

CASE REPORT

Diffusion-Weighted Imaging and Diffusion Tensor Imaging of Asymptomatic Lumbar Disc Herniation

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Abstract : Diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) were performed on a healthy 31-year-old man with asymptomatic lumbar disc herniation. Although the left S1 nerve root was obviously entrapped by a herniated mass, neither DWI nor DTI showed any significant findings for the nerve root. Decreased apparent diffusion coefficient (ADC) values and increased fractional anisotropy (FA) values were found. These results are contrary to those in previously published studies of symptomatic patients, in which a combination of increased ADC and decreased FA seem to have a relationship with nerve injury and subsequent symptoms, such as leg pain or palsy. Our results seen in an asymptomatic subject suggest that the compressed nerve with no injury, such as edema, demyelination, or persistent axonal injury, may be indicated by a combination of decreased ADC and increased FA. ADC and FA could therefore be potential tools to elucidate the pathomechanism of radiculopathy. *J. Med. Invest.* 61 : 197-203, February, 2014

Keywords : asymptomatic, lumbar spine, disc herniation, diffusion tensor imaging, diffusion-weighted imaging

INTRODUCTION

The relationship between abnormalities in the lumbar spine and symptoms such as low back pain, leg pain, muscle weakness, and sensory disturbance is controversial. In particular, the frequent presence of disc abnormalities seen on imaging findings in the asymptomatic population can confound spine surgeons (1-3). Two imaging techniques have been reported in the last couple of years to help surgeons resolve the problem of this discrepancy between imaging findings and clinical symptoms : diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI). Using DWI, Eguchi *et al.* reported

increased apparent diffusion coefficient (ADC) values in a compressed dorsal root ganglion and distal spinal nerves, values which were thought to reflect an entrapped nerve root due to edema and Wallatian degeneration (4, 5). DTI is widely used in the evaluation of the central nervous system and recently fractional anisotropy (FA) has been reported as a potential tool for the diagnosis of lumbar nerve entrapment. FA is a quantitative diffusion value reflecting the global anisotropy of the analyzed structure. Eguchi *et al.* reported that mean FA values in entrapped nerve roots were significantly lower than those in intact nerve roots (6). Other studies also reported that, without exception, entrapped nerve roots in symptomatic patients showed increased ADC values and decreased FA values (7).

However, there have been no reports to date describing ADC and FA values in asymptomatic subjects with an entrapped nerve root. In this report, we describe the DWI and DTI findings from 3.0-T

Received for publication July 3, 2013 ; accepted August 1, 2013.

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magnetic resonance imaging (MRI) and the paradoxical results of ADC and FA values of a lumbar nerve root entrapped by herniated discs in an asymptomatic subject.

CASE REPORT

Physical examinations

A 31-year-old man was recruited to our study as a healthy volunteer. He had no past history of any low back disease and had no experience of low back pain or leg pain. Examination by a certificated spine surgeon showed no neurological findings, including any that may have arisen during the straight-leg raising, femoral nerve stretching, muscle weakness, and sensory disturbance tests. The study protocol was approved by the institutional review board of our hospital and written informed consent was obtained from the volunteer subject.

Imaging findings

MRI examination was performed on a 3.0-T MR unit (Achieva ; Philips Healthcare, Best, The Netherlands) using a five-element phased-array surface

coil. Conventional MRI showed a mass herniated into the spinal canal on the left side at L5-S1, and the mass appeared to be entrapping the left S1 nerve root (Figure 1). Three-dimensional water-excitation balanced fast field echo (FFE) images of the lumbosacral plexus confirmed the left S1 spinal nerve was entrapped by the herniated mass (Figure 2). A coronal reformatted image from axial DWI using $b = 800$ (2.5 mm thickness) showed no abnormalities in this subject, such as nerve indentation and discontinuity, or swelling in the involved dorsal root ganglion and distal spinal nerve, similarly to the cases reported by Eguchi *et al.* (4) (Figure 3). There were also no abnormalities in a limited field of view using 1.5 mm slice thickness focused on the L5/S1 level (not shown).

DTI fiber tracking did not show that the subject's left S1 nerve root was disrupted (Figure 4). Figure 5 shows the mean FA and ADC values at each level at a baseline visit and 3 months later. At the L5/S1 disc level, the mean FA values of the entrapped nerve on the left were higher than those of the intact nerve on the right at the baseline visit. The mean ADC values of the compressed nerve on the left were consistently lower than those of the

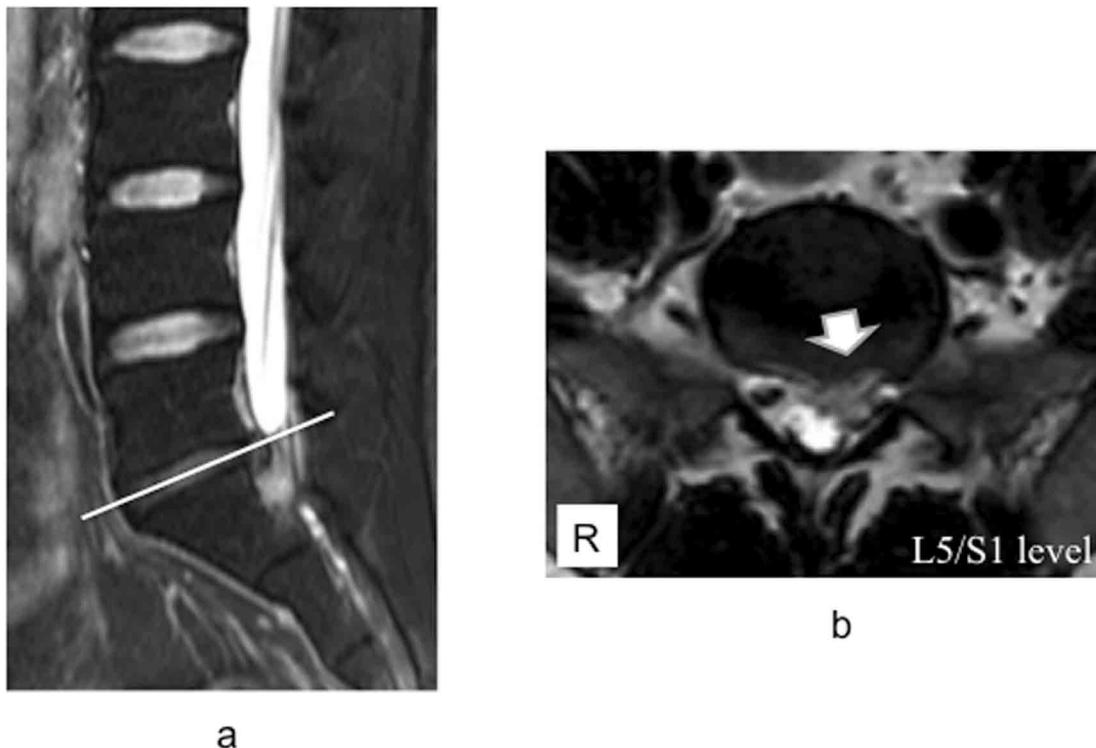


Figure 1 Sagittal and axial T2-weighted images of the lumbar spine. a) Sagittal image shows a mass posteriorly herniated from the L5/S1 intervertebral disc. b) Axial image shows the mass was herniated predominantly on the left side (arrow).

intact nerve on the right at the L5/S1 disc level. Similar results for ADC and FA values were obtained 3 months later (Figure 5). During the 3

months, he had no experience of low back pain or leg pain.

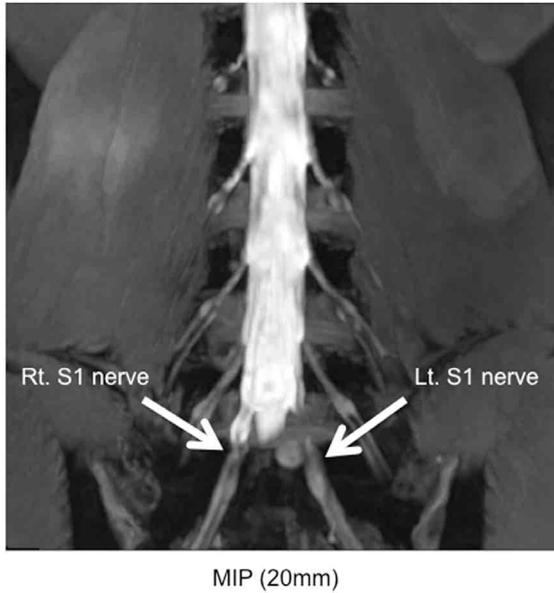


Figure 2 Coronal three-dimensional water-excitation balanced fast field echo sequence (TR, 8.6 msec ; TE, 4.6 msec ; flip angle, 25 degree ; slice thickness, 2.5 mm ; matrix, 512 × 512 ; FOV, 250 mm × 250 mm) and thick-slice (20 mm) coronal maximum intensity projection images were reconstructed as MR myelography, which showed discontinuity of the left S1 spinal nerve due to a herniated mass.

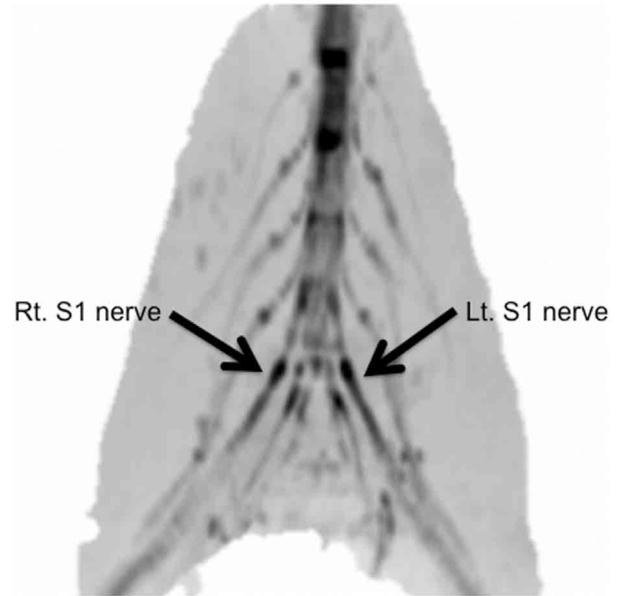


Figure 3 Diffusion-weighted image (DWI) acquired using axial short inversion time inversion-recovery echo-planner imaging (TR, 14353 ; TE, 65 ; inversion time, 260 msec ; echo train length, 95 ; slice thickness, 1.5 mm ; b-factor, 800) with unidirectional motion probing gradients. Maximum intensity projection images were postprocessed. The DWI fails to show any abnormalities such as nerve indentation and discontinuity.

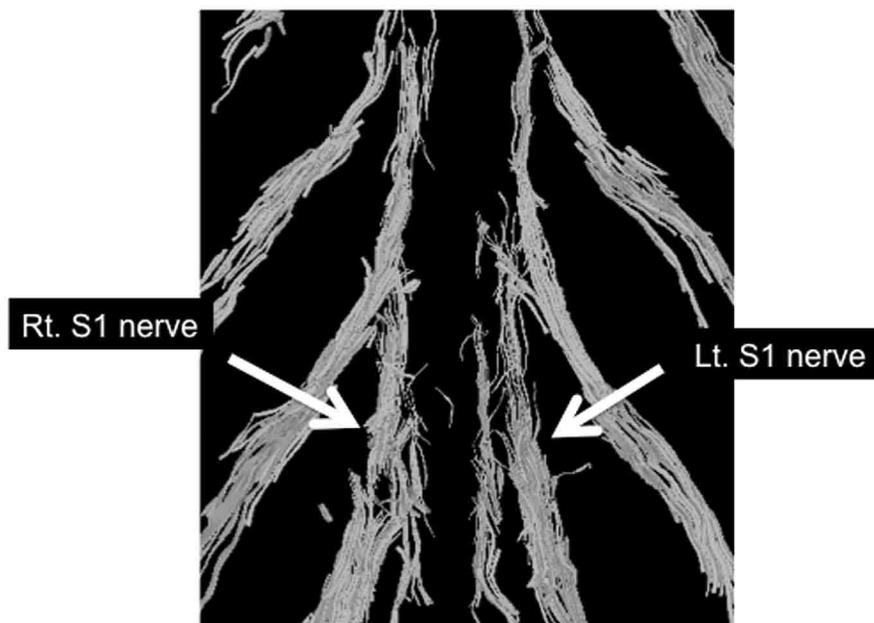


Figure 4 Diffusion tensor image fiber tracking (11084.6/73.7 ms for TR/TE, respectively ; flip angle, 90° ; field of view, 280 mm ; b-value, 800 s/mm² ; MPG, 33 directions ; slice thickness/gap, 1.5 mm ; number of slice, 60 ; actual voxel size, 11.49 × 2.98 × 1.50 mm³ ; total scan time 7 min 35 s) failed to show disruption or discontinuity of the left S1 nerve root.

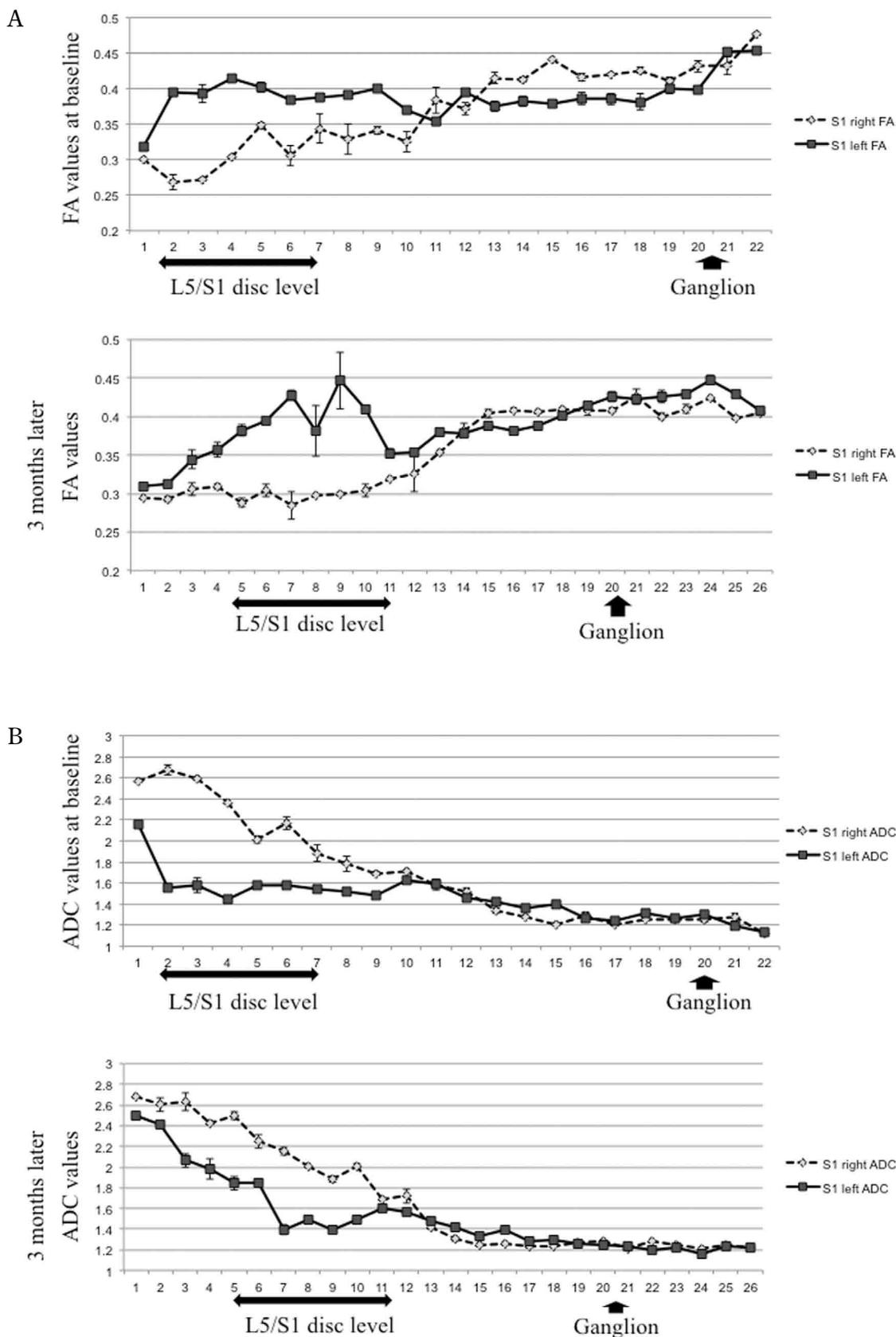


Figure 5 Mean FA and ADC values at all consecutive points along the S1 nerves were quantified by direct measurement of FA and ADC, by placing a region of interest on the axial DTI with fiber tracking. All measurements were performed on PC workstations using the imaging software Achieva 3T TX system, Release 3.2. Fibers were confirmed to pass through the target nerve on coronal and sagittal view images. The thresholds for tracking termination were 0.1 for FA, 27° for the angle, and 3 mm for minimum fiber length. a) Mean FA values of the compressed nerve at the L5/S1 disc level are consistently higher than those of intact nerve at baseline visit. b) Mean ADC values of the compressed nerve at the L5/S1 disc level were consistently lower than those of intact nerve. Similar results were obtained 3 months later.

DISCUSSION

Although conventional MRI and MR myelography using balanced FFE clearly showed a nerve root entrapped by a herniated disc in the asymptomatic subject, DWI and DTI failed to show any nerve abnormalities. These results suggest that DWI and DTI can identify only symptomatic nerve roots, not asymptomatic ones. Furthermore, the decreased ADC values and increased FA values on the affected nerve root which were measured at the herniated disc level were different from the results of previous studies (4-7). It is possible that ADC and FA values on an asymptomatic nerve associated with a herniated disc may show different behavior from those on a symptomatic nerve.

Asymptomatic intervertebral disc degeneration and herniation are commonly seen in clinical practice, and MRI studies in healthy volunteers have demonstrated a high prevalence (20-76%) of asymptomatic disc herniations (1-3). Moreover, the pathomechanism of sciatica has still not been elucidated, although it is currently thought to involve a combination of mechanical and biochemical factors. The discrepancy between imaging findings and lack of clinical symptoms can make an accurate diagnosis and surgical planning difficult at times.

MRI has a multiplanar imaging capability that enables the musculoskeletal system to be visualized with excellent tissue contrast and without radiation exposure. It plays an important role in the assessment of spinal disorders such as lumbar disc herniation, lumbar spinal canal stenosis, and spinal tumors. However, conventional MRI is not sufficient for depicting abnormalities of the nerve roots and peripheral nerves. Routinely acquired T1- and T2-weighted images do not provide enough contrast to discriminate nerves from surrounding background tissues, especially veins (8), but the recent imaging advances in DWI and DTI have already been successfully applied to visualize abnormal conditions such as tumors, trauma, and neuritis (9-18).

Several studies using DWI or DTI of the lumbar spine have been reported (4, 5, 19). Increased ADC values and decreased FA values were reported for entrapped nerve roots in symptomatic patients (4-7). Olmarker *et al.* reported that intraneural edema might form in nerve roots more easily than in peripheral nerves after compression injury (20). Furthermore, several studies reported that increased ADC values were observed in injured nerves with demyelination (21, 22), while decreased FA values

on peripheral nerves were associated with axonal degeneration and regeneration in rat and mouse sciatic nerves (23, 24). Thus, the combination of decreased ADC values and increased FA values seems to have a relationship with nerve injury as well as subsequent symptoms such as leg pain or palsy.

Although the left S1 nerve root was clearly compressed in our asymptomatic subject, DWI did not show any findings for the nerve root. The decreased ADC values and increased FA values obtained for the compressed S1 nerve are noteworthy as they are contrary to findings in symptomatic patients. Our findings suggest that the occurrence of both decreased ADC and increased FA values may indicate that the compressed nerve has no injury such as edema, demyelination, or persistent axonal injury (Figure 6).

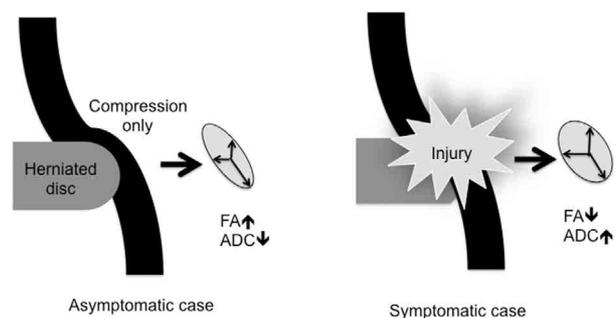


Figure 6 Hypothesis of changes in ADC and FA in asymptomatic and symptomatic subjects. In our asymptomatic case, FA was increased and ADC was decreased following compression of the nerve root without injury; symptomatic cases show decreased FA and increased ADC probably due to intraneural edema associated with nerve injury.

The limitations of this report include the lack of pathological confirmation and the presentation of a single case (though the subject was scanned twice within a 3-month interval and a similar pattern of ADC and FA values was obtained). Despite the remaining problems with and the need for further improvement of MRI techniques, we believe the ADC and FA values are potentially tools for elucidating the pathomechanism of radiculopathy.

DECLARATION OF INTEREST

The authors report no conflict of interest.

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