and Discussion:

3D SHINKEI acquisitions were successful in all subjects. In parameter optimization, iMSDE gradient-strength was chosen Venc=1cm/s (maximum strength at the present) because signal-suppressed from slowing-flow vessels (e.g. veins) **[Fig. 2a]**. Additionally, using that with 3-axis direction (AP, RL, and FH direction) was more effectively blood signal-suppression. iMSDE preparation duration (iMSDE-prep) was chosen "semi-long" prep-time (50ms) because to minimize signal-loss of nerve-sheath while suppressed muscle-signals **[Fig. 2b]**. VRFA modulation was chosen tissue-specific modulation because high SNR and blurring-artifact reduction balance in efficiency than low-constant and TRAPS **[Fig. 2c]**. Additionally, moderate effective-TE (61ms) was chosen for increase SNR of nerve sheath **[Fig. 2d]**.

Fig. 3 shows optimized-3D SHINKEI revealed detailed anatomy of brachial plexus, lumbosacral plexus, and cranial nerves.

Conclusion:

In this study, 3D SHINKEI clearly revealed detailed anatomy of brachial plexus, lumbosacral plexus, and cranial nerves. These results suggest that the sequence based on 3D SHINKEI can be used for fast high-resolution volumetric imaging of the peripheral nervous system. Further investigation is needed for clinical evaluation and limitation.

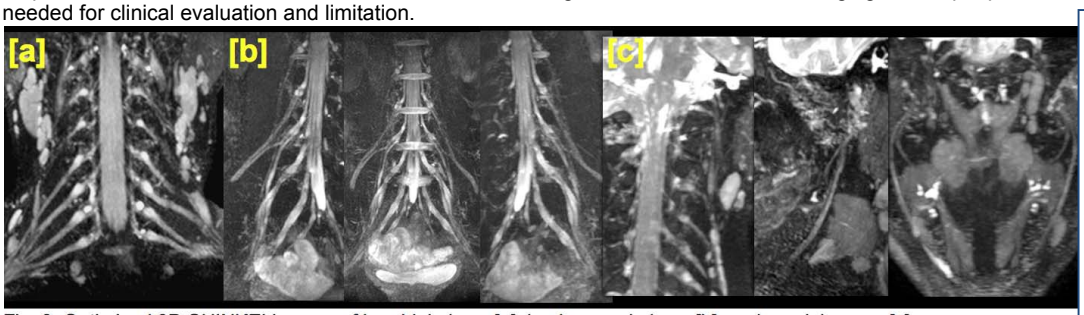

Fig. 3 Optimized 3D SHINKEI images of brachial plexus[a], lumbosacral plexus[b], and cranial nerves[c].

References:
[1] Fiiler, Lancet 341, 659-661(1993);
[2] Filler, JNS 85: 299-309(1996);
[3] Cudlip, JNS 96: 755-759(2002);
[4] Maravilla, AJNR 19: 1011–1023(1998);
[5] Viallon, Eur Radiol 18 : 1018–1023(2008);
[6] Takahara, Radiology 249: 653–660(2008);
[7] Yamashita, NEJM 361 : 538–539(2009);
[8] Zhang, AJNR 29 : 1092–94(2008);
[9] Zhang, JMRI 27 : 454–458(2009);
[10] Naganawa, MRMS 9 , 153-158(2010);
[11] Wang J, JMRI 31 : 1256-1263(2010);
[12] Alsop, MRM 37: 176 –184(1997);
[13] Hennig, MRM 49: 527–535(2003);
[14] Mugler JP III, Proc. ISMRM 11,p203(2003)
[15] Busse , MRM 55: 1030–1037(2006).