의학 석사 학위 논문

요추 신경공 협착증:
새로운 등급 체계의 임상적 효용성

New grading system for lumbar foraminal stenosis: Evaluation of teachability and correlation of operability

2013년 2월

서울대학교 대학원

의학과 임상의과학 전공

강성은

요추 신경공 협착증:
새로운 등급 체계의 임상적 효용성

New grading system for lumbar foraminal stenosis: Evaluation of teachability and correlation of operability

지도 교수 이준우

이 논문을 의학석사 학위논문으로 제출함

2012년 10월

서울대학교 대학원

의학과 임상의과학 전공

강성은

강성은의 의학 석사 학위 논문을 인준함

2012년 12월

위 원 장　　윤창진　　　(인)

부위원장　　이준우　　　(인)

위원　　　　염진섭　　　(인)

New grading system for lumbar foraminal stenosis: Evaluation of teachability and correlation of operability

by

Sung Eun Kang

A thesis submitted to the Department of Clinical Medical Sciences in partial fulfillment of the requirements for the Degree of Master of Science in Clinical Medical Sciences at Seoul National University College of Medicine.

December 2012

Approved by Thesis Committee:

Professor ______Chang Jin Yoon______Chairman_________

Professor ______Joon Woo Lee___Vice chairman_________

Professor ______Jin Sup Yeom___________________________

학위논문 원문제공 서비스에 대한 동의서

본인의 학위논문에 대하여 서울대학교가 아래와 같이 학위논문 저작물을 제공하는 것에 동의합니다.

1. 동의사항

①본인의 논문을 보존이나 인터넷 등을 통한 온라인 서비스 목적으로 복제할 경우 저작물의 내용을 변경하지 않는 범위 내에서의 복제를 허용합니다.

②본인의 논문을 디지털화하여 인터넷 등 정보통신망을 통한 논문의 일부 또는 전부의 복제.배포 및 전송 시 무료로 제공하는 것에 동의합니다.

2. 개인(저작자)의 의무

본 논문의 저작권을 타인에게 양도하거나 또는 출판을 허락하는 등 동의 내용을 변경하고자 할 때는 소속대학(원)에 공개의 유보 또는 해지를 즉시 통보하겠습니다.

3. 서울대학교의 의무

①서울대학교는 본 논문을 외부에 제공할 경우 저작권 보호장치(DRM)를 사용하여야 합니다.

②서울대학교는 본 논문에 대한 공개의 유보나 해지 신청 시 즉시 처리해야 합니다.

논문제목: 요추 신경공 협착증: 새로운 등급 체계의 임상적 효용성

학위구분: **석사 ■.박사 □**
학　과: 의학과 임상의과학 전공
학　번: 2011-21960
연 락 처 : 서울대학교 병원 영상의학과
저 작 자: 강 성 은 (인)
제 출 일: 2013 년 1월 25일

서울대학교총장 귀하

ABSTRACT

PURPOSE

Our aim was to investigate the reliability and teachability of a new grading system for lumbar foraminal stenosis that was introduced by Lee et al. (i.e., the Lee system). The second aim was to evaluate the correlation between the new imaging grading system and operability.

MATERIALS AND METHODS

The study was approved by the institutional review board of our hospital. A total of 100 patients (27 men, 73 women; mean age: 68.7 years; age range: 60-89 years) who underwent magnetic resonance imaging (MRI) of the lumbar spine were enrolled. Two musculoskeletal radiologists, two neurosurgeons, two orthopedic surgeons, and four radiology residents independently analyzed a total of 600 lumbar foramina (both L3-L4, L4-5 and L5-S1) and graded them using the Lee system. Interobserver and interobserver agreement was analyzed using the interclass correlation coefficient (ICC), the percentage agreement, and kappa statistics. Operability of each lumbar foramen was determined by four surgeons. The correlations between operability and stenosis grading were assessed using Spearman’s correlation.

RESULTS

Interobserver agreement among ten observers showed excellent reliability, as defined by the ICC value of 0.938. The average percentage agreement was 65.8%, and the overall kappa value was 0.55. The ICC for the intraobserver agreement of two observers was 0.897 and 0.787, indicating excellent agreement. The percentage agreements and kappa value were 83% ($\kappa = 0.81$) and 74% ($\kappa = 0.65$), respectively. Lumbar foraminal stenosis grading and operability were significantly correlated (rho Spearman's: 0.550, 0.717, 0.765, and 0.667; $p < 0.0001$)

CONCLUSION

The Lee system for lumbar foraminal stenosis is a reliable classification system for surgeons, radiologists, and trainees.

Key words: Lumbar neural foraminal stenosis, Classification, Lumbar spine MRI

Student number: 2011-21960

Contents

List of Tables

List of Figures

INTRODUCTION

Lumbar foraminal stenosis involves diminished space for the exiting nerve root induced by the age-related degenerative changes of disc space narrowing, osteophyte formation on facet joints, and hypertrophy of the ligamentum flavum (1, 2) It is a common cause of lower back pain and radiating pain to the lower extremities in elderly patients, and the incidence of lateral root entrapment has been reported as 8-11% (2-4). Among patients older than 65 years, surgery for degenerative lumbar spine is becoming increasingly common. Therefore, it is important to provide comprehensive indications for surgical treatment that account for a patient’s symptoms, level of disability, and the degree of lumbar foraminal stenosis indicated from an imaging study (5).

For imaging studies, magnetic resonance imaging (MRI) is the modality of choice to diagnose lumbar foraminal stenosis, although a gold standard grading system has not yet been established (6-8). Previously, Wildermuth et al. suggested that the grading system used for lumbar foraminal stenosis is only based on the level of perineural fat obliteration (6). In 2010, Lee et al. proposed a new MRI grading system for lumbar foraminal stenosis using the presence of morphologic changes in the nerve root as well as the degree of perineural fat obliteration (9). Recently, Park et al. found that between two subspecialized musculoskeletal (MSK) radiologists, the new grading system proposed by Lee et al. (the Lee system) showed better interobserver agreement than Wildermuth's classification (10).

For routine clinical application, it is essential for a grading system to have good interobserver agreement among not only specialized MSK radiologists but also surgeons and residents in training in order to improve communication and diagnosis. We hypothesized that the Lee system could improve teachability and interobserver agreement among surgeons and residents. Therefore, the aim of this study is to evaluate the reliability, teachability, and clinical applications of the Lee system for lumbar foraminal stenosis.

MATERIALS AND METHODS

Lee System for Lumbar Foraminal Stenosis

Using T1-weighted sagittal images, the Lee system consists of four grades as follows: Grade 0 refers to the absence of foraminal stenosis; grade 1 (mild stenosis) refers to perineural fat obliteration surrounding the nerve root in transverse or vertical directions with no morphologic changes in the nerve; grade 2 (moderate stenosis) refers to perineural fat obliteration surrounding the nerve root in four directions with no morphologic changes in the nerve root; and grade 3 (severe stenosis) refers to the collapse of or morphologic changes in the nerve root, whether perineural fat obliteration is present or not (9) (Fig. 1). The T2-weighted sagittal and axial images were provided as a supplement for the examiners when they were not confident and needed additional information to determine the grade of lumbar foraminal stenosis.

Case Selection

This retrospective study was approved by the institutional review board of our hospital, and the requirement for informed consent was waived for this analysis. All 100 patients were identified from our hospital's lumbar spine MRI database from September to November 2011. Among them, 88 patients had undergone lumbar spine MRI scans in our institution. We also included 12 patients who had lumbar spine MRI in outside hospitals to evaluate the performance of the Lee system using various MRI scanners.

The exclusion criteria were as follows: patients who were under 60 years old; patients who had malignancy including solid tumors and hematologic disorders, history of recent trauma, evidence of infections or remote osteoporotic compression fractures, previous lumbar spine surgery, and disc extrusions with superior migration.

Our study population consists of 27 (27%) men and 73 (73%) women. The mean age of the subjects was 68.7 years, ranging from 60 to 89 years.

Image Acquisition

In our institution, all patients underwent MRI scans with a 1.5-T scanner (Gyroscan, Philips Healthcare) using a Synergy Spine Coil (Philips Healthcare) on the spine position. The sagittal and axial images were obtained using T1-weighted spin echo (TR/TE, 500/15) and T2-weighted fast spin-echo (TR/TE, 3,600/120). The parameters of the MRI scanners were 4 mm slice thickness, 0.4 mm slice gap, 32 cm field of view (FOV) for the sagittal image, 16 cm FOV for the axial images, 512 × 512 matrix, 90° flip angle, and 3 excitations.

The MRI images from outside hospitals were performed using various MRI scanners with different parameters. T1-weighted sagittal images and supplementary T2-weighted axial images were used for the grading. All imported MRI images were randomly numbered 1-100 together with those from our institution.

Image Interpretation

MR imaging examinations were interpreted by a total of 10 observers in the different departments with various levels of experience as follows: two orthopedic surgeons who specialized in spine surgery with five years and eight years of experience, respectively; two neurosurgeons who specialized in spine surgery with four years of experience; one MSK specialized radiologist with eight years of experience; one radiology fellow with four months of training in the MSK subspecialty; two postgraduate year 3 (PGY-3) radiology residents; and two postgraduate year 2 (PGY-2) radiology residents. The PGY-3 and PGY-2 residents had both trained in MSK radiology for two months, but the time intervals between this study and their rotations in MSK differed (5-6 months for PGY-3 and 7-10 days for PGY-2).

A total of 600 lumbar foramina (six foramina per person) from bilateral L3-4, L4-5, and L5-S1 levels were evaluated. Lumbar foramina of L1-2 and L2-3 levels were not included due to the scarcity of foraminal stenosis within those levels. The MR images of each subject were offered in the form of a PowerPoint presentation slide. As a set of three sequential T1-weighted sagittal images for each side foramina consisted of one image that was centered at the middle of pedicle and the other two images bilaterally adjacent to the one. Displaying monitors were not uniform across the observers. For all observers, the Lee system was introduced using the schematic figures and figure legends of a previously published article (9). Independently, all 10 observers (four surgeons, two MSK radiologists, and four radiology residents) interpreted the sets of MRI images to assess the grade of lumbar foraminal stenosis using the Lee system; all were blind to each patient's history, symptoms, and age. To assess the intraobserver variability, we had a second session. Two observers (one radiology fellow in the MSK subspecialty and one PGY-2 resident) repeated the interpretation after an interval of six months in order to minimize memory bias.

To evaluate the feasibility of the Lee system as a preoperative tool, four surgeons were asked whether each foramen had been considered as a surgical case. They responded based on the given MR imaging only.

Statistical Analysis

Interobserver and intraobserver agreement of the Lee system was analyzed using the interclass correlation coefficient (ICC) (average measure) with a two-way random model for the 10 observers. ICC measured values ranging from 0 to 1, with 0 representing no agreement and 1 being perfect agreement. To interpret the ICC values, we used the following scale suggested by Shrout and Fleiss: ICC values of less than 0.40 refer to poor reliability, values of 0.40–0.75 indicate fair-to-good reliability, and values of greater than 0.75 indicate excellent reliability (11, 12).

Furthermore, the kappa statistics and the percentage of agreement were assessed. Each observer's response was compared with other observers, and the weighted kappa statistics were calculated for a total 45 comparisons and then averaged for the 10 observers (13). The kappa values were interpreted as follows: kappa values of 0-0.20 refer to slight agreement, values of 0.21-0.40 indicate fair agreement, values of 0.41-0.60 indicate moderate agreement, values of 0.61-0.80 indicate substantial agreement, and values of 0.81 or greater indicate excellent agreement.

We evaluated the tendency for the cases with higher grades on the Lee system to require more lumbar spine surgery. Using the Spearman correlation, we analyzed the correlation between operability and the Lee system grade. Interobserver agreement for the operability was also evaluated among surgeons using the kappa statistics and ICC. SPSS (version 16.0, SPSS) and MedCalc software (version 11.1.1.0, MedCalc Software) were used.

RESULTS

The distribution of the lumbar neural foraminal stenoses according to the consensus of observers is summarized on Table 1. Grade 0, the absence of neural foraminal stenosis, comprised approximately 65 % of the total data. Grade 1, mild stenosis, comprised about 20% and most frequently grade of stenosis. Grades 2 and 3 stenoses were noted with a similar frequency around 6-7%. Lumbar foraminal stenosis at the L4-5 level was observed in 39.7% (left) and 42.3% (right) of cases, just as frequently as at L5-S1 level (left: 45.4% and right: 43.4%), while stenosis at the L3-4 level was observed in 17.6% (right) and 20.1 %(left).

The distribution of stenosis grade assessed by each observer is summarized in Table 2. Among the 10 observers, the two most experienced clinicians (one orthopedic surgeon with eight years of experience and one MSK subspecialized radiologist with eight years of experience) had a tendency to classify lumbar foraminal stenosis as grade 1 less frequently than the other observers. All surgeons classified grade 3 more frequently than the radiologist.

Interobserver Agreement

The interobserver agreement is summarized on Table 3. The ICC (average measure) among the 10 observers was 0.938 (range: 0. 930 - 0.945, $p < 0.0001$), which indicated excellent reliability. The average percentage agreement was 65.8%, ranging from 57.6% to 78.6%. The overall kappa value was 0.55, indicating moderate agreement.

We calculated the interobserver agreement among eight observers, excluding the two PGY-3 radiology residents. They were assumed to be unfamiliar with spine MRIs because of the long time interval between this study and their rotations in MSK. Among these eight observers, the kappa value was slightly increased (0.61), indicating substantial agreement. On the other hand, ICC and the average percentage agreement were almost the same (0.937 and 65.8%, respectively).

In addition, two observers repeated the interpretation to assess intraobserver agreement in the second session. Otherwise, we evaluated the differences of these two observers between the first and second sessions. In the first session, the ICC value was 0.758 and the percentage agreement was 72.2% with a kappa value of 0.61. Interestingly, in the second session, each value of interobserver agreement increased slightly as follows: ICC value = 0.850, percentage agreement = 78.3%, and kappa value = 0.74.

Intraobserver Agreement

Intraobserver agreement of the two observers was excellent, as determined by the ICC values of 0.897 and 0.787. The ICC value of observer 1 (one radiology fellow in the MSK subspecialty) was higher than observer 2 (PGY-2 resident). For observer 1, the percentage agreement was 83% with a kappa value of 0.81, while the percentage agreement was 74% and the kappa value was 0.65 for observer 2. The level of intraobserver reliability thus showed substantial to excellent agreement.

Operability

Each surgeon was asked to determine which lumbar foramen was considered operable, and the results were shown in Table 4. Among the total of 600 lumbar foramina included in this study, the mean number of operable cases was 70.5 (11.75%, 70.5/600) ranging from 66 to 77. The number of surgical candidates increased as the grade of stenosis increased. Among the operable foramina, grade 3 stenosis was the most frequently observed (range: 61.3 – 100.0%), while grade 2 stenosis ranged from 10.2 – 39.7%. For two surgeons (one orthopedic surgeon and one neurosurgeon), four and five foramina, respectively, were considered operable in the group of grade 0 stenosis. For each surgeon, the Spearman correlation coefficients of the grading of lumbar foraminal stenosis and operability were 0.55, 0.717, 0.765, and 0.667 ($p < 0.0001$), indicating a significant correlation. Among four surgeons, interobserver agreement for the operability of lumbar foraminal stenosis was calculated using ICC, which was 0.839, ranging from 0.817 to 0.859, indicating excellent reliability.

TABLE

Table 1. Distribution of lumbar foraminal stenoses

Level	Grade 0		Grade 1		Grade 2		Grade 3		Total
	Right	Left	Right	Left	Right	Left	Right	Left	
L3-4	825 (41.3)	798 (39.9)	107 (5.4)	136 (6.8)	35 (1.8)	44 (2.2)	34 (1.7)	21 (1.2)	2000
L4-5	578 (14.5)	602 (30.1)	224 (11.2)	203 (10.2)	96 (4.8)	102 (5.1)	103 (5.2)	92 (4.6)	2000
L5-S1	567 (28.4)	545 (27.3)	250 (1.3)	285 (14.3)	100 (5.0)	88 (4.4)	84 (4.2)	81 (4.1)	2000
Total	1970 (32.8)	1941 (32.4)	581 (9.7)	624 (3.9)	231 (3.9)	234 (3.9)	221 (6.7)	194 (3.2)	6000

Note – Data are numbers (%) of foramina.

Table 2. Number of each grade assessed by 10 observers

	Surgeons				Radiologists					
	OS 1	OS 2	NS 1	NS 2	MSK S	MSK F	PGY 3A	PGY 3B	PGY 2A	PGY 2B
Grade 0	403	323	273	323	528	423	474	466	336	351
Grade 1	68	137	198	137	40	97	101	104	161	156
Grade 2	85	78	85	78	8	41	23	17	73	62
Grade 3	44	62	44	62	24	39	2	13	30	31
Total	600	600	600	600	600	600	600	600	600	600

Note – Data are numbers of foramina.

OS = orthopedic surgeon, NS = neurosurgeon, MSK = musculoskeletal,

F = fellow, S = specialist, PGY = post-graduate year

Table 3. Interobserver agreement

Method	L3-4		L4-5		L5-S1		Overall
	Right	Left	Right	Left	Right	Left	
ICC	0.911	0.878	0.949	0.944	0.933	0.935	0.938
Agreement (%)	78.6	73.0	61.9	60.9	57.6	59.8	65.3
Weighted κ	0.48	0.38	0.57	0.55	0.52	0.53	0.55

Table 4. Number of grades and operable lumbar neural foramina assessed by each surgeon

	OS 1		OS 2		NS 1		NS 2	
	Foramen	Operable case[a]	Foramen	Operable case	Foramen	Operable case	Foramen	Operable case
Grade 0	403	4 (0.9)	323	0 (0)	273	0 (0)	323	5 (1.5)
Grade 1	68	7 (10.3)	137	0 (0)	198	5 (2.5)	137	4 (2.9)
Grade 2	85	23 (27.1)	78	8 (10.2)	85	37 (43.5)	78	31 (39.7)
Grade 3	44	38 (86.4)	62	58 (93.5)	44	44 (100)	62	38(61.3)
Total	600	73	600	66	600	86	600	77
rho[b]	0.55		0.717		0.765		0.667	

Note – Data are numbers (%) of foramina.

[a] Foramina have been considered operable cases.

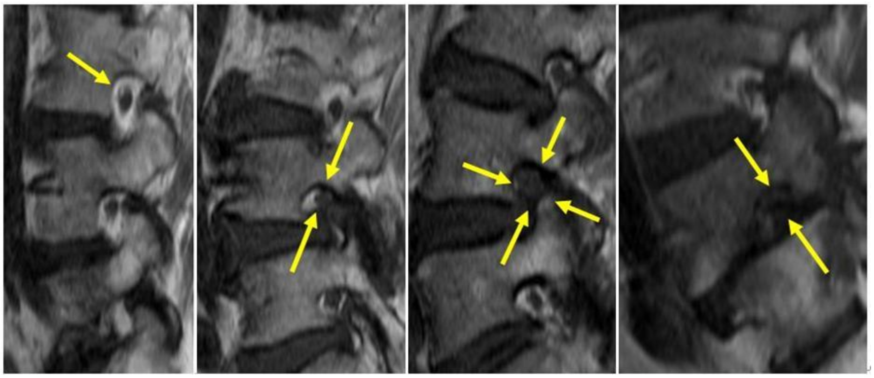
[b] Correlation is significant at the 0.01 level using Spearman's correlation.

OS = orthopedic surgeon, NS = neurosurgeon

FIGURE

Figure 1. Representative cases of the Lee system for lumbar foraminal stenosis

A B C D



A. Grade 0 (no stenosis): T1-weighted sagittal MRI image of a 61-year-old woman with lower back pain shows a normal nerve root surrounded by perineural fat with no morphologic changes (arrow).

B. Grade 1 (mild stenosis): T1-weighted sagittal MRI image of a 66-year-old woman with lower back pain shows perineural fat obliteration in a vertical direction (arrow) at the level of L4-L5, caused by hypertrophied ligamentum flavum and narrowing of the transverse width of the neural foramen. The morphology of the nerve root is intact with no compression.

C. Grade 2 (moderate stenosis): T1-weighted sagittal MRI image of a 62-year-old woman with lower back pain shows perineural fat obliteration in four directions (arrow) at the level of L4-L5. A bulging disc is also observed. The morphology of the nerve root is intact.

D. Grade 3 (severe stenosis): T1-weighted sagittal MRI image of a 71-year-old woman with paresthesia in the right leg shows compression of the right L5 nerve root in the neural foramen at the L4-5 level. This grade 3 stenosis is caused by disc space narrowing and spondylolytic spondylolisthesis at the L4-L5 level.

DISCUSSION

According to our results, among the 10 observers, including four surgeons, two radiology residents, and two MSK specialized radiologists, the interobserver agreement using the Lee system for lumbar foraminal stenosis was excellent using ICC (ICC = 0.938) while moderate agreement was found using the kappa statistics (κ of the Lee system = 0.545). Previously, Park et al. reported substantially correlation between two MSK specialized radiologists (12 and 10 years of experience) using the Lee system (κ of the Lee system = 0.767). That is, the interobserver agreement between MSK specialized radiologists was higher than in our study. In our study, we included more observers with different levels of experience and from various departments. In clinical practice, it is important for MSK specialized radiologists as well as surgeons and trainees to be able to identify the degree of lumbar neural foraminal stenosis in patients to improve communication and interdisciplinary understanding. From this point of view, the Lee system is a reliable method of reporting the grade of lumbar foraminal stenosis for surgeons, radiologists, and trainees.

Furthermore, in our study, the Lee system was introduced only in terms of schematic figures and figure legends from a previous published article. Considering this fact, the average percentage agreement was 65.8%, which is a high level of agreement among surgeons, radiologists, and even trainees. Even though the PGY-3 radiology residents in our study who were not familiar with how to interpret lumbar spine MRIs (due to the length of time (five and six months) between their rotations in MSK and this study), the results including these two residents were sufficient enough to prove that the Lee system is teachable. Moreover, these findings imply that the Lee system is simple enough to be learned easily and applied in clinical practice.

Among surgeons, the interobserver agreement of operability was reliable and the grade of lumbar foraminal stenosis had a significant positive correlation with operability. Interestingly, the average proportion of surgical candidates with grade 3 stenosis was 85.3% (ranging from 61.3 % to 100%) while the average with grade 2 stenosis was 30.13% (ranging from 10.2% to 43.5%). That is, surgeons considered cases with grade 3 stenosis to be surgical candidates more than twice as frequently as those with grade 2 stenosis. Morphologic changes or compression of the nerve root distinguish grade 3 stenosis from grade 2 stenosis in the Lee system, and also differentiate the Lee system from Wildermuth's classification system. In our study, to determine surgical candidates for lumbar neural foraminal stenosis, surgeons were influenced by morphologic changes and nerve root compression, a factor considered in the Lee system. This finding implied that the Lee system can provide clinically important information for surgeons to determine operability in patients with lumbar neural foraminal stenosis.

Recognizing and determining appropriate treatment for lumbar neural foraminal stenosis are important for controlling radicular symptoms (7, 14) because lumbar neural foraminal stenosis is considered an important etiology of lumbar radicular symptomatology. In 1995, Hasegawa et al. published a study noting that decreased foraminal height and posterior disc height attributed nerve root compression significantly in a cadaveric study (1). They suggested that a foraminal height of 15 mm or less and a posterior disc height of 4 mm or less might be an indicator of lumbar neural foraminal stenosis. The exiting nerve root compression may caused by anteroposterior stenosis, which is a result of a combination of disc space narrowing and hypertrophy of structures anterior to the facet joint capsule. In addition to anteroposterior stenosis, craniocaudal stenosis is an additional etiology for lumbar foraminal stenosis. Posterolateral osteophytes from the vertebral body towards to lumbar foramen may lead to craniocaudal stenosis, which is then aggravated by a bulging annulus fibrosis or a herniated disc (7). Thus, these two types of static changes in the lumbar foramen have been important to observe in imaging studies. In 1998, Wildermuth et al. introduced a semi-quantitative classification of lumbar foraminal stenosis focusing on the degree of epidural fat obliteration only (6). In 2006, Attias et al. reported that poor interobserver agreement was observed using Wildermuth’s classification system, and there were significant differences between foraminal measurements carried out with MRIs and on the cadavers (15). In 2010, Lee et al. introduced a new classification system using perineural fat obliteration and nerve root morphology. This classification was evaluated by Park et al. in 2012 (10) as being a more practical and reliable method than Wildermuth's classification system. Furthermore, our study supported that Lee system for grading lumbar foraminal stenosis is reliable as well as teachable.

There were several limitations to our study. First, we classified the grade and operable cases based only on MRI imaging without correlating the findings with symptoms. Because this study was retrospective, the correlation between the grade of stenosis and patient symptoms was not enough to evaluate. Nevertheless, the purpose of this study was to evaluate the reliability of the Lee system among a variety of observers with different training levels and from different departments. The correlation stenosis grade with patient symptoms might be helpful to effectively apply the Lee system in clinical practice. Further studies on the Lee system are needed to assess the correlation of MRI imaging and patients symptoms based on patient pain scales such as the visual analogue scale (VAS). Second, dynamic changes caused by patients' posture were not evaluated in this study. Lumbar radicular pain is associated with dynamic foraminal stenosis during extension, which has been found to decrease all the foraminal dimensions significantly and reduce the cross-sectional area more than 15% compared to the neutral position (16). In our study, all patients underwent an MRI in a neutral supine position without extension. In spite of that, difference between positional changes may be insignificant because all patients were in the same position. However, further investigation is needed to evaluate the correlation of the MRI with dynamic posture.

In conclusion, we suggest that the Lee system for lumbar foraminal stenosis is a reliable method of assessing the grade of lumbar neural foraminal stenosis and simple enough for surgeons, radiologists, and trainees to learn and apply in clinical practice. In addition, it provides important information for surgeons to determine which patients with lumbar foraminal stenosis are surgical candidates.

REFERENCES

1. Hasegawa T, An HS, Haughton VM, Nowicki BH. Lumbar foraminal stenosis: critical heights of the intervertebral discs and foramina. A cryomicrotome study in cadavera. The Journal of Bone and Joint Surgery American volume. 1995;77(1):32.
2. Katz JN, Harris MB. Lumbar spinal stenosis. New England Journal of Medicine. 2008;358(8):818-25.
3. Jenis L, An H, Gordin R. Foraminal stenosis of the lumbar spine: a review of 65 surgical cases. American Journal of Orthopedics (Belle Mead, NJ). 2001;30(3):205.
4. Yamada K, Matsuda H, Nabeta M, Habunaga H, Suzuki A, Nakamura H. Clinical outcomes of microscopic decompression for degenerative lumbar foraminal stenosis: a comparison between patients with and without degenerative lumbar scoliosis. European Spine Journal. 2011;20(6):947-53.
5. Deyo RA. Treatment of lumbar spinal stenosis: a balancing act. The Spine Journal. 2010;10(7):625-7.
6. Wildermuth S, Zanetti M, Duewell S, et al. Lumbar spine: quantitative and qualitative assessment of positional (upright flexion and extension) MR imaging and myelography. Radiology. 1998;207(2):391-8.
7. Jenis LG, An HS. Spine update: lumbar foraminal stenosis. Spine. 2000;25(3):389-94.
8. Borenstein DG, O'Mara JW, Boden SD, et al. The value of magnetic resonance imaging of the lumbar spine to predict low-back pain in asymptomatic subjects A seven-year follow-up study. The Journal of Bone & Joint Surgery. 2001;83(9):1306-11.
9. Lee S, Lee JW, Yeom JS, et al. A practical MRI grading system for lumbar foraminal stenosis. American Journal of Roentgenology. 2010;194(4):1095-8.
10. Park H-J, Kim SS, Lee S-Y, et al. Clinical correlation of a new MR i maging method for assessing lumbar foraminal stenosis. American Journal of Neuroradiology. 2012.
11. Menz HB, Latt MD, Tiedemann A, Mun San Kwan M, Lord SR.

Reliability of the GAITRite< sup>®</sup> walkway system for the quantification of temporo-spatial parameters of gait in young and older people. Gait & Posture. 2004;20(1):20-5.
12. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychological Bulletin. 1979;86(2):420.
13. Kundel HL, Polansky M. Measurement of observer agreement. Radiology. 2003;228(2):303-8.
14. Burton CV, Kirkaldy-Willis W, Yong-Hing K, Heithoff KB. Causes of failure of surgery on the lumbar spine. Clinical Orthopaedics and Related Research. 1981(157):191.
15. Attias N, Hayman A, Hipp JA, Noble P, Esses SI. Assessment of magnetic resonance imaging in the diagnosis of lumbar spine foraminal stenosis—a surgeon's perspective. Journal of Spinal Disorders & Techniques. 2006;19(4):249-56.
16. Inufusa A, An HS, Lim TH, Hasegawa T, Haughton VM, Nowicki BH. Anatomic changes of the spinal canal and intervertebral foramen associated with flexion-extension movement. Spine. 1996;21(21):2412-20.

국문초록

연구목표: 2010. 4월 American Journal of Roentgenology에 발표되었던 요추 신경공 협착증의 새로운 등급체계의 학습 효과 및 수술 고려 측면에서의 임상적인 효용성을 평가해 본다.

연구재료 및 방법: 영상의학과 전문의 2명, 영상의학과 전공의 4명 (2년차 2명, 3년 차 2명) 과 외과계 전문의 4명 (정형외과 2명, 신경외과 2명) 이 요추 자기공명영상의 시행한 100명의 환자의 영상에서 좌, 우 요추 신경공을 기준으로 3장씩 시상면 영상을 기준으로 요추 신경공 협착증의 새로운 등급체계 (Lee system) 에 따라 0-3 등급을 매긴다. 추가로 외과계 전문의 4명은 수술 고려 대상이 되는 요추 신경공 협착증을 선별한다. 총 10명의 실험자에 대한 Lee system 의 재현성에 대한 평가는 interclass correlation coefficient, kappa 분석, 일치도 백분율을 이용하였으며 협착 정도와 수술 대상의 상관관계는 스피어만 상관계수로 분석하였다.

결과: 10명의 실험자에서 Lee system 의 interobserver agreement 는 우수한 일치도를 보였으며 (ICC value: 0.938, kappa value: 0.545, 일치도 백분율: 65.8%) 두 실험자에서 시행한 intraobserver agreement 평

가에 있어서 우수한 일치도를 보였다(kappa value: 0.897, 0.787). Lee system 으로 평가한 요추 신경공 협착 정도는 수술 대상이 되는 환자군과 높은 상관관계를 보였다 (r= 0.55, 0.717,0.765, 0.667)

결론: 요추 신경공 협착증에 있어서 새로운 등급 체계인 Lee system 은 적용이 용이하며 재현성이 우수한 방법으로 앞으로 자기공명영상에서 요추 신경공 협착증 평가에 도움이 될 수 있을 것으로 보인다.

주요어 : 요추 신경공 협착증, 등급 체계, 요추 자기공명영상

학 번 : 2011-21960