Exploring Peripheral Nerve, Macro and Micro-Vasculature Imaging Applications at Ultra-High Field MRI

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INTRODUCTION: Objective, non-invasive, sequential monitoring of peripheral nerve(PN) regeneration and revascularization after surgery is critical for evaluation of the efficacy of re-innervation and treatment strategies that may have important implications in recovery and outcome in PN/vessel injury as well as in VCA. For the first time, our group built a forearm/hand MRI coil for 7 Tesla MRI that provides extremely high resolution [1] of upper extremity anatomy including neurovascular structures. This study utilizes 7T strength to explore nerve (Diffusion imaging) and vessel imaging (Non-contrast enhanced(nCE) MRA imaging and vessel segmentation)

METHODS: An in-house built actively detuned TEM resonator in conjunction with 8-ch receive array was developed. Diffusion-weighted images were used to perform diffusion tensor/spectrum imaging (DTI/DSI) of peripheral nerves [2], and post-processing were carried out in DSI studio(CMU, PA). Secondly, nCE MRA techniques like time-of-flight [3] was applied to look at digital proper palmer artery for the first time at 7T for vessel imaging for volunteer enrolled under university approved IRB at 7T Siemens scanner.

RESULTS: Figure 1 shows T1 VIBE images(vessel wall, brachial artery and its branches, nerves, joint anatomy), T2DESS (bone structure, high intensity delineated nerve, synovial fluid, cartilage delineation), T2* SWI micro-vasculature, TOF (time-of-flight nCE MRA) images. An experienced physicians were able to identify not only first and second order arteries (palmer arch) but also specifically smaller ones (proper digital palmer (PDP) arteries) first time on non-contrast sequence at 7T. Figure 2 shows fiber tractrography for both nerves (0.823 for MN and 0.478 for RN). All the T1W VIBE images were exported in DICOM format to MIPAV (NIH, MD) to segment the vasculature structure. showing major arteries (brachial branches) and venous structure in forearm.

CONCLUSION: Diffusion based MRI is a non-invasive, non-disruptive strategy for linear, non-invasive assessment of water diffusion parameters (FA and DC) in nerves as indirect correlates of neuroregeneration after transection, repair or transplant related outcomes. UHF DTI data can be compared to validated measures like histomorphometry, immunohistochemistry, electrophysiology (EMG, NCV) and functional gait analysis (sciatic function index) and increase our insights into overall functional outcomes after nerve repair, reconstruction or transplantation.Our ongoing studies are looking at neuropathy and transplant patient population focusing on nerve regeneration and vessel (flow/lumen and wall constriction) imaging in forearm and hand

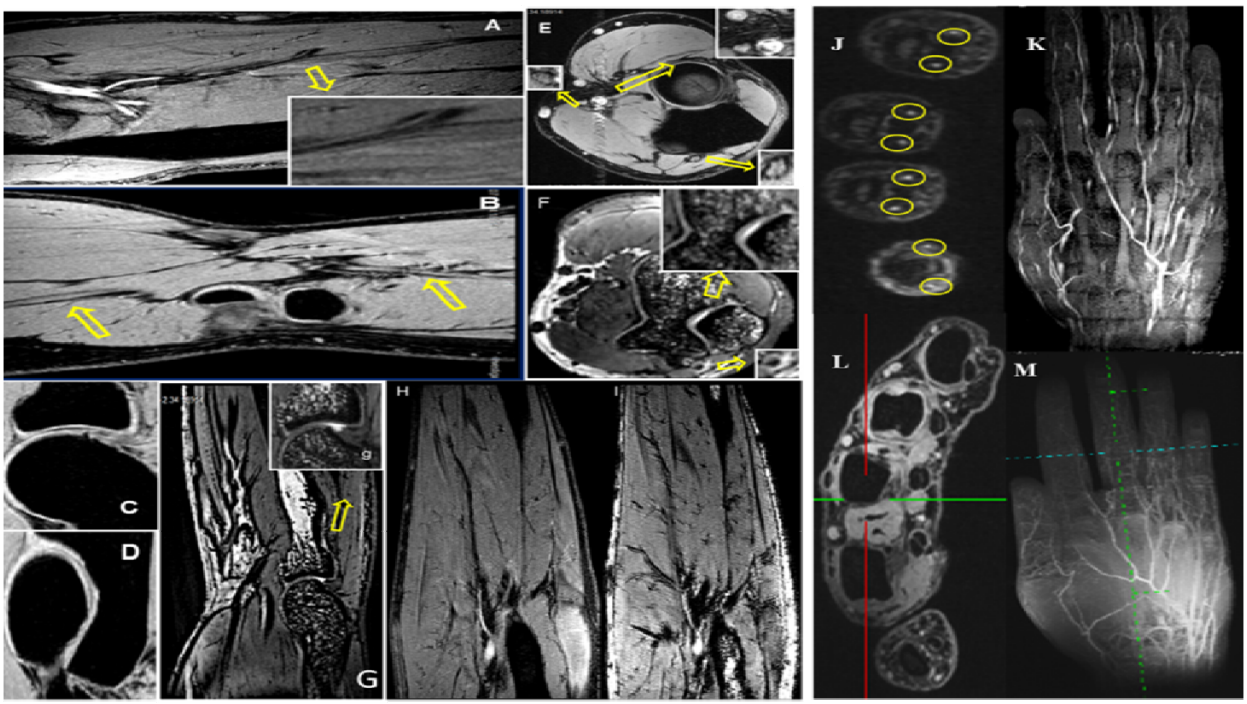
REFERENCES:

[1] Vaughan JT et al, 7T vs. 4T: RF power, homogeneity, and signal-to-noise comparison in head images. Magn Res Med. 2001;46:24–30.
[2] Jambawalikar S, et al., Diffusion tensor imaging of peripheral nerves. Skeletal Radiol 2010;39:1073–1079.
[3] Zhang W. High Resolution MRA of digital arteries in SSC patients on 3T: preliminary study.

FIGURE LEGENDS

Figure 1: A; Forearm (vessel wall delineation(arrow), Brachial artery and its branches; B; radial and median nerves (arrows); C and D: Supracondylar joint anatomy with osseocartilagenous detail; E. Median and radial nerves(arrows) and arterial sections (radial artery) with vessel wall delineation; [F,G]: exquisite contrast for viewing cartilage and synovial fluid; I: T2 SWI micro-vasculature shown in SWI compare to T1VIBE (H); [J,K]: Non-contrast enhanced MRA(TOF) image of palmer and DPP (digital proper palmer) arteries; L: T1VIBE of hand image depicting ligaments, tendons, bone, vessels, cartilage; M: MIP image clearly showing vasculature in hand)

Figure 2 [A, B, C]: T1VIBE, T2DESS, and DTI color coded map showing radial an median nerves, [D,E, F]: Sag, axial, and cor. (showing RN, MN respectively), [G]: 3D view of both nerves , [H, I]: tractrography data(radial and median nerves), [J,K,L]: Vessel segmentation, [M,N]: Slice showing Paint grow method



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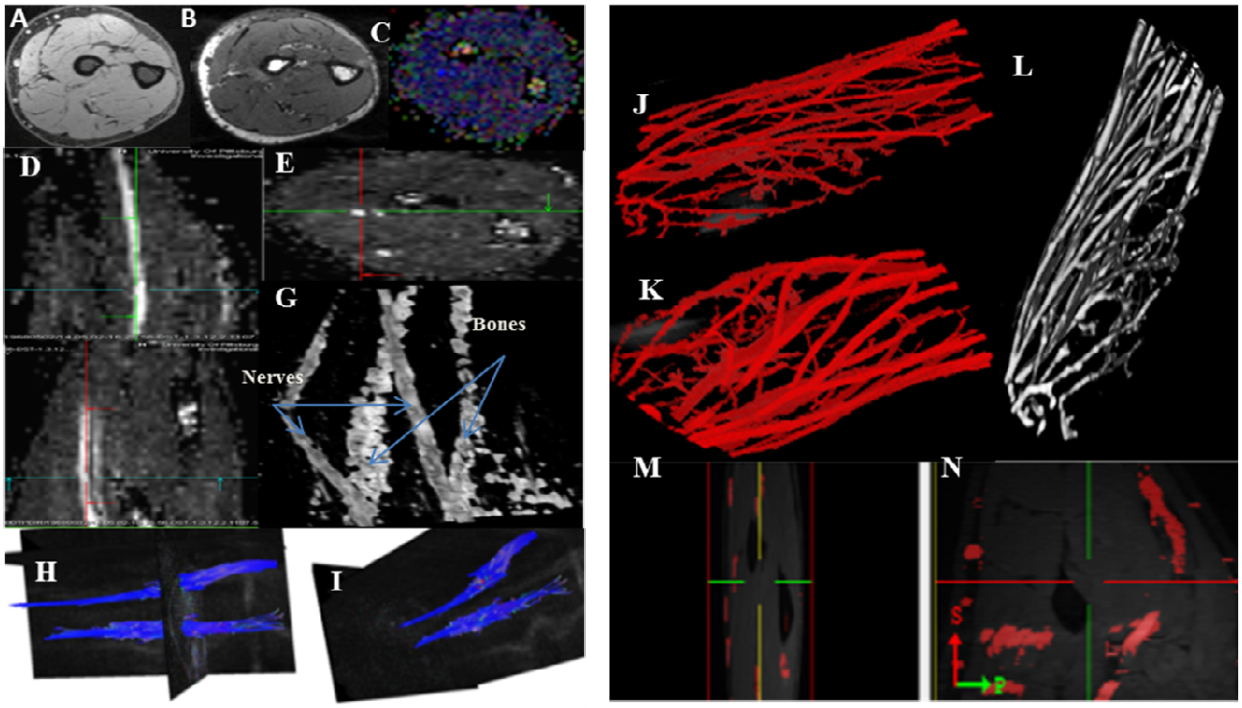

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Table 1: 7T Musculoskeletal imaging protocol

Sequences	FOV(mm)	TR/TE	Slices
B_1^+ field map	100 x 100	1500/1.8	112
T1 VIBE(304x512)	95 x 160	12/4.5	288
DTI (D:32, b=1300)	700 x 620	7000/83	65
DSI (b=0 to 2000)	700 x 620	8000/80	65
TOF(236x640)	85 x 208	12/4.5	