Measurement of the local pressure of the intervertebral foramen and the electrophysiological values of the epidural nerve roots in the vertebral foramen

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Introduction
The most common and characteristic symptom in lumbar spinal stenosis is neurogenic intermittent claudication. It is generally considered that the genesis of leg symptoms may be the result of ischemia caused by mechanical stress to the spinal nerve root. Recent developments in diagnostic imaging procedures such as MRI have made it easy to visualize nerve root compression, however, the epidural nerve root entrapment in the vertebral foramen makes it difficult to diagnose based only on radiological findings. The diagnostic value of the epidural nerve root entrapment in the vertebral foramen can be determined based not only on the morphological findings but also based on the functional findings by nerve root infiltration. We have measured the local pressure of the intervertebral foramen of the lumbar spine during surgery, and evaluated electrophysiological function of the epidural nerve roots using the compound muscle action potentials (CMAPS) from tibialis anterior (TA) after lumbar spine epidural nerve root stimulation.

Materials and Methods
A total of forty-one patients, aged from 18-83 years of age were studied. All patients underwent lumbar spine surgery. Thirty-four patients were diagnosed to have lumbar spinal stenosis (58 vertebral foramen), while eight had lumbar disc herniation (8 vertebral foramen). The mean age was 66.4 years in lumbar spinal stenosis and 25.6 years in lumbar disc herniation. There was significant difference between the age of the patients with two subjects (P<0.0001), and those with lumbar disc herniation had no significant osteospondylosis based on the radiological findings or the symptoms of neurogenic intermittent claudication. We therefore considered the patients with lumbar disc herniation to be the control subjects.

The local pressure of the intervertebral foramen was measured in all patients, for all of the vertebral foramen. A micro-tip catheter transducer (MPC-500, Miller Instruments Inc, TX) was used as a pressure transducer. After exposing the interlaminar space, the catheter transducer was inserted from the interlaminar space and placed just below the pedicle in the vertebral foramen. The local pressure was continuously measured while the lumbar spine postures were changed. Three different postures were studied, e.g., the lumbar spine flexion, neutral and extension posture.

In addition, twenty-four L5 nerve roots from 20 patients were electrophysiologically evaluated using the CMAPs. Sixteen patients were diagnosed to have lumbar spinal stenosis (20 L5 nerve roots), while four had lumbar disc herniation (4 L5 nerve roots). The CMAPs were recorded using the surface electrode on the TA muscle and the L5 nerve root was directly stimulated by a nerve stimulator probe after exposing the interlaminar space. The latency and amplitude of the CMAPs were obtained in the lumbar spine flexion and extension posture.

Results
The local pressure of the intervertebral foramen was 15.57±9.84 mmHg in the lumbar spine flexion, and 24.74±12.6 mmHg in the neutral, and 36.46±19.14 mmHg in the extension posture. The peak values of the local pressure significantly increased (P=0.001) according to the three different postures.

The local pressure of the L5/S1 foramen in lumbar spinal stenosis was 17.81±10.79 mmHg, 27.02±13.5 mmHg and 37.97±18.93 mmHg in each posture, and 11.5±6.26 mmHg, 16.75±13.13 mmHg and 26.06±19.21 mmHg in lumbar disc herniation. A significant difference in the local pressure was found between the patients with two subjects only in the lumbar spine neutral posture (P=0.041).

Regarding the latency of the CMAPs, eleven of 24 L5 nerve roots showed prolonged latencies in the lumbar spine extension than in the flexion posture. Circumstantially, eleven of 20 L5 nerve roots with the lumbar spinal stenosis and none with the lumbar disc herniation showed prolonged latencies in the lumbar spine extension posture. The average values of the latencies in the lumbar spine flexion posture was 15.42±1.92 ms and 15.65±1.92 ms in the lumbar spine extension posture. The latencies were prolonged significantly in the lumbar spine extension posture (P<0.033). Moreover, no significant difference was found between the patients with lumbar spinal stenosis and lumbar disc herniation, however, the patients with lumbar spinal stenosis tended to show prolonged latencies than the lumbar disc herniation. (P=0.0884).

On the other hand, regarding the amplitude of the CMAPs, twenty-three of 24 L5 nerve roots showed deteriorated amplitudes in the lumbar spine extension than in the flexion posture. The average values of the amplitudes in the lumbar spine flexion posture was 685.3±118.98 µV and 348.11±674.39 µv in the extension posture. The amplitudes deteriorated significantly in the lumbar spine extension (P<0.0001).

However, no significant difference was found between the patients with lumbar spinal stenosis and lumbar disc herniation.

Discussion
Several studies have shown that the mechanical pressure on the nerve root could cause a disturbance in the blood supply and nutrition of the nerve root, and the critical pressure levels were thus determined regarding the impairment of basic neurologic events in the nerve root. The hypoxic conditions of the nerve root was thus considered to induced the radicular pain.

Our findings demonstrated that the local pressure of the intervertebral foramen increased gradually during lumbar spine extension, moreover, the electrophysiological values of the epidural nerve roots as evaluated by the CMAPs were found to deteriorate in line with the increasing local pressure of the intervertebral foramen. We considered that the local pressure of the intervertebral foramen thus reflected the external stress on the epidural nerve root in the vertebral foramen. These results demonstrated that the mechanical stress on the epidural nerve roots increased during lumbar spine extension, and an increase in the external stress on the epidural nerve roots by their surrounding tissues in the vertebral foramen appears to cause a reduction in the intradiscal blood flow. As a result of the reduction in the intradiscal blood flow, the electrophysiological values of the epidural nerve roots deteriorated, thereby inducing radicular pain.

In addition, the local pressure of the intervertebral foramen in lumbar spinal stenosis tended to be higher than that in lumbar disc herniation. The subjects with lumbar spinal stenosis thus seemed to have some degeneration in the tissue surrounding their epidural nerve roots in the vertebral foramen. Therefore, the subjects with lumbar spinal stenosis are considered to induce more mechanical stress on the epidural nerve roots in the vertebral foramen than in the subjects with lumbar disc herniation which we defined to be the control subjects. In our study, there were no significant differences in the electrophysiological values of the epidural nerve roots evaluated by the latency and amplitude of the CMAPs between two subjects. However, no prolonged latencies were seen in lumbar disc herniation, while 11 of 20 L5 nerve roots with lumbar spinal stenosis showed prolonged latencies. This result demonstrated that the mechanical stress on the epidural nerve root in the vertebral foramen in lumbar spinal stenosis was larger than that in the control subjects.

All patients with lumbar spinal stenosis in this study only showed a recovery from their leg symptoms after decompression of the stenotic intracranial lesions by means of surgical procedures. These results suggested that claudication, which may be induced in lumbar spinal stenosis, seemed to occur with a double crushing of the nerve root, which included in the spinal canal and the vertebral foramen. As a result of decompression of the spinal canal lesion, the blood flow in the epidural nerve root in the vertebral foramen, which is peripheral to the spinal canal lesion, improved, thus resulting in an improvement in the clinical symptoms.

However, there are still some issues left unanswered in the current study. Therefore, using the current investigation as a pilot study, further research using larger patient populations may help to resolve several unclear results in this study while also clarifying the details of the morphologic and the functional values of the epidural nerve roots in the vertebral foramen of the lumbar spine.