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Original Investigation

The Role of Triangular Vertebral Canal Shape in Surgical Management of Patients with Lumbar Spinal Stenosis: A Cross-Sectional Study

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ABSTRACT

AIM: We assessed the role of triangular vertebral canal shape (VCS) in pain severity, pain-related findings, and postoperative satisfaction in patients with lumbar spinal stenosis (LSS) who had undergone decompressive surgery.

MATERIAL and METHODS: This cross-sectional study conducted at a single center included 61 consecutive patients who had undergone surgical treatment for LSS. By comparing pre- and postoperative data, the role of triangular VCS in pain severity [assessed using a visual analog scale (VAS)], pain-related findings, and postoperative satisfaction of patients was examined. VCS was determined to be triangular, oval, or circular based on magnetic resonance imaging (MRI) and magnetic resonance myelography (MRM) findings.

RESULTS: Preoperative VAS scores of patients with triangular VCS were significantly higher than those of patients with oval and circular VCSs ($p<0.05$). No significant difference was found in postoperative VAS scores among patients with triangular, oval, and circular VCSs. In all subgroups, postoperative VAS scores were significantly lower than preoperative scores ($p<0.05$). This postoperative decrease in VAS scores was significantly higher among patients with triangular VCS than in those with oval or circular VCS ($p<0.05$).

CONCLUSION: Combined use of MRI and MRM can be recommended for symptomatic patients when planning surgery. Although pain severity decreased postoperatively in all patients, this decrease was more pronounced in patients with triangular VCS than in those with oval or circular VCS. During preoperative counseling of patients with LSS, the presence of triangular VCS should be considered. This may improve surgical outcome and patient satisfaction.

KEYWORDS: Decompressive surgery, Lumbar spinal stenosis, Magnetic resonance imaging, Magnetic resonance myelography, Triangular vertebral canal shape

ABBREVIATIONS: CT: Computed tomography, **LSS:** Lumbar spinal stenosis, **MRI:** Magnetic resonance imaging, **MRM:** Magnetic resonance myelography, **VAS:** Visual analog scale, **VCS:** Vertebral canal shape

INTRODUCTION

Lumbar spinal stenosis (LSS) is caused by narrowing of the spinal canal due to bone and/or soft tissues. This leads to mechanical compression of nerve root canals or the intervertebral foramen tunnels, with subsequent symptoms of radiculopathy or claudication, or other neurological symptoms. Because of one or more of these anatomical states, LSS can develop in the five lumbar vertebral bodies

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(19,27). Lumbar stenosis, whether congenital or acquired, is a common condition. It may develop in isolation, with or without an associated disc bulge or herniation, or it may be related to degenerative spondylolisthesis or scoliosis. Symptomatic LSS is characterized by neurogenic claudication and/or lumbar or sacral radiculopathy (1,4,30). Many factors are associated with LSS development, which can be congenital and/or acquired. An important factor that affects the severity of the clinical presentation of LSS is the spinal canal shape. A circular or oval canal shape provides the most central and lateral recess space for the neural elements. The smallest cross-sectional area is observed in the trefoil-shaped canal, which is present in 15% of individuals and predisposes them to lateral recess stenosis (14,22).

As the term "stenosis" implies, radiological criteria are essential for a correct diagnosis of LSS. The ideal imaging modality that perfectly reflects the clinical presentation and predicts the future course of the pathophysiology of LSS is difficult to develop. Therefore, it is essential for physicians to understand the limitations, scope, and potential of neuroimaging in the context of spinal stenosis. The North American Spine Society (NASS) guidelines have stated that imaging is the key non-invasive test for diagnosing LSS, but no radiological criteria for stenosis are provided (7,20,21). The spinal canal area appears narrower on computed tomography (CT) than on axial magnetic resonance imaging (MRI), which could be related to the superior ability of multidetector CT to differentiate cortical bone from soft tissue, such as the ligamentum flavum (9). MRI plays a key role in the diagnosis of spinal stenosis (28). However, compared with conventional MRI, magnetic resonance myelography (MRM) provides more specific information for a preoperative diagnosis of symptomatic foraminal stenosis (2). Furthermore, MRI is recommended in patients with LSS, and radiological findings are used in particular for preoperative planning (6).

The most common reason for lumbar spine surgery in older patients is LSS. However, with surgical treatment, satisfactory symptomatic improvement is observed in 60%, 85% of appropriately selected patients. Surgical options include decompressive laminotomy, flavectomy, and foraminotomy (4,5,10,23).

The association between abnormal MRI findings and pain severity in patients with LSS has not yet been completely understood (6). During preoperative counseling of such patients, neurosurgeons should provide more detailed information about the postoperative course, outcome, and follow-up to increase patient satisfaction. From the experience at our neurosurgery center, we believe that sufficient importance is not given to the preoperative assessment of vertebral canal shape (VCS) as an important factor that determines the surgical features of LSS. This study aimed to assess the role of triangular VCS in pain severity, and pain-related findings, and postoperative satisfaction of patients with LSS who had undergone decompressive surgery for the management of LSS.

MATERIAL and METHODS

Study Population

This cross-sectional study was conducted at a single center and included 61 consecutive patients who had undergone lumbar laminectomy, flavectomy, or foraminotomy alone or in combination for the management of LSS. The study was approved by the Human Research Ethics Committee of our university. All participants provided written informed consent before participation in the study.

The inclusion criteria for all patients were a preoperative diagnosis made based on MRI and MRM findings, complaints of pain and pain-related symptoms ongoing for >12 months, a radiological diagnosis of LSS with pain and/or numbness in the lumbar dermatomal distribution, motor or sensory neurological signs (hypoesthesia, hyperesthesia, allodynia, or dysesthesia) in the affected dermatomes, sufficient cognitive ability to participate in the study, and neurogenic intermittent claudication. The exclusion criteria for all were rheumatoid arthritis, known peripheral neuropathy, spondylolisthesis, a history of surgery for LSS, chronic depression, or the use of antidepressant medication.

Radiological Evaluation

MRI and MRM examinations were conducted using three 1.5-T scanners (Magnetom Aera; Siemens, Erlangen, Germany), and sagittal and axial T2-weighted images from the L1 to S1 levels were obtained (Figure 1A-C).

The height and depth of the lateral recess were used to define lateral stenosis. The depth of the lateral recess was measured between the superior articular facet and the top part of the pedicle. Recess height was specified as the distance between the most anterior point of the superior articular facet and the posterior border of the vertebral body. A lateral recess height of ≤2 mm and/or a lateral recess depth of ≤3 mm were considered as diagnostic for lateral recess stenosis. The anteroposterior diameter of the osseous spinal canal was defined as a distance of <10 mm (29). A diameter of ≤3 mm was considered as diagnostic for stenosis (3) (Figure 2).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 23.0 for Windows (SPSS, Inc., Chicago, IL, USA). Data were presented using descriptive methods. Visual analog scale (VAS) scores of the study subgroups with triangular, oval, and circular VCSs were analyzed using the *t*-test and ANOVA with *post hoc* Tukey test. A p value of <0.05 was considered to indicate statistically significant difference.

RESULTS

Age, sex, vertebral level from L1 to L5, anteroposterior and transverse diameters, the presence of facet hypertrophy, and left and right lateral recess measurements of the patients categorized according to VCS are presented in Table I. No significant difference in terms of age was observed among the study subgroups (p>0.05). Due to the low number of patients in the circular shape subgroup, the ratios of sex were not

compared, but overall, the number of female patients was higher in all subgroups except the oval subgroup. The ratios of vertebral levels were not compared due to low number of patients in the subgroups, but overall, there were more patients with L4 and L5 vertebral canal stenosis in all subgroups. No significant difference was observed anteroposterior and transverse diameters among the subgroups (p>0.05). The ratios of facet hypertrophy were not compared due to low number of patients in the subgroups, but overall, the presence of facet hypertrophy was higher in the triangular VCS subgroup than in the other subgroups. The values of lateral recess measurements in the subgroups were similar (p>0.05). Lateral recess stenosis was more pronounced in the triangular and circular VCS subgroups than in the oval VCS subgroup, but the difference was not statistically significant.

Figure 3 shows the VAS-related data of patients categorized according to VCSs. Preoperative VAS scores of patients with

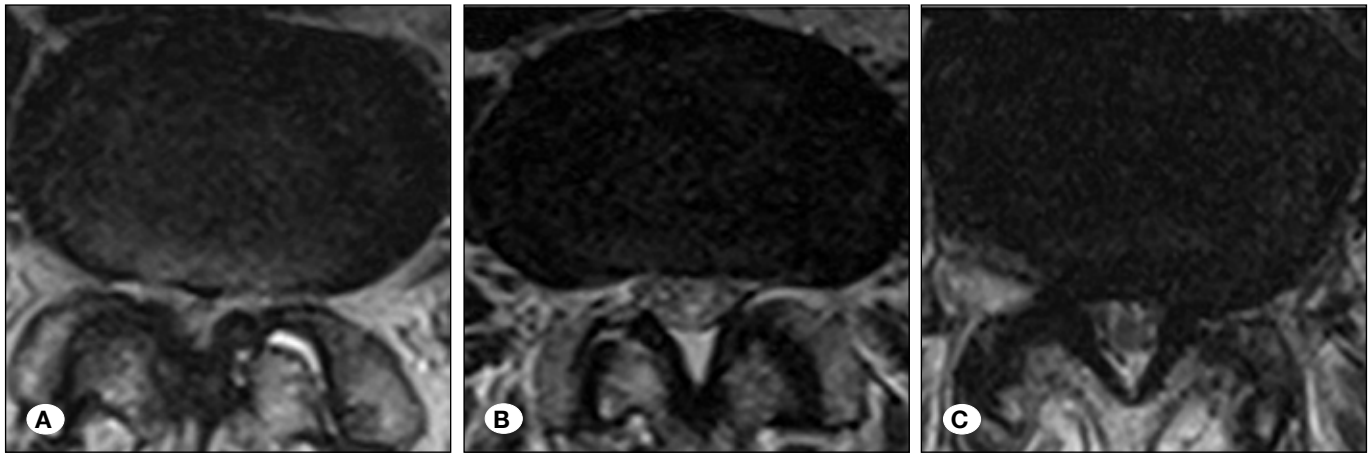

Figure 1A-C: Representative magnetic resonance images demonstrating oval, circular, and triangular vertebral canal shapes.

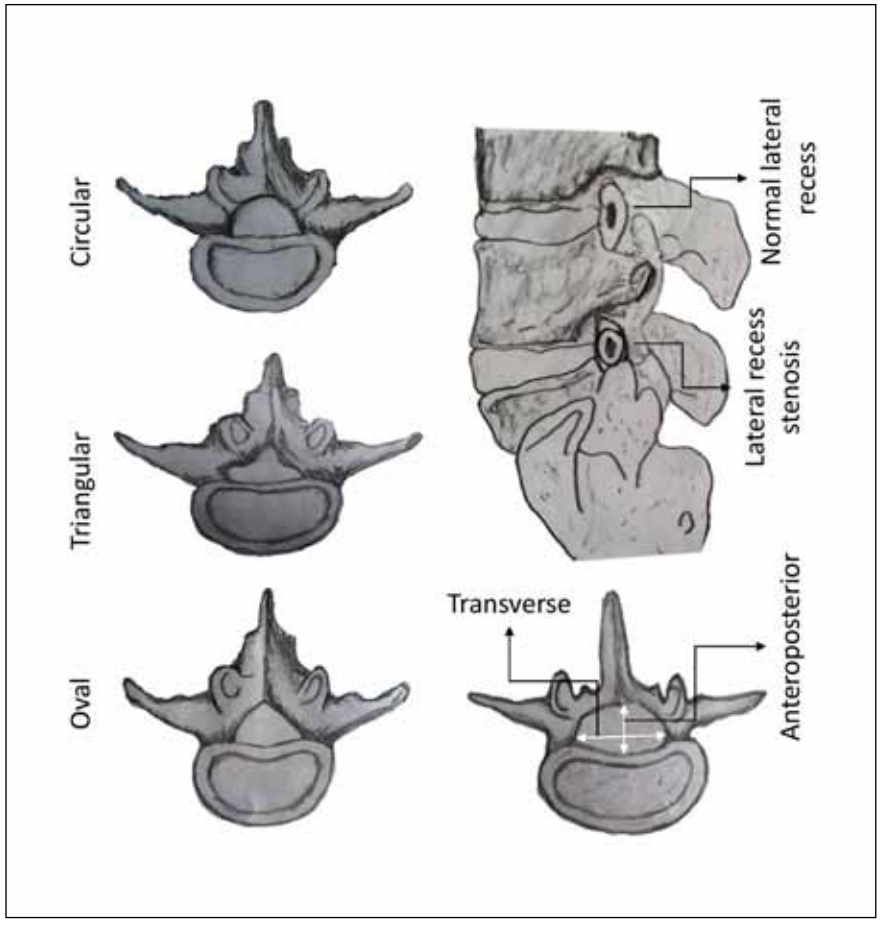

Figure 2: Drawings showing three vertebral canal shapes as well as normal and stenotic recesses and vertebral canals used for transverse and anteroposterior measurements.

Table I: Selected Clinical Data of Study Population

	Triangular (n=44)	Oval (n=11)	Circular (n=6)
Age (years)	58.8±12.7	58.5±15.8	61.5±14.5
Gender			
Female	30 (68.2%)	5 (45.5%)	4 (66.7%)
Male	14 (31.8%)	6 (54.5%)	2 (33.3%)
Vertebral level of stenosis			
L1	0 (0%)	0 (0%)	0 (0%)
L2	2 (4.5%)	1 (9.1%)	0 (0%)
L3	4 (9.1%)	0 (0%)	3 (50%)
L4	20 (45.5%)	5 (45.5%)	1 (16.7%)
L5	18 (40.9%)	5 (45.5%)	2 (33.3%)
Anteroposterior diameter (mm)	9.2±2.1	8.3±2.1	9.3±2.7
Transverse diameter (mm)	16.4±4	17.3±4.3	14.1±5.3
Facet hypertrophy			
Yes	30 (68.2%)	5 (45.5%)	3 (50%)
No	14 (31.8%)	6 (54.5%)	3 (50%)
Lateral recess measurement (mm)			
Right	2.14±1.07	2.68±1.45	2.00±0.84
Left	2.10±1.01	2.53±1.74	1.41±082
Postoperative decrease >50% in pain-related symptoms	34 (77%)	12 (70%)	
Patient satisfaction	36 (81.8%)	13 (76.4%)	

Data were presented as mean±SD and number (%). Overall, after statistical tests, there was no significant difference among the study subgroups according to the numerical data presented.

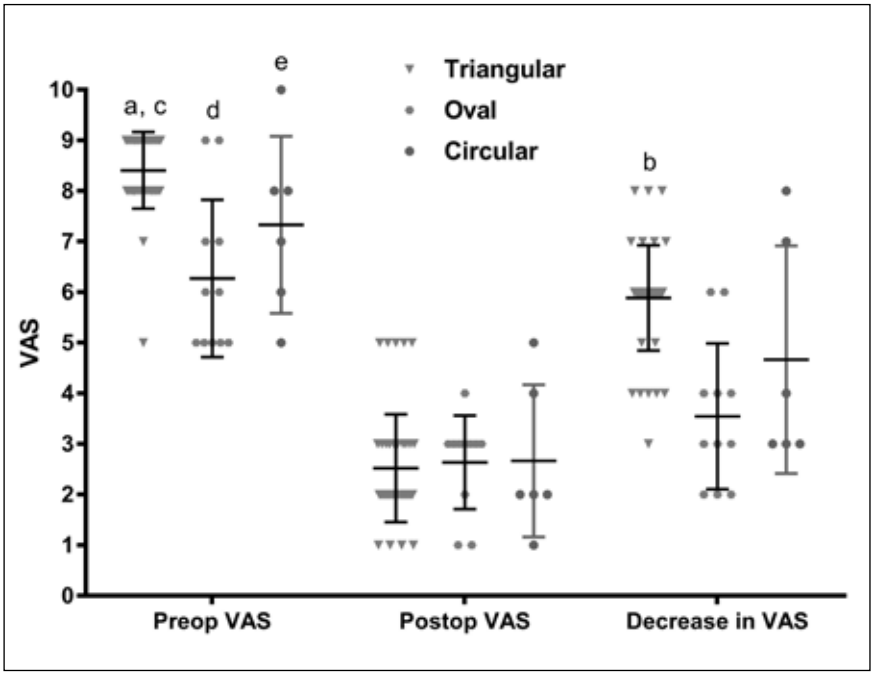

Figure 3: Visual analog scale (VAS) scores as pre- and postoperative measurements and the changes in study patients categorized according to the vertebral canal shape (VCS). Data were presented as a whisker plot with mean ± SD and raw values of the study patients. Data were analyzed using ANOVA with the Tukey test. [a]$p < 0.05$, indicating that postoperative VAS scores are significantly higher than preoperative scores for oval and circular VCSs. No significant difference was observed in preoperative VAS scores between oval and circular VCSs. No significant difference was observed in postoperative VAS scores among triangular, oval, and circular VCSs. [c,d,e]$p< 0.05$, indicating that preoperative VAS scores are significantly higher than postoperative scores for triangular, oval, and circular VCSs. [b]$p< 0.05$, indicating that the decrease in VAS scores is significantly higher than that for oval and circular VCSs. No significant difference was observed in the decrease in VAS scores for oval and circular VCSs.

triangular VCS were significantly higher than those of patients with oval and circular VCSs ($p<0.05$). Preoperative VAS scores of patients with oval and circular VCSs were similar ($p>0.05$). Postoperative VAS scores of patients with triangular, oval, and circular VCSs were similar ($p>0.05$) and were significantly lower than their respective preoperative scores ($p<0.05$). Comparison of the decrease from pre- to postoperative VAS scores among the subgroups revealed that the decrease in patients with triangular VCS was significantly greater than that in patients with oval and circular VCSs ($p<0.05$), whereas the decrease in patients with oval and circular VCSs was similar ($p>0.05$).

DISCUSSION

We evaluated the importance of VCS in the operative management of LSS. After statistical comparisons, no overall significant difference was noted in clinical parameters, including age and lateral recess measurements. Although not analyzed statistically, the ratios of female patients and facet hypertrophy in patients with triangular VCS and the ratios of L4 and L5 vertebral canal stenosis were high in all subgroups. The main findings of this study were the pre- and postoperative VAS scores of the study patients. Preoperative pain severity was greater in patients with triangular VCS than in those with oval and circular VCSs. However, no difference was observed in postoperative pain severity among the three VCS subgroups, and a statistically significant decrease was observed in pain severity postoperatively in all three VCS subgroups. The decrease in pain severity postoperatively was more significant in patients with triangular VCS than in those with oval and circular VCSs. The decreases in pain severity were similar in the oval and circular VCS subgroups.

There are no clear statistics on the prevalence of neuropathic pain in the general population, and it is known to be associated with many congenital or acquired disorders, including LSS. Inherited or primary spinal stenosis caused by congenital LSS, scoliosis, or achondroplasia is uncommon and is generally observed in the third decade of life. Acquired or secondary spinal stenosis is generally a consequence of degenerative changes and post-traumatic, iatrogenic, or metabolic factors that involve bone and/or ligament hypertrophy and usually develops later, after 50 years of age (18). When the total area of the spinal canal, lateral recesses, or neural foramina is decreased, the neural structures passing through that space are compromised (4). Lumbar canal stenosis, the most common form of spinal stenosis, causes neurogenic intermittent claudication and radiculopathy, and these symptoms dominate the clinical presentation. Symptoms of radiculopathy, back pain, and muscular fatigue tend to be predominant in the standing position or during walking, indicating a relationship to spinal posture (8,29). Surgery to improve the quality of life is usually performed only after conservative treatment fails (12). The symptoms associated with LSS, including walking tolerance, are ameliorated by surgical nerve root and dural tube decompression (14,32).

In a 2011 review, the NASS guidelines for the diagnosis and treatment of degenerative lumbar stenosis were revised (21). The definition of LSS by the NASS includes clinical (neurogenic claudication) and radiological (morphological abnormalities) criteria: Degenerative lumbar spinal stenosis describes a condition in which there is diminished space available for the neural and vascular elements in the lumbar spine secondary to degenerative changes in the spinal canal. When symptomatic, this causes a variable clinical syndrome of gluteal and/or lower extremity pain and/or fatigue, which may occur with or without back pain. Symptomatic lumbar spinal stenosis has certain characteristic provocative and palliative features. Provocative features include upright exercise-, such as walking, or positionally induced neurogenic claudication. Palliative features commonly include symptomatic relief with forward flexion, sitting, and/or recumbency.

For bony anatomy, although CT may be preferable to MRI, the modality of choice for diagnosis is still MRI as clear definition is provided of bony anatomy, soft tissues, and neural structures, such as the conus medullaris and spinal nerve roots within the canal and neural foramina, and there is a very low risk of complications. Cross-sectional imaging is generally acquired in a neutral supine position that under-recognizes the dynamic and load-bearing functions of the spinal column (7,9,26,31). A recent review by Steurer et al. (29), who evaluated the radiological criteria used as inclusion criteria in clinical studies on different treatments in patients with LSS, noted that no consensus has been reached by experts on well-defined, unambiguous radiological and clinical criteria to define LSS.

There remains ongoing debate in the current literature concerning the correlation between abnormal MRI findings and pain severity (11,13,16,17). It has been shown that symptoms often poorly correlate with radiological findings (13). An accurate correlation between clinical symptoms of lumbar spinal canal narrowing and radiological findings may not be present. Some patients may have only minor symptoms, although significant spinal narrowing may be observed radiologically, whereas others may experience more severe symptoms even with moderate canal narrowing. The VAS score has been shown to be effective in the assessment of the severity of the manifestations in LSS in addition to measuring the postoperative improvement after neural decompression (24,25). Ishimoto et al.(15) reported that in the MRI evaluation, a considerable number of asymptomatic patients exhibited a moderate or even severe narrowing of the spinal canal, defined as a loss of more than one-third or two-third area, respectively. Therefore, a static image of the lumbar canal in the supine position may not represent the dimensions of the spinal canal during standing or walking (6). The spinal canal is a dynamic structure, and its diameter varies with changing posture and bodily activities (16). As stated in a recent review by Burgstaller et al.(6), innovative approaches to learn more about the causal relationship between radiological and pain-related findings are warranted.

CONCLUSION

For spine surgeons, planning the type of surgery to be performed in a patient, it is crucial to understand the causal associations between clinical symptoms and radiological

findings. In the light of recent literature and our own experience, the combined use of MRI and MRM can be recommended for symptomatic patients before surgical planning. Triangular VCS is more pronounced in the lower vertebrae, and this may be related to the frequency of LSS in females. The frequency of facet hypertrophy and more pronounced lateral recess stenosis with triangular VCS may also be a factor responsible for increased pain severity in such cases. In the current study, pain severity decreased in all patients, but the decrease was more pronounced in patients with triangular VCS. In neurosurgical practice, during preoperative counseling of patients with LSS, the presence of triangular VCS needs to be considered. This may improve patient satisfaction and postoperative outcomes.

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■ REFERENCES

1. Alvarez JA, Hardy RH Jr: Lumbar spine stenosis: A common cause of back and leg pain. Am Fam Physician 57:1825-1834,1998
2. Aota Y, Niwa T, Yoshikawa K, Fujiwara A, Asada T, Saito T: Magnetic resonance imaging and magnetic resonance myelography in the presurgical diagnosis of lumbar foraminal stenosis. Spine (Phila Pa 1976) 32:896-903, 2007
3. Beers GJ, Carter AP, Leiter BE, Tilak SP, Shah RR: Interobserver discrepancies in distance measurements from lumbar spine CT scans. AJR Am J Roentgenol 144:395-398, 1985
4. Binder DK, Schmidt MH, Weinstein PR: Lumbar spinal stenosis. Semin Neurol 22:157-166, 2002
5. Brian W, Su BW, Rihn J, Byers R, Albert TJ: Surgical management of lumbar spinal stenosis. In: Herkowitz HN, Garfin SR, Frank J. Eismont FJ, Bell GR, Balderston RA (eds), Rothman-Simeone The Spine. 6th ed. Philadelphia, Pa: Elsevier Saunders, 2011:1064-1077
6. Burgstaller JM, Schüffler PJ, Buhmann JM, Andreisek G, Winklhofer S, Del Grande F, Mattle M, Brunner F, Karakoumis G, Steurer J, Held U; LSOS Study Group: Is there an association between pain and magnetic resonance imaging parameters in patients with lumbar spinal stenosis? Spine (Phila Pa 1976) 41: E1053-1062, 2016
7. Cowley P: Neuroimaging of spinal canal stenosis. Magn Reson Imaging Clin N Am 24:523-539, 2016
8. Deasy J: Acquired lumbar spinal stenosis. JAAPA 28:19-23, 2015
9. Eun SS, Lee HY, Lee SH, Kim KH, Liu WC: MRI versus CT for the diagnosis of lumbar spinal stenosis. J Neuroradiol 39: 104-109, 2012
10. Fujiwara Y, Manabe H, Sumida T, Izumi B, Nakanishi K, Tanaka N, Adachi N: Facet preserving technique by en bloc flavectomy in microscopic posterior decompression surgery for lumbar spinal stenosis: Semicircumferential decompression (SCD). Clin Spine Surg 30:197-203, 2017
11. Geisser ME, Haig AJ, Tong HC, Yamakawa KS, Quint DJ, Hoff JT, Miner JA, Phalke VV: Spinal canal size and clinical symptoms among persons diagnosed with lumbar spinal stenosis. Clin J Pain 23:780-785, 2007
12. Gunzburg R, Keller TS, Szpalski M, Vandeputte K, Spratt KF: Clinical and psychofunctional measures of conservative decompression surgery for lumbar spinal stenosis: A prospective cohort study. Eur Spine J 12:197-204, 2003
13. Haig AJ, Tong HC, Yamakawa KS, Quint DJ, Hoff JT, Chiodo A, Miner JA, Choksi VR, Geisser ME, Parres CM: Spinal stenosis, back pain, or no symptoms at all? A masked study comparing radiologic and electrodiagnostic diagnoses to the clinical impression. Arch Phys Med Rehabil 87:897-903, 2006
14. Hilibrand AS, Rand N: Degenerative lumbar stenosis: Diagnosis and management. J Am Acad Orthop Surg 7:239-249, 1999
15. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, Takiguchi N, Minamide A, Oka H, Kawaguchi H, Nakamura K, Akune T, Yoshida M: Associations between radiographic lumbar spinal stenosis and clinical symptoms in the general population: The Wakayama Spine Study. Osteoarthritis Cartilage 21:783-788, 2013
16. Kim HJ, Suh BG, Lee DB, Lee GW, Kim DW, Kang KT, Chang BS, Lee CK, Yeom JS: The influence of pain sensitivity on the symptom severity in patients with lumbar spinal stenosis. Pain Physician 16:135-144, 2013
17. Kuittinen P, Sipola P, Aalto TJ, Määttä S, Parviainen A, Saari T, Sinikallio S, Savolainen S, Turunen V, Kröger H, Airaksinen O, Leinonen V: Correlation of lateral stenosis in MRI with symptoms, walking capacity and EMG findings in patients with surgically confirmed lateral lumbar spinal canal stenosis. BMC Musculoskelet Disord 15:247, 2014
18. Kuramoto A, Chang L, Graham J, Holmes S: Lumbar spinal stenosis with exacerbation of back pain with extension: A potential contraindication for supine MRI with sedation. J Neuroimaging 21:92-94, 2011
19. Levin K: Lumbar spinal stenosis: Pathophysiology, clinical features, and diagnosis. In: Wilterdink JL (ed), UpToDate, Waltham, MA. Accessed May 16, 2017
20. Mamisch N, Brumann M, Hodler J, Held U, Brunner F, Steurer J, Lumbar Spinal Stenosis Outcome Study Working Group Zurich: Radiologic criteria for the diagnosis of spinal stenosis: Results of a Delphi survey. Radiology 264: 174-179, 2012
21. NASS revised 2011 guidelines for diagnosis and treatment of degenerative lumbar stenosis. Available at: www.spine.org. Assessed May 16, 2017
22. Patel CK, Truumees E: Spinal stenosis: Pathophysiology, clinical diagnosis, and differential diagnosis. In: Herkowitz HN, Garfin SR, Frank J, Eismont FJ, Bell GR, Balderston RA (eds), Rothman-Simeone The Spine. 6th ed. Philadelphia, Pa: Elsevier Saunders, 2011:1064-1077
23. Phan K, Teng I, Schultz K, Mobbs RJ: Treatment of lumbar spinal stenosis by microscopic unilateral laminectomy for bilateral decompression: A technical note. Orthop Surg 9: 241-246, 2017

24. Prasad BC, Ramesh Chandra VV, Devi BV, Chivukula SS, Pundarikakshaiah K: Clinical, radiological, and functional evaluation of surgical treatment in degenerative lumbar canal stenosis. Neurol India 64:677-683, 2016
25. Resnick DK, Choudhri TF, Dailey AT, Groff MW, Khoo L, Matz PG, Mummaneni P, Watters WC 3rd, Wang J, Walters BC, Hadley MN; American Association of Neurological Surgeons/ Congress of Neurological Surgeons: Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 6: Magnetic resonance imaging and discography for patient selection for lumbar fusion. J Neurosurg Spine 2:662-669, 2005
26. Saifuddin A: The imaging of lumbar spinal stenosis. Clin Radiol 55:581-594, 2000
27. Sengupta DK, Herkowitz HN: Lumbar spinal stenosis. Treatment strategies and indications for surgery. Orthop Clin North Am 34:281-295, 2003
28. Sigmundsson FG, Kang XP, Jönsson B, Strömqvist B: Correlation between disability and MRI findings in lumbar spinal stenosis: A prospective study of 109 patients operated on by decompression. Acta Orthop 82:204-210, 2011
29. Steurer J, Roner S, Gnannt R, Hodler J; LumbSten Research Collaboration: Quantitative radiologic criteria for the diagnosis of lumbar spinal stenosis: A systematic literature review. BMC Musculoskelet Disord 12:175, 2011
30. Truumees E: Spinal stenosis: Pathophysiology, clinical and radiologic classification. Instr Course Lect 54: 287-302, 2005
31. Wildermuth S, Zanetti M, Duewell S, Schmid MR, Romanowski B, Benini A, Böni T, Hodler J: Lumbar spine: Quantitative and qualitative assessment of positional (upright flexion and extension) MR imaging and myelography. Radiology 207: 391-398,1998
32. Yamazaki K, Yoshida S, Ito T, Toba T, Kato S, Shimamura T: Postoperative outcome of lumbar spinal canal stenosis after fenestration: Correlation with changes in intradural and extradural tube on magnetic resonance imaging. J Orthop Surg (Hong Kong) 10:136-143, 2002