3T MR Imaging of Peripheral Nerves Using 3D Diffusion-Weighted PSIF Technique

Avneesh Chhabra[1], M.D.; Theodore Soldatos[1], M.D.; Aaron Flammang[1]; Wesley Gilson[1]; Abraham Padua[2]; John A Carrino[1], M.D., M.P.H.

[1]Johns Hopkins University, Baltimore, MD, USA
[2]Siemens Healthcare, MR RD Management, Malvern, PA, USA

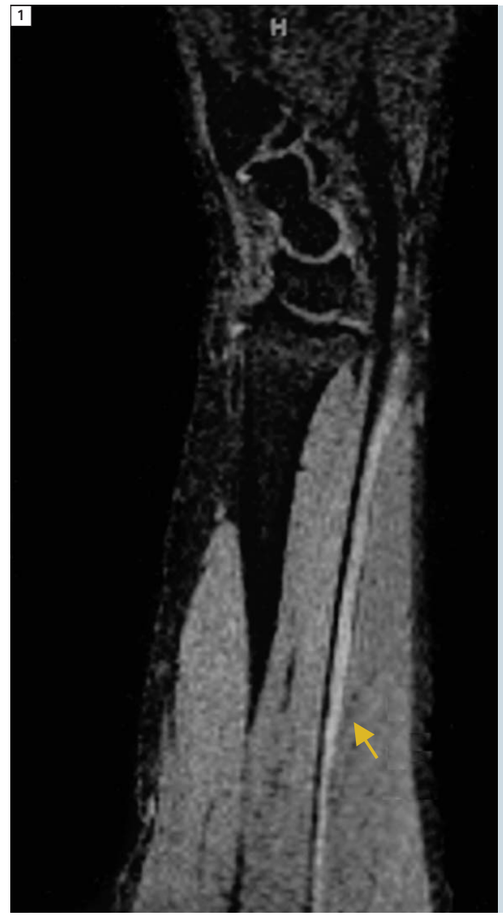
High-resolution magnetic resonance (MR) Neurography is a novel imaging technique, which enables multiplanar imaging of peripheral nerves, as well as diagnosis and localization of entrapment and non-entrapment peripheral neuropathies related to etiologies, such as inflammation, tumor and trauma. Typically, MR Neurography techniques utilize a combination of fat-saturated T2-weighted, short inversion time recovery (STIR), or T2 spectral adiabatic inversion recovery turbo spin echo (T2 SPAIR TSE) images for the detection of the nerve signal, contour and size changes, as well as T1-weighted spin echo or fluid attenuated long inversion recovery (FLAIR) images for the anatomic assessment of the involved areas, based on the abundant intra- and perineural fat. However, the diagnostic ability of conventional MR Neurography is limited in the evaluation of smaller peripheral nerves of the axial and appendicular skeleton, where the similar caliber and T2 signal intensity of peripheral nerves and adjacent vessels render discrimination of the above structures difficult, if not impossible. Since nerve injuries and entrapments commonly lead to effacement of perineural fat in the area of involvement, T1-weighted images are often not helpful. In addition, an attempt to suppress vascular signal with saturation bands often fails in distal locations of the body, as the peripheral nerves frequently course through various obliquities.

Due to recent advances in 3T MR imaging with incorporation of optimized extremity coils and new pulse sequences, 3-dimensional high-resolution and high-contrast demonstration of the peripheral nerves is possible. The 3-dimensional diffusion-weighted sequence based on reversed fast imaging with steady-state precession (3D-PSIF) has been recently implemented in high-resolution MR Neurography imaging protocols and has a potential to overcome most of the above mentioned challenges in small peripheral nerve imaging. The 3D-PSIF is a balanced gradient echo steady-state free precession (SSFP or PSIF) sequence with inherent features of a spin-echo sequence, as compared with other unbalanced spoiled or refocused gradient-echo techniques, such as fast low-angle shot (FLASH), fast field-echo, and gradient recall acquisition using steady-states (GRASS or FISP). Therefore, the 3D-PSIF sequence demonstrates less influence of local magnetic field inhomogeneities on the spin relaxation. The water-excitation technique enables uniform fat suppression and is unaffected by the chemical shift effect. Although 3D-PSIF may also be performed without fat saturation, fat-suppressed images usually provide better nerve-to-background contrast ratio. In addition, the application of diffusion moment provides suppression of water signal. In most cases, a diffusion moment value of 80–90 mT/m*ms provides an acceptable compromise in peripheral nerve-to-background contrast and image signal-to-noise ratios (SNR). Since the signal depends strongly on the steady-state condition, all moving structures, such as flowing blood, demonstrate a loss of signal intensity. As a result, the high T2 signal intensity of peripheral nerves is effectively differentiated from the nulled signal of adjacent vessels (Figs. 1, 2). Although 3D-PSIF images provide predominantly T2 contrast, there is a potential to perform post-contrast imag-

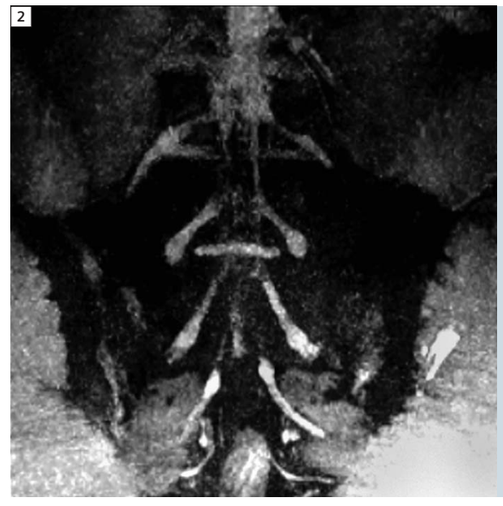
Table 1: Acquisition parameters for 3D-PSIF at 3T

The typical acquisition parameters employed for the 3D-PSIF sequence in a Siemens 3T MAGNETOM Verio scanner. The spatial resolution of this technique yields 0.9 x 0.9 x 0.9 mm voxel sizes and, whenever possible, this dimension is preserved. When examining areas requiring larger or smaller coverage, the scan matrix and the FOV are adjusted accordingly. This and number of slices are all that is changed. Scan time is typically kept below 6 minutes 30 seconds through the use of parallel acquisition. High quality thin MIP projections are rendered for display purposes.

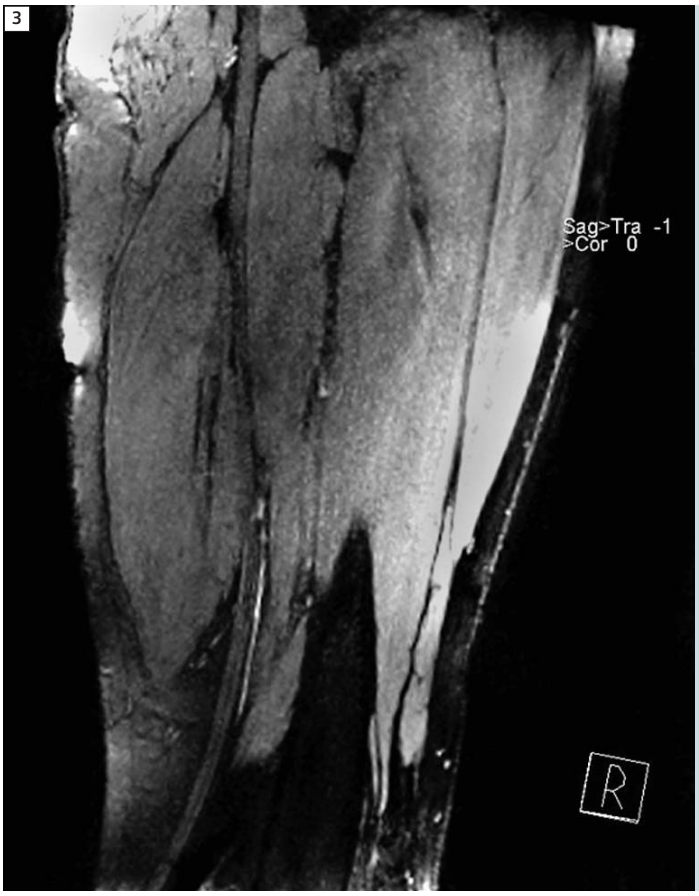
Acquisition parameter	Value
Slabs	1
FOV	172 mm
Slice thickness	0.9 mm
TR	12 ms
TE	4.1 ms
Averages	1
Coil	8-channel knee coil
PAT	GRAPPA 2
Flip angle	30
Fat suppression	Water Excitation Normal
Diffusion mode	Phase
Diffusion moment mT/m*ms	85
Diffusion directions	1
Dimension	3D
Elliptical scanning	On
Asymmetric echo	Off
Receiver bandwidth	230 Hz/Px
Acquisition time	4 min 37 sec



1 Sagittal 3D-PSIF image of the forearm and wrist demonstrates the median nerve (arrow) along its entire course.



2 Coronal 3D-PSIF image of the lumbosacral plexus demonstrates excellent discrimination of the nerve roots from adjacent soft-tissue structures.



3 Coronal 3D-PSIF maximum intensity projection (MIP) of the thigh demonstrates the course of the sciatic nerve.

ing following administration of intravenous gadolinium. In 3D-PSIF imaging, the acquisition of isotropic voxels enables the data set to be reformatted into any imaging plane without significant loss of resolution. The latter feature may provide confirmation of anatomic continuity, as well as identification of branching, focal enlargement, course deviation and/or displacement of peripheral nerves. In addition, maximum intensity projections (MIPs) can be employed to further enhance the conspicuity of the nerves and provide images, which can be distributed to referring physicians for better depiction and understanding of nerve anatomy and pathology (Fig. 3). Table 1 displays the typical acquisition parameters employed for the 3D-PSIF sequence in a Siemens 3T MAGNETOM Verio scanner. In clinical practice, 3D-PSIF has proven more efficient than the conventional STIR and T2 SPAIR TSE sequences in differentiating small peripheral nerves from adjacent vessels. In the extremities, and particularly distal to the knee and elbow joints, the commonly encountered T2 hyperintense subcutaneous and/or fascial edema restricts the identification of small peripheral nerves on conventional T2-weighted sequences. In contrast, the inherent diffusion sensitive gradients of 3D-PSIF enable selective suppression of the water signal of the stationary subcutaneous and fascial edema, thus improving the conspicuity of small peripheral nerves in the above areas. On the other hand, the inherent high TE values of 3D-PSIF images result in lower SNR as compared to conventional fat-saturated T2-weighted images, which remain superior in delineating the fascicular structure of the nerves. In post-contrast imaging, as compared to the three-dimensional volumetric interpolated breathhold examination (3D VIBE) sequence, the 3D-PSIF technique provides better visualization of the nerve fascicles, as well as more adequate assessment of the anatomic relationship between fascicles and enhancing intraneural and/or extraneural tumors.
In summary, the 3D-PSIF sequence with high spatial resolution and high contrast provides reliable and objective identification of peripheral nerve anatomy and may be incorporated as part of the high-resolution MR study of peripheral nerves, whenever accurate nerve localization and/or pre-surgical evaluation are required.

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- Imaging of peripheral nerves – status quo by Mirko Pham University of Heidelberg, Germany
- Peripheral nerve imaging from head to toe by Meng Quan-Fei. The First Affiliated Hospital of Sun Yat-sen University, Guangzhou, China

Contact
John A. Carrino, M.D., M.P.H.
Associate Professor of Radiology and Orthopedic Surgery
Section Chief, Musculoskeletal Radiology
The Russel H. Morgan Department of Radiology and Radiological Science
601 North Caroline St. /JHOC 5165
Baltimore, MD 21287-0856
USA
carrino@jhmi.edu