



To Assess Whether Lee's Grading System for Central Lumbar Spinal Stenosis Can Be Used as a Decision-Making Tool for Surgical Treatment

요추 중심 신경관 협착에 있어서 Lee's Grade를 통한 MRI 평가방법이 수술적 치료 결정에 유용한가에 대한 연구

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Purpose To evaluate the correlation between Lee's grades and surgical intervention for central lumbar spinal stenosis (CLSS) and to assess whether this grading system can be used as a decision-making tool for the surgical treatment of this condition.

Materials and Methods This retrospective study included 290 patients (M:F = 156:134; mean age, 46 ± 16 years). Radiologists assessed the presence and grade of CLSS at the stenosis point according to Lee's grading system, in which CLSS is classified into four grades according to the shape of the cauda equina. Correlation coefficients (r_s) between Lee's grades and the operation were calculated with Spearman rank correlation.

Results Among the operated patients, grade 2 was the most commonly assigned grade (50%–58%), grade 3 was less common (35%), and grade 0 was the least common (2%–3%). Among the non-operated patients, grade 1 was the most common (63%–65%), grade 0 was less common (15%–16%), and grade 3 was the least common (8%). The distribution of grades differed between the operated and non-operated groups ($p < 0.001$). Less than 25% of patients who underwent surgery were assigned grades 0 and 1, and more than 88% were assigned grades 2 and 3. A moderate correlation was found between the grade and surgical intervention ($r_s = 0.632$ and $r_s = 0.583$).

Conclusion Lee's grade was moderately correlated with surgical intervention. Lee's grading system can be a decision-making tool for the surgical treatment of CLSS.

Index terms Magnetic Resonance; Lumbar Vertebrae; Surgery; Spinal Stenosis; Spinal Canal

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INTRODUCTION

Central lumbar spinal stenosis (CLSS) results in intermittent neurologic claudication, radicular pain, and sensory and motor disturbances in the lower extremities (1). Lee et al. (2) reported a new MRI grading system for CLSS (Lee's grade) in which CLSS is classified into four grades according to cauda equina shape on T2-weighted axial images (Fig. 1). Park et al. (3) reported that Lee's grade 0 is associated with lack of neurologic manifestation (negative neurologic manifestations; NNMs); and grade 3, with positive neurologic manifestations (PNMs). Grade 2 was associated with more cases of PNM than NNM, and so this grade requires further evaluation. However, until now, no studies have assessed the relationship between Lee's grade and surgical intervention for CLSS. If a relationship between Lee's grade and surgical intervention can be established, then this grading system can be used as an objective method for surgical decision making, and its simplicity may help to establish a therapeutic plan.

The purpose of this study was to evaluate the relationship between Lee's grade and the surgical intervention for CLSS and to determine whether this grading system can be used as a decision-making tool for surgical treatment of this condition.

MATERIALS AND METHODS

STUDY GROUP

The Institutional Review Board of our hospital approved this study. Informed consent was not obtained due to the retrospective nature of the study (IRB No. KBSMC 2014-07-027). A total of consecutive 290 patients who found to meet inclusion criteria were included in the study: 156 patients were male (54%) and 134 patients were female (46%). The mean age was 45.5 years (standard deviation, 16, 16–84 years). The inclusion criteria were who had single level CLSS from L3–4 to L5–S1 among the patients who had visited our hospital due to low back pain, radiating pain of the lower extremities, tingling sensations, or weakness of the leg or foot and had underwent MRI of the lumbar spine between February 2004 and June 2013. Sixty four patients with multi-level stenosis, twenty four patients with a history of spine surgery and twelve patients with lumbar spinal stenosis above L3 were excluded. Thirty six patients with foraminal stenosis of the lumbar spine were also excluded because Lee's grade is designed for central stenosis.

MRI PARAMETERS

Used MR hardware of this study was 3 Tesla (T) magnet MR (Achieva; Philips Medical Systems, Best, the Netherlands) and 1.5T magnet MR (Intera, Philips Medical Systems) with syn-spine coil according to the same imaging protocol. T1- and T2-weighted images of axial and sagittal planes were obtained in supine position. A field of view (FOV) of 32 cm, matrix of 512×256 pixels, and slice (SL) thickness of 4 mm were used for sagittal images. A FOV of 15 cm, matrix of 256×320 pixels, and SL of 4 mm were used for axial images. MR sequences included sagittal T1-weighted spin echo (repetition time/echo time = 500–600/10–20 msec, echo train length = 8), T2-weighted image (2500–3500/100–150, 23), axial T2-weighted fast spin echo (2500–3500/50–150, 19), and T1-weighted fast spin echo (600–700/10–20, 7). Total scan time

was about 20 minutes.

ANALYSIS OF THE IMAGES

Image interpretations were performed by two musculoskeletal radiologists (with 10 and 15 years of experience respectively) independently. The radiologists did not know the radiologic diagnosis and clinical findings. A total of 290 patients were evaluated qualitatively from L3–4 level to L5–S1 level. Interpreters of image assessed the presence and grade of CLSS at the stenosis point according to Lee's grading system (2). CLSS was composed of four grades according to the degree of separation of the cauda equina on T2-weighted axial images: grade 0, no stenosis and the anterior cerebrospinal fluid (CSF) space is not separated; grade 1, mild CLSS in which the anterior portion of the CSF space is obliterated mildly, but no aggregation of the cauda equina; grade 2, moderate CLSS, in which the anterior portion of the CSF space is obliterated moderately and the cauda equina is partially aggregated; and grade 3, severe CLSS, in which the anterior portion of the CSF space is obliterated so markedly that it shows marked compression of the dural sac, and the cauda equina appear as a single bundle (Fig. 1). The level graded by each radiologist was the most severely stenotic level and the grading results of both radiologists were used for independent statistical analysis.

CLINICAL CORRELATIONS

One clinician and both radiologists reviewed medical records and operation records to ascertain whether surgery was performed and with which procedure. They also evaluated whether the level of graded stenosis corresponded to the level of surgery. If not, the case was not classified as a surgical case. The surgical procedures included four types: laminectomy, discectomy, foraminotomy, and internal fixation. The mean intervals between the symptom and MR evaluation of were calculated.

STATISTICAL ANALYSIS

The frequency of each grade in relation to whether or not surgical intervention was performed was assessed with a chi-square test. Kappa (κ) statistics were used to assess inter-reader agreement between the two radiologists for grading of CLSS. The interpretation of the κ values were as follows: poor ($\kappa < 0.1$), slight ($0.1 \leq \kappa \leq 0.2$), fair ($0.2 < \kappa \leq 0.4$), moderate ($0.4 < \kappa \leq 0.6$), substantial ($0.6 < \kappa \leq 0.8$), and almost perfect ($0.8 < \kappa \leq 1$) (4). Correlation coefficients (r_s) between the grade and operation were acquired with nonparametric correlation analysis (Spearman rank correlation). For analyses of the relationships between MR findings and characteristics of the study group, the association of MRI grades and operations was evaluated in relation to age (≥ 57 years and < 57 years) (3). Here, we used reference age as 57 years old because Park et al. (3) reported their study results on the correlation of the grades and neurologic manifestation based on this age originally and we wanted to compare our result to those data. An r_s between 0.1 and 0.3 mean weak correlation; between 0.3 and 0.7, moderate correlation; between 0.7 and 0.9, relatively high correlation; and above 0.9, very high correlation (5). We used PASW software version 18.0 (IBM Corp., Armonk, NY, USA) for statistical analyses, and p values ≤ 0.05 were considered statistically significant.

Fig. 1. Illustration of Lee's grading system.

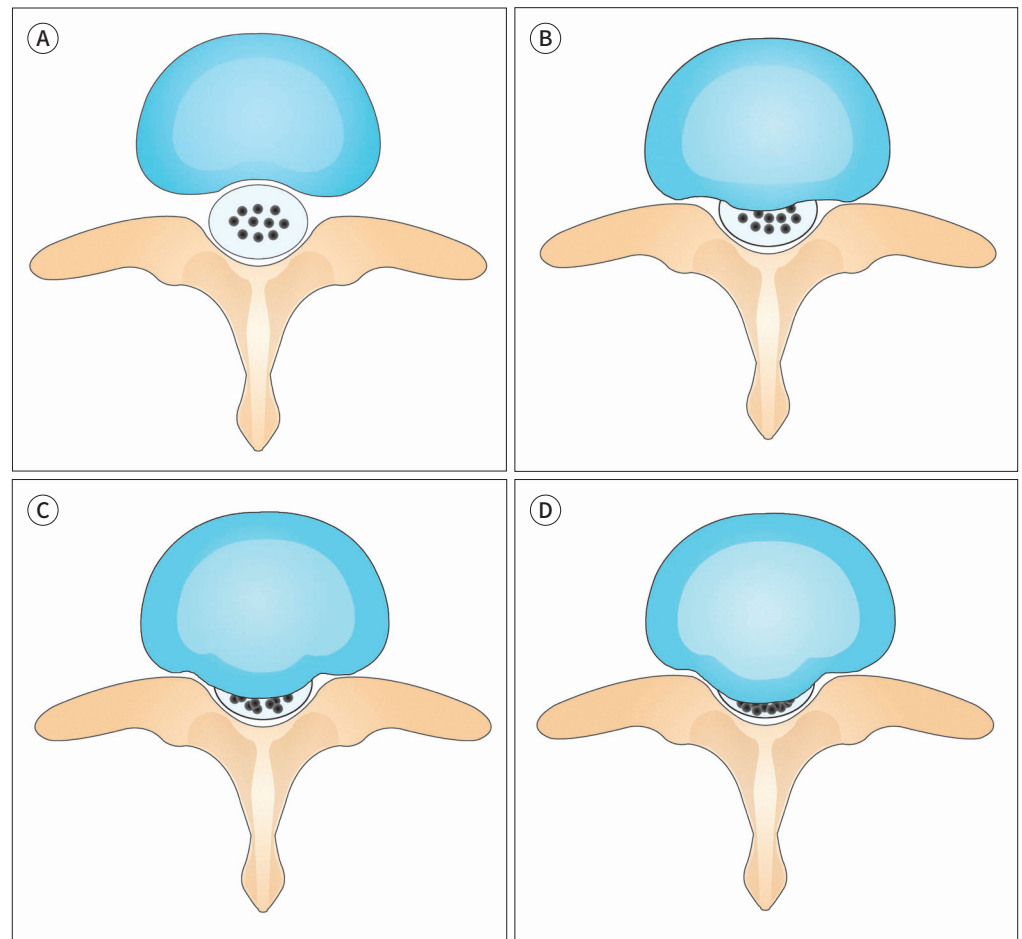
A. Grade 0: no CLSS, and the anterior CSF space is not obliterated.

B. Grade 1: mild CLSS, in which the anterior CSF space is mildly obliterated, but all cauda equina can be clearly separated from each other.

C. Grade 2: moderate CLSS, in which the anterior CSF space is moderately obliterated and some of the cauda equina are aggregated, making it impossible to visually separate them.

D. Grade 3: severe CLSS, in which the anterior CSF space is obliterated so severely that it shows marked compression of the dural sac, and none of the cauda equina can be visually separated from each other, appearing instead as one bundle.

CLSS = central lumbar spinal stenosis, CSF = cerebrospinal fluid



RESULTS

Of the 290 patients included in this study, 223 were under 57 years of age (77%), and 67 were older than 57 years (23%). There were 186 patients (64%) who underwent surgical intervention and 104 who were treated conservatively (36%). The mean intervals between the symptom and MR evaluation of were 146 days for non-operated patients and 268 days for operated patients. The frequency of each grade of CLSS is summarized in Table 1. In the operated patients, grade 2 was most common (50%–58%), grade 3 was less common (35%), and grade 0 was least common (2%–3%) (Figs. 2, 3). Three (by reader 1 and five by reader 2) patients of grade 0 treated with operation, because of severe unbearable pain. In the non-operated pa-

Table 1. Distribution of Lee's Grades in Relation to Whether or Not the Patients Underwent Surgery

Surgery	Grade 0 (%)	Grade 1 (%)	Grade 2 (%)	Grade 3 (%)	Total (%)
Operated patients	3 (2)/5 (3)	9 (5)/23 (12)	108 (58)/93 (50)	66 (35)/65 (35)	186 (100)/186 (100)
Non-operated patients	16 (15)/17 (16)	65 (63)/68 (65)	15 (14)/11 (11)	8 (8)/8 (8)	104 (100)/104 (100)
Total	19 (7)/22 (8)	74 (25)/91 (31)	123 (42)/104 (36)	74 (26)/73 (25)	290 (100)/290 (100)
<i>p</i> *	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	

Reader 1/reader 2.

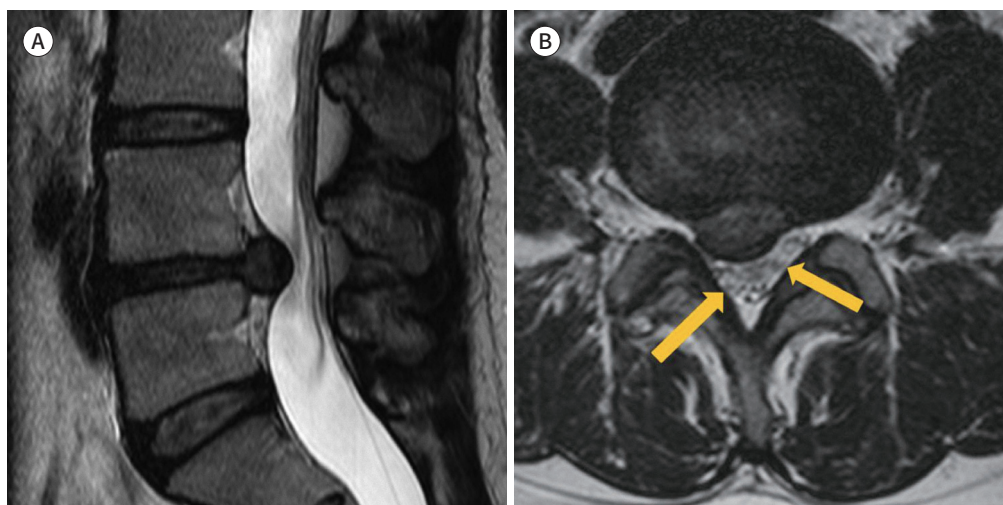
*Comparison between operated and non-operated patients.

Fig. 2. Grade 2, operated patient: a 44-year-old female with a tingling sensation and claudication in both lower extremities for two months.

A. Sagittal T2-weighted fast spin-echo image (3000/100, TR/TE) shows compression of the spinal canal by an extruded L4-5 disc.

B. Axial T2-weighted fast spin-echo image (2500/100, TR/TE) shows moderate central stenosis with some cauda equina aggregation (arrows), classified as grade 2. The patient underwent surgical intervention.

TE = echo time, TR = repetition time



tients, grade 1 was most common (63%–65%), grade 0 was less common (15%–16%), and grade 3 was least common (8%) (Figs. 4, 5). The distribution of grades differed between the operated and non-operated groups ($p < 0.001$). Table 2 summarizes the frequency of each grade in relation to the type of surgery. The overall inter-observer agreements were almost perfect ($\kappa = 0.812$), and agreements in relation to the operation were substantial for operated patients ($\kappa = 0.712$) and almost perfect for non-operated patients ($\kappa = 0.877$) (Table 3). Table 4 summarizes the correlation between each grade and the surgical intervention. Whereas the frequencies of grades 0 and 1 were below 25%, the frequencies of grades 2 and 3 were more than 88%. A moderate correlation between grade and operation was found ($r_s = 0.632$ and $r_s = 0.583$) (Table 5). When we classified the entire study population into a younger and older age group with 57 years as the threshold between groups, the r_s of the younger group were higher than older group ($r_s = 0.653$ and 0.589 vs. $r_s = 0.412$ and 0.413 , reader 1 and reader 2, respectively), however, the interpretations were all moderate correlation. We found two cases of grade 0 (by both reader) who underwent surgery. Both patient proved to have disc sequestration which compressing nerve root without thecal sac compression.

Fig. 3. Grade 3, operated patient: a 28-year-old male with radiating pain and claudication in both lower extremities for several years.

A. Sagittal T2-weighted fast spin-echo image (2500/100, TR/TE) shows extruded disc material from the L4-5 disc (arrow).

B. Axial T2-weighted fast spin-echo image (2700/100, TR/TE) shows severe central stenosis with prominent aggregation of the cauda equina (arrows), classified as grade 3. The patient underwent surgical intervention.

TE = echo time, TR = repetition time

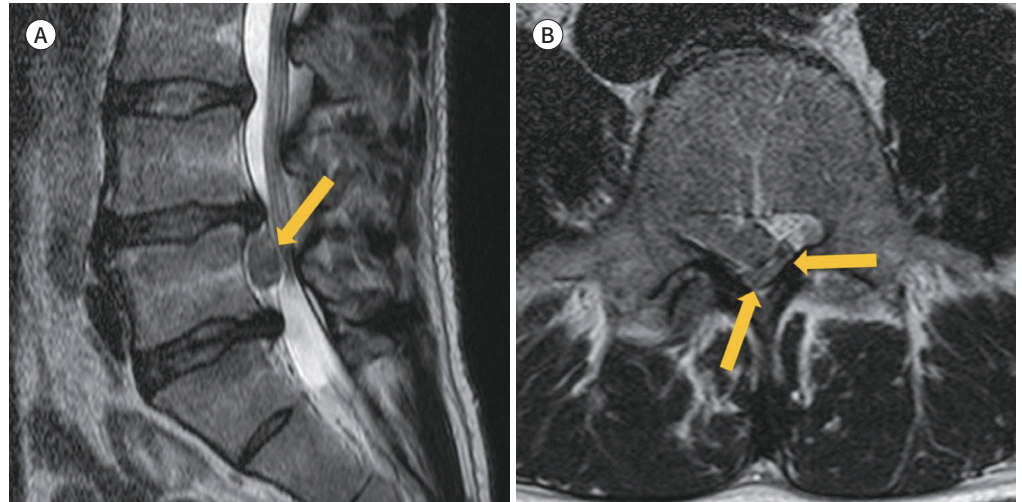


Fig. 4. Grade 1, non-operated patient: a 28-year-old male with lower back pain for several years.

A. Sagittal T2-weighted fast spin-echo image (3200/100, TR/TE) shows mildly protruded disc material from the L4-5 disc.

B. Axial T2-weighted fast spin-echo image (2600/100, TR/TE) shows mild central stenosis without aggregation of the cauda equina, classified as grade 1. The patient underwent medical treatment.

TE = echo time, TR = repetition time



DISCUSSION

Although many previous studies have looked for an association between radiologic findings and clinical outcomes, most clinicians do not rely on radiologic findings alone when making treatment plans. Many clinicians believe that radiologic findings cannot predict clin-

ical severity and outcome with high enough accuracy (2). Ishimoto et al. (6) reported that only 18% of patients with severe central stenosis (narrowing of more than two-thirds of the spinal canal) were symptomatic. Other researches have reported that for central stenosis de-

Fig. 5. Grade 2, non-operated patient: a 68-year-old male with lower back pain and a tingling sensation in both lower legs for two months.

A. Sagittal T2-weighted fast spin-echo image (3000/100, TR/TE) shows extruded disc material from the L3-4 disc.

B. Axial T2-weighted fast spin-echo image (2700/100, TR/TE) shows central stenosis with aggregation of the cauda equina (arrow), classified as grade 2. The patient underwent conservative treatment.

TE = echo time, TR = repetition time

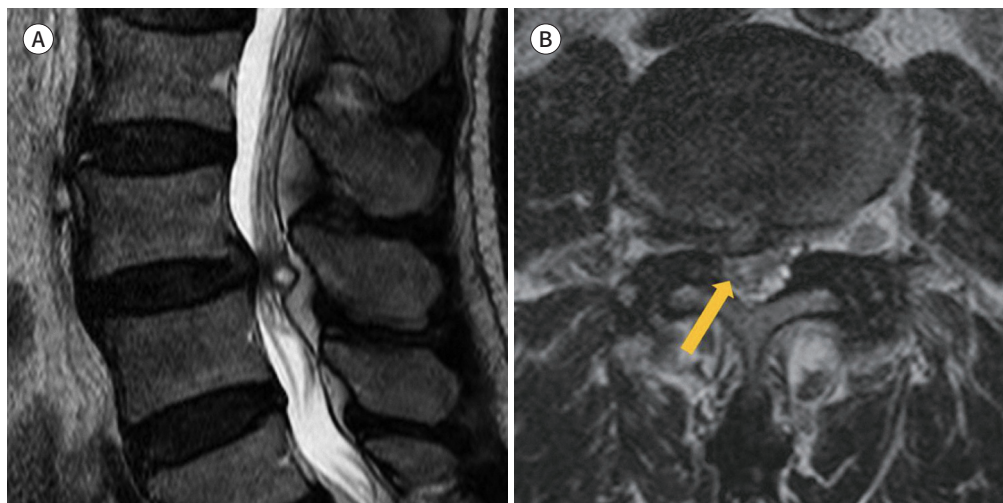


Table 2. Distribution of Lee's Grades in Relation to the Type of Surgery

Surgery	Grade 0	Grade 1	Grade 2	Grade 3	Total
1	1/1	0/2	2/1	7/6	10/10
2	1/1	0/8	8/0	9/9	18/18
1, 2	0/0	4/10	40/34	14/14	58/58
1, 2, 3	1/3	5/3	49/49	32/32	87/87
1, 2, 3, 4	0/0	0/0	1/1	1/1	2/2
1, 3	0/0	0/0	5/5	2/2	7/7
1, 4	0/0	0/0	0/0	1/1	1/1
2, 3	0/0	0/0	2/2	0/0	2/2
3, 4	0/0	0/0	1/1	0/0	1/1
Total	3/5	9/23	108/93	66/65	186/186

Reader 1/reader 2.

1 = laminectomy, 2 = discectomy, 3 = foraminotomy, 4 = internal fixation

Table 3. Inter-Observer Reliability with Lee's Grading System

Levels	Operated Patients	Non-Operated Patients	Total
Kappa value*	0.712	0.877	0.812
95% confidence interval	0.623-0.802	0.788-0.965	0.757-0.868

*Poor ($\kappa < 0.1$), slight ($0.1 \leq \kappa \leq 0.2$), fair ($0.2 < \kappa \leq 0.4$), moderate ($0.4 < \kappa \leq 0.6$), substantial ($0.6 < \kappa \leq 0.8$), and almost perfect ($0.8 < \kappa \leq 1$).

Table 4. Correlation between Lee's Grades and Surgical Intervention for Each Reader

Radiologist	Grade 0 (%)	Grade 1 (%)	Grade 2 (%)	Grade 3 (%)	Total (%)
Reader 1	3/19 (16)	9/74 (12)	108/123 (88)	66/74 (89)	186/290 (64)
Reader 2	5/22 (23)	23/91 (25)	93/104 (89)	65/73 (89)	186/290 (64)

Table 5. Correlation Coefficients between the Lee's Grade and Surgical Intervention of Central Lumbar Spinal Stenosis

Observer	Total	< 57 Years of Age (n = 223)	≥ 57 Years of Age (n = 67)	p-Value
Reader 1	0.632	0.653	0.412	< 0.001
Reader 2	0.583	0.589	0.413	< 0.001

Correlation coefficients = weak ($0.1 \leq r_s < 0.3$), moderate ($0.3 \leq r_s < 0.7$), relatively high ($0.7 \leq r_s < 0.9$), very high ($0.9 \leq r_s$).

tected on radiologic modalities such as MRI, CT, and myelography, no close relationships between the degree of stenosis and clinical symptoms are present (7-9). However, Lee et al. (2) recently introduced a new MR grading system and the system was proved to be closely related to clinical manifestations (2, 3). Lee's grade has been a very reliable and easy system to use in daily clinical practice and is commonly used in our hospital (2). The grading system is composed of four grades from 0 to 3. The main difference between each grade is the shape of the cauda equina on T2-weighted axial images. The correlation between encroachment of the cauda equina with its nerve root and clinical symptoms has been reported previously, and the suggested pathophysiologic mechanism is the direct obstruction of blood flow or venous congestion to the cauda equina due to extrinsic compression (10). The reproducibility of Lee's grade was very good (κ value > 0.8) without reference to the operation, and the κ value was similar to that reported in previous studies (2, 3). Therefore, Lee's grade appears to be an objective grading method in the evaluation of CLSS. Park et al. (3) reported correlations between Lee's grade and neurologic manifestation ranging from 0.591 to 0.654, which is equivalent to moderate correlation. They evaluated the correlation between the grade and clinical manifestations, such as symptoms and neurologic signs. Our study revealed a similar correlation between the grade and surgical intervention (total $r_s = 0.632$, $r_s = 0.583$). However, in the older age group (≥ 57 years), the correlation was lower (0.412 and 0.413) than it was for the younger age group (0.653 and 0.589) (Table 5). In contrast, the correlation between Lee's grade and neurologic manifestation was higher in the older (≥ 57 years) than the younger age group (< 57 years) in the study of Park et al. (3) (older: 0.650 and 0.645; younger: 0.634 and 0.500). These differences may be due to differences in patient compliance in relation to age or the trend for surgeons to be fearful of legal problems because older patients have an increased risk of surgical complications and mortality due to surgical treatment (11). Moreover, many older patients have comorbidities that limit their surgical options (12, 13). Although we had excluded the cases of foraminal stenosis, not a few cases of patients underwent foraminotomy combined with laminectomy, discectomy or internal fixation (Table 2). However, these procedures were a supplementary technique for decompression of the central stenosis and preventive step for neural foraminal stenosis not for decompression for preexisting foraminal stenosis.

One of the limitations of this study was its retrospective design. We reviewed medical records after the entire treatment had been performed. Therefore, we could not determine whether the radiological report concerning the grade of stenosis had influenced on the therapeutic plan. Another limitation was that the study was not based on the evaluation of the surgical outcome. We did not classify surgical results as either successful or not successful. The third limitation was that we did not include a truly healthy control group because most patients underwent MRI due to a health problem.

In conclusion, Lee's grade was moderately correlated with the surgical intervention. The older age group showed a lower correlation than the younger age group. Most patients with grade 2 or 3 underwent surgical intervention. Therefore, Lee's grading system can be a decision making tool for surgical treatment of CLSS.

Author Contributions

Conceptualization, P.H.J.; data curation, Y.J.W., P.H.J.; formal analysis, P.H.J., K.J.N.; investigation, A.D.Y., P.H.J.; methodology, P.H.J.; project administration, P.H.J.; resources, P.H.J., A.D.Y.; supervision, P.H.J.; validation, P.H.J.; visualization, P.H.J.; writing—original draft, A.D.Y., Y.J.W.; and writing—review & editing, P.H.J., K.J.N.

Conflicts of Interest

Hee Jin Park has been a Editorial Board Member of the Journal of the Korean Society of Radiology since 2021; however, he was not involved in the peer reviewer selection, evaluation, or decision process of this article. Otherwise, no other potential conflicts of interest relevant to this article were reported.

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요추 중심 신경관 협착에 있어서 Lee's Grade를 통한 MRI 평가방법이 수술적 치료 결정에 유용한가에 대한 연구

안도연 · 박희진* · 이정우 · 김지나

목적 요추 중심부 협착증(central lumbar spinal stenosis; 이하 CLSS)에 대하여 Lee grading system과 외과적 수술과의 상관관계를 평가하고 이것이 CLSS에 대하여 치료 방법을 정하기 위한 의사 결정 도구로 사용될 수 있는지 평가하고자 하였다.

대상과 방법 이 후향적 연구에는 290명의 환자가 포함되었다(남:여 = 156:134; 평균 연령, 46 ± 16세). 영상의학과 전문의들은 CLSS를 4등급으로 분류하는 Lee grading system에 따라 협착 지점에서 CLSS의 유무와 등급을 평가했다. Spearman 순위 상관관계를 사용하여 Lee의 등급과 수술 시행 여부 간의 상관 계수를 계산했다.

결과 수술을 시행한 환자에서 2등급이 가장 흔했고(50%–58%), 3등급이 다음으로 흔했으며(35%), 0등급이 가장 흔하지 않았다(2%–3%). 수술을 받지 않은 환자의 경우 1등급이 가장 흔했고(63%–65%), 0등급이 그 다음(15%–16%), 3등급이 가장 흔하지 않았다(8%). 등급 분포는 수술 치료군과 비수술 치료군 사이에서 유의하게 차이가 있었다($p < 0.001$). 수술을 받은 환자의 25% 미만에서 0과 1등급이 있었던 반면 2등급과 3등급이 88% 이상이었다. 등급과 수술 사이에 중간 정도(moderate)의 상관관계가 있었다($r_s = 0.632$ and $r_s = 0.583$).

결론 Lee grading system은 수술적 치료 시행과 중간 정도의 상관관계가 있었다. Lee grading system은 CLSS의 치료 방법 결정에서 유용하게 사용할 수 있다.

성균관대학교 의과대학 강북삼성병원 영상의학과