Visualization and quantitative evaluation of lumbar nerve roots using diffusion tensor imaging.

Yasuhiro OIkawa[1], Yawara Eguchi[1], Seiji Ohtori[1], Sumihisa Orita[1], Kazuyo Yamauchi[1], Miyako Suzuki[1], Yoshihiro Sakuma[1], Go Kubota[1], Kazuhide Inage[1], Takeshi Saino[1], HIrotaka Sato[2], Hiroki Ando[2], Masatoshi Kojima[2], Kenichiro Okumura[2], Yoshitada Masuda[2], Atsuya Watanabe[3], and Kazuhisa Takahashi[1]

[1]Orthopaedic Surgery, Graduate School of Medicine, Chiba University, Chiba, Chiba, Japan, [2]Radiology, Graduate School of Medicine, Chiba University, Chiba, Chiba, Japan, [3]Orthopaedic Surgery, Teikyou University Chiba Medical Center, Ichihara, Chiba, Japan

TARGET AUDIENCE: Clinicians (orthopaedic surgeons and neurosurgeons) and researchers

INTRODUCTION: Conventional imaging modalities for the lumbar spinal degenerative disease have a good potential for morphological evaluation. By contrast, quantitative evaluation of nerve damage has been shown to be difficult. Diffusion tensor imaging (DTI) and diffusion tensor tractography (DTT) have been reported as novel imaging tools for a quantitative nerve evaluation[1]. Recently several authors have reported DTI as a potential tool for the diagnosis of foraminal stenosis[2]. The purpose of this study was to visualize and evaluate the lumbar nerve roots quantitatively.

MATERIALS AND METHODS: Thirty-four patients (25 male, mean age 63.3 years) with degenerated lumbar disease who underwent 3.0 T MRI and surgical treatment were included. In all subjects, DTI was performed by using a special sensitivity array encoding technique, factor: 2; chemical shift selective suppression; and an echo-planar imaging sequence with a free-breathing scanning technique. The following imaging parameters were set: 800 s/mm^2 b-value; MPG, 11 directions; 6000/76 ms for TR/TE, respectively; axial section orientation, 3/0-mm section thickness/gap; 320 $\times$ 256 mm FOV; 96 $\times$ 192 matrix; 3.3 $\times$ 1.66 $\times$ 3.0 mm^3 actual voxel size; 1.6 $\times$ 1.6 $\times$ 4.0 mm^3 calculated voxel size; 4 excitations; 50 total sections; and 4 min 54 s scan time. Fractional anisotropy (FA) was calculated from a FA map, and ROIs were placed on "intraspinal", "intraforaminal", and "extraforaminal" zones. Fiber tracking was performed by placing ROIs at intraspinal and extraforaminal zones. Tractography, was investigated. Volume-One (http:// www.volume-one.org/), dTVIISR (second release; http://www.ut-radiology.umin.jp/people/masutani/dTV.htm) and functool DTI processing (GE Healthcare, Milwaukee, Wisconsin) were used for tractography and FA mapping.

RESULT: In asymptomatic nerves, tractography showed all L3–S1 spinal nerve roots clearly (Fig.1). Abnormality of tractographies were classified into three types by the shape; "Disruption", "Narrowing", and "Tapering" (Fig. 2). In normal nerve roots, FA values (mean ± SD) of nerve were 0.247 ± 0.070 for intraspinal, 0.323 ± 0.060 for intraforaminal, and 0.337 ± 0.059 for extraframinal zones . Differences were not found between each level of nerve root levels (L3–S1). The mean FA value of intraforaminal zones was 0.288 ± 0.047 in the Disruption type and 0.300 ± 0.048 in the Narrowing type, which is significantly lower than that for normal nerve roots. The mean FA of extraforaminal zones was 0.280 ± 0.056 in the Tapering type, significantly lower than normal nerve . Foraminal stenosis in lumbar spinal stenosis showed more abnormalities with characteristic distribution in the Disruption type. Compared with the asymptomatic side, a lower FA value was observed in the symptomatic side.

DISCUSSION: Beaulieu et al reported that Wallerian degeneration after peripheral nerve injury reduces the anisotrophy of water diffusion[3]. Several studies have reported FA value for lumbar nerve roots, which was lower in compressed nerves than intact nerves[2,4,5]. This study showed trends for FA of lumbar spinal nerves. FA increases further from the intraspinal zone and is less in symptomatic roots.

Fig.1. Tractography of lumbar nerve root merged with T2-WI.

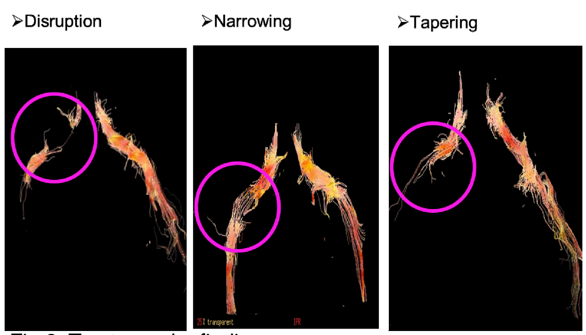

Fig.2. Tractography findings
Classified into three types by the shape of tractography.

CONCLUSION: This study demonstrates that tractography shows abnormal findings for nerve roots in lumbar spinal degeneration and so DTI may offer not only morphological evaluation, but also quantitative evaluation. We believe that DTI is a potential tool for the diagnosis of lumbar spinal degenerative disease.

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