Neuroradiological Assessment of the Thickness of the Yellow Ligament in Degenerative Lumbar Canal Stenosis

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Abstract
In this study, we express numerically the thickness of the yellow ligament at the level of L3/4, L4/5 and L5/S1 in degenerative lumbar canal stenosis caused by thickened yellow ligament. The thickness of the yellow ligament in patients with degenerative lumbar canal stenosis (stenosis group) and age-matched lumbar disc herniation patients (hernia group; as a control) were measured on CT myelography. In the stenosis group, the mean thickness of the yellow ligament were 4.2 ± 1.5mm (L3/4), 5.3 ± 1.9 mm (L4/5) and 5.6 ± 2.2mm (L5/S1). In the hernia group, the mean thickness of the yellow ligament were 3.0 ± 2.0 mm (L3/4) and 3.8 ± 2.4mm (L4/5) and 4.8 ± 2.7 mm (L5/S1). Statistically differences were observed between the stenosis group and the hernia group in all three levels (p<0.05).

Key words: degenerative lumbar canal stenosis, yellow ligament, CT myelography

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Introduction
Thickened yellow ligament has an important role as a compression factor in the central type lumbar canal stenosis. Elsberg reported the first case of the hypertrophy of the yellow ligament in 1913 [8]. After this report, some reports described the thickened yellow ligament as an important compression factor in lumbar canal stenosis. According to these reports and our own experience, for central type lumbar canal stenosis, we performed partial laminectomy and bilateral ligamentectomy sparing the spinous process and the interspinous ligament to decompress of the dural sac with good clinical results. In this report, we express numerically the thickness of the yellow ligament in such central type lumbar canal stenosis cases on CT myelogram.

Materials and Methods
Between February 1983 and December 1994, the authors underwent 270 surgeries of the lumbar canal stenosis. At first, from this group, central type lumbar canal stenosis treated by partial laminectomy with bilateral ligamentectomy were selected, and then, 50 cases were randomly selected from this group and were measured their maximum thickness of the yellow ligament at L3/4, L4/5 and L5/S on CT.

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myelography (CTM). The formula for calculating the thickness of the yellow ligament was: (thickness of the right side + thickness of the left side) / 2 (Figure 1).

As a control group, the thickness of the yellow ligament were also examined in the age matched 50 patients of lumbar disc herniation cases treated by partial hemilaminectomy with disectomy.

All values are expressed as mean plus and minus standard deviation (SD). In each level, a two-tailed unpaired T test was used to compare the thickness of the yellow ligament for two groups. P<0.05 was regarded as significant.

Results

Among 41 males and 9 females, patient ages ranged from 38 to 76 years (mean age 58.2 years) in the stenosis group. In the hernia group, there were 29 males and 21 females and the mean age was 56.4 years with range of 36-76 years (Table 1).

In the stenosis group, the mean thickness of the yellow ligament were 4.2 ± 1.5 mm (L3/4), 5.3 ± 1.9 mm (L4/5) and 5.6 ± 2.2 mm (L5/S1). In the hernia group, the mean thickness of the yellow ligament were 3.0 ± 2.0 mm (L3/4) and 3.8 ± 2.4 mm (L4/5) and 4.8 ± 2.7 mm (L5/S1). Thus, statistically the difference was observed between the stenosis group and hernia group (p<0.05) (Table 2).

Discussion

Lumbar canal stenosis is the most common pathological condition causing compression of the cauda equina or lumbosacral nerve roots. The definition and classification of the lumbar canal stenosis has been controversial. In this disorder, the posterior spinal structures play an important role. Verbiest introduced the concept of bony lumbar canal stenosis in 1954 [23]. He measured the size of the lumbar spinal canal at surgery. According to his definition, only the bony factors were considered essential: the term "lumbar canal stenosis" was used only for congenital bony canal stenosis. Yong-Hing et al described that thickened yellow ligament was a secondary change due to a thickened lamina or shortened interpedicular distance, the main factors in lumbar canal stenosis was narrowing of the bony spinal canal and enlarged articular processes [26]. Depending of these reports, bony narrowing of the canal is considered to be the primary compression factor in lumbar canal stenosis, total and wide laminectomy has been selected as surgical procedure for lumbar canal stenosis.

On the other hand, numerous authors have emphasized the role of the hypertrophied facet joint in the lumbar canal stenosis. There have been debates on, however, whether or not hypertrophy of the yellow ligament exists. In 1913, Elsberg reported the first example of hypertrophy of the yellow ligament [8]. After him, some authors affirmed the buckling of the yellow ligament into the spinal canal, and others reported the hypertrophy of the degenerative ligament at surgery [1,3,5,6,7,13,15,16,20,21,22,25]. In 1976, Arnoldi et al defined lumbar canal stenosis as any type of narrowing of the spinal canal, nerve root canals or intervertebral foramina [1]. In their classification, soft tissues such as intervertebral disc or yellow ligament also play an important role in causing lumbar canal stenosis.

After the application of CT scan and MRI in the assessment of spinal disorders, features of the yellow ligament can be clearly measured and the role of such a ligament in the lumbar canal stenosis has been examined more exactly than before [4,9,14,24]. In
Table 1: Demographic data

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<th>Stenosis</th>
<th>Hernia</th>
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</thead>
<tbody>
<tr>
<td>age (range)</td>
<td>58.2 (38-76)</td>
<td>56.4 (36-76)</td>
</tr>
<tr>
<td>male</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td>female</td>
<td>9</td>
<td>21</td>
</tr>
</tbody>
</table>

Stenosis, lumbar canal stenosis; Hernia, lumbar disc herniation.

1985, Schonstrom et al reported that the thickened yellow ligament caused lumbar canal stenosis in 77% of their lumbar canal stenosis series [18]. In 1992, Yoshida et al. investigated the pathogenesis of the hypertrophy of the yellow ligament [27]. In this report, 45 cases of lumbar canal stenosis were evaluated by CT scan, statistically significant differences in transverse area and thickness of the yellow ligament were evident compared to those of the lumbar disc hernia.

Sakamaki et al reported the natural history of the yellow ligament thickness in the lumbar spine [17]. In this report, the yellow ligament thickness was measured on MRI in 162 low back pain or leg pain patients. The thickened change was observed accompanying with aging. By our knowledge, no report was found about the sex difference of the thickness of the yellow ligament.

The standard surgery for degenerative lumbar canal stenosis has been wide decompressive laminectomy. This procedure should be selected due to the reason that the degenerative lumbar canal stenosis is primarily caused by bony overgrowth into a narrow spinal canal and is not caused by thickened yellow ligament. After our meticulous investigation of the preoperative radiological examinations, the total laminectomy seemed unnecessary to decompress the dural tube. Depending on this observation, fenestration (bilateral partial hemilaminectomy sparing the spinous process and the interspinous ligament) had been advocated for the lumbar canal stenosis as the less invasive surgery at our institution until 1994. In 1994 we studied 270 lumbar canal stenosis patients of our institute, the stenosis was primarily caused by degenerative facet joint, thickened yellow ligament and herniated disc in 127 patients (47%) [10]. Also, in many cases, thickened yellow ligament was the most important compression factor. Based on this result, at our institution, lumbar canal stenosis patients due to thickened yellow ligament have been treated by unilateral partial hemilaminectomy with bilateral ligamentectomy for less invasive surgery since 1995 [11,12,19]. This procedure was introduced by Wiltse in 1988 to remove not only yellow ligament but also inner part of the lamina through hemilaminectomy, and modified by Poletti to remove bilateral yellow ligament via unilateral laminectomy [14,24]. In Poletti’s report, to calculate quantitative values for the cross-sectional area (CSA) and the volume of the lumbar yellow ligament on CT myelography, the dural sacs were allowed to re-expand to its normal size. The patients were free from their symptoms after the removal of the thickened yellow ligament. Also, we reported the efficacy of this procedure presenting normalized CSA and symptom relief after surgery [19].

In this report, we express numerically the yellow ligament thickness in patients with central type lumbar canal stenosis due to thickened yellow ligament, comparing with lumbar disc herniation patients. At the level of L3/4, L4/5 and L5/S1, the yellow ligament thickness of the stenosis group was statistically significant compared to those of the hernia group (p<0.05). In patients with lumbar disc herniation, the herniated disc is definitely the most

Table 2: Thickness of the Yellow Ligament

<table>
<thead>
<tr>
<th></th>
<th>Stenosis</th>
<th>Hernia</th>
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<tbody>
<tr>
<td>L3/4</td>
<td>4.2 ± 1.5*</td>
<td>3.0 ± 2.0</td>
</tr>
<tr>
<td>L4/5</td>
<td>5.3 ± 1.9*</td>
<td>3.8 ± 2.4</td>
</tr>
<tr>
<td>L5/S1</td>
<td>5.6 ± 2.2*</td>
<td>4.8 ± 2.7</td>
</tr>
</tbody>
</table>

Data are means ± SD (mm). Stenosis, lumbar canal stenosis; Hernia, lumbar disc herniation. *P<0.05 vs. hernia group of the same level.
important compression factor, but the posterior component is not, therefore the hernia group should be treated as a control group. Based on our results, the yellow ligament of the stenosis group is markedly thickened with the significantly increased numerical value of the yellow ligament: 4.2mm, 5.3mm and 5.6mm, of L3/4, L4/5 and L5/S1, respectively. This proved the yellow ligament to have thickened changes and to affect the compression factor (Table2). During the evaluation of the patients with lumbar canal stenosis, however, not only neuroradiological findings but in addition neurological findings should be meticulously evaluated for less invasive surgery.

Acknowledgement

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Editor-in-Chief's comment: Hiroshi Nakagawa, M.D. (Global Spine Inc.)

The authors neuroradiologically evaluated the significantly increased numerical data in the hypertrophied yellow ligaments in the central-type lumbar canal stenosis which we have recognized in neurosurgical practice for many years.

Hemisemilaminectomy with bilateral ligamentectomy is the routine and less invasive procedure of choice among microneurosurgeons. With the recent advent of ultrasonic bone curettes, opposite-side decompression can be safely done through the unilateral approach.

Since the yellow ligament is not a compressive factor in herniated disc group, we have routinely been doing microdiscectomy with preservation of the yellow ligament.

Reviewer's comment: 松村 明

（筑波大学大学院人間総合科学研究科，脳神経機能制御医学（脳神経外科））

Minamiらは変性による腰椎管狭帯症患者における黄色靭帯の厚さについて定量的な計測を行い、age matched controlと比べて複数の椎間レベルで有意に肥厚していることを示した。変形性腰椎症の成因としては椎間関節成分も影響して症状を呈するので、黄色靭帯の厚さだけでは病態全体を論じることはできない。しかしながら、黄色靭帯の厚さをあらかじめ認識しておくことは手術を行う際の参考となり、骨成分の除圧のみならず黄色靭帯の外科的処理をきちんと行うことを意識しておくことにより、確実な手術成績につながることが期待される。

このような観点からして黄色靭帯に着目したMinamiらの論文は臨床的にも意義があり、日本人におけるデータについて対照群を含めた検討を行い、きちんとした結果をまとめたことに敬意を表する。

今後、本研究をさらに進め、骨成分などを含めた腰椎管全体の狭帯についても定量的な評価を行い、面積や狭帯の形状による症状の違いや手術手法の選択、臨床症状の回復程度など、多角的な観点からの検討を行うことにより臨床的にさらに有用な情報がもたらされることを期待する。