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Validity of MRI Measurements in Lumbar Spinal Canal Stenosis

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Abstract

Background Lumbar spinal canal stenosis results from compression of spinal cord and/or nerves at any level of lumbar vertebra. The relationship between clinical features of the patients and the degree of stenosis is not clear and there is no accepted "gold standard" for the diagnosis of lumbar stenosis.

Objective To evaluate the relationship between the degree of radiologically confirmed stenosis and the severity of Oswestry disability Index and to assess the most valid parameter for the diagnosis of the lumbar stenosis.

Methods A cross-sectional study conducted on randomly selected patients with lumbar stenosis at Magnetic Resonance Image Unit of Al-Imamein Al-Kadhimein Medical City in Baghdad from May to September 2018. All patients filled Oswestry disability Index questionnaire and underwent examination using 1.5 Tesla magnetic resonance unit (Avanto, SIEMENS).

Results A total of 41 patients were included (51.46±12.62) years of age. The measurements of spinal canal including the cross-sectional area of dural sac at intervertebral levels, stenosis ratio, and depth of lateral recesses are found to be correlated significantly with the level of disability assessed by Oswestry disability Index. At all levels, neither the cross-sectional area of the lateral recesses nor Ligamentous interfacet distance correlated significantly to the level of disability.

Conclusion Magnetic resonance image measurements of spinal canal correlated to the level of disability. Stenosis ratio and cross-sectional area of dural sac at intervertebral disc were more sensitive measurements for lumbar stenosis than other parameters.

Keywords Oswestry disability Index, Spinal stenosis, magnetic resonance image

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List of abbreviations: AP = Anterior-Posterior, CSA = Cross-sectional area, LID = Ligamentous interfacet distance, LRD = Lateral recess depth, LSCS = Lumbar spinal canal stenosis, MRI = Magnetic resonance image, ODI = Oswestry Disability Index, SR = Stenosis ratio

Introduction

Spinal stenosis refers to the compression of the neural elements in the spinal canal, lateral recesses, neural foramina, or any combination of these locations secondary to soft tissue or bony abnormalities [1,2]. Soft tissue abnormalities that can lead to spinal stenosis include hypertrophy of the ligamentum flavum, bulging disc(s) and ossification of the posterior longitudinal ligament. While bony causes include; congenitally narrow spinal canal, osteophytes, facet osteoarthritis, or spondylolisthesis. A spinal canal that was borderline normal in size may become stenotic when any of these processes superimposes to further narrow the canal [3].

The evaluation of patients with known or suspected lumbar spinal stenosis is one of the primary indications for magnetic resonance image (MRI) of the lumbar spine [1,2,4]. MRI is

considered the best single imaging modality of the spine for its ability to demonstrate all of the spinal components; bone, discs, ligaments, fatty tissue, dura, cerebrospinal fluid, neural tissue, and blood vessels with superb contrast resolution [5], and for its accurate measurement of the dimension of the spinal canal and spinal cord in various planes [6]. MRI findings may correspond to the severity and duration of the compression [4].

A variety of both radiological and anatomical measurements of normal lumbar spinal canal were performed to define the lumbar spinal canal stenosis (LSCS) and to correlate the severity of lumbar spinal stenosis symptoms with the extent of narrowing of the spinal canal dimensions. Although some studies focused on cross-sectional area (CSA) of the dural sac, transverse diameter, or dural sac anterior-posterior (AP) diameter for the diagnosis of LSCS [7,8]. Generally, the relationship between the clinical feature of the patients and the degree of a radiologically confirmed stenosis is not clear and there is no accepted "gold standard" for the diagnosis of LSCS [9]. The Oswestry Disability Index (ODI) also known as the Oswestry Low Back Pain Disability Questionnaire) is an extremely important tool that researchers and disability evaluators use to measure a patient's permanent functional disability. The test is considered the 'gold standard' of low back functional outcome tools [10]. Therefore, the aim of this study was to evaluate the relationship between the degree of radiologically confirmed stenosis and the severity of ODI and to assess the most valid measurement for the diagnosis of the LSCS.

Methods

Design and setting

This a prospective cross-sectional study carried out in MRI unit of Radiology Department in Al-Imamein Kadhimein Medical city in Baghdad during the period from May to September, 2018.

Study population

Forty-one adult selected symptomatic patients were included in the study. The exclusion criteria were: previous lumbar vertebral fracture, or surgery of the spine, Spinal tumors, pregnancy, gross spinal pathology (spondylolisthesis), recent trauma, and vertebral abnormalities. The presenting symptoms of the patients were lower back pain, neurologic claudication, unilateral or bilateral sciatic pain, and/or numbness, consequently.

Data collection

The data collected by researcher from the patients directly and filled in a prepared questionnaire. The questionnaire included the followings: demographic characteristic of each patient, grading scale to quantify disability, and lumbar vertebral canal anthropometric measurements.

The Clinical grading was done using ODI scoring. It was considered the "gold standard" to quantify disability in a patient with low backache [10]. Every patient answered the ODI questionnaire. ODI comprised of 10 questions, these questions give the physician information about how the pain affect the ability of the patient to overcome in everyday life. The method of Scoring is as follows: (0-20%): minimal disability; (21-40%): moderate disability; (41-60%): severe disability; (61-80%): crippling back pain; and (81-100%): bed-bound [11].

Quantitative MRI image evaluation for LSCS were calculated as following: CSA of dural sac at each mid-vertebral level (L1, L2, L3, L4, and L5) and CSA of dural sac at for each level of the intervertebral discs; CSA of left and right lateral canals; AP diameter of dural sac; Transverse diameter of dural sac; ligamentous interfacet distance (LID); and lateral recess depth (LRD) for each level of the intervertebral discs (L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1). On a diagnostic workstation, the measurements performed using a program measured the parameters in centimeters (cm) as shown in figure 1.

MRI examination

All patients underwent MRI examination using 1.5 Tesla MR unit (Avanto, SIEMENS, German). Each patient was placed in supine position. T2-weighted axial and sagittal images were obtained (TR/TE 5700/99 ms; for axial scan; FoV read: 280 mm; FoV phase: 100.0%; FOV: AP: 350 mm; RL: 263 mm; FH: 350 mm; slice thickness, 4.0 mm; flip angle, 150°.

Image analysis

Two readers including a single skilled radiologist with 10-year experience participated in the evaluations of each patient in the current study.

- AP diameter was measured on the axial plane: "distance between middle of vertebral body and middle of basis of spinous process at border of dural sac"
- LID was measured on axial MRI as "the distance between the inner surfaces of ligamentum flavum on a line connecting the joint disc of facet joints".
- LRD was measured on the axial plane as "distance between the superior articular facet and the top part of the pedicle". as shown in figure 1.
- The stenosis ratio (SR) is defined as the ratio of the CSA of the spinal canal at the intervertebral discs to the CSA at the next mid-vertebral level above. It has been used as index for measuring the severity of the stenosis [12].

In the measurement of the CSA of the lateral recess, if there is interruption of the lateral recess due to disc bulge, summation of the patent zones of the lateral recess were calculated.

Grouping of SR according to degree of stenosis LSCS performed using quartile analysis with the SR as follows: (no lumbar stenosis) between 0.75 and 1, (mild stenosis) between 0.50 and 0.75, (moderate stenosis) between 0.25 and 0.50, and (severe stenosis) between 0 between 0.25. Compromise of the nerve root in the lateral recess was grouped as follows: LRD >0.5 cm (no stenosis); 0.3-0.5 cm (relative stenosis); and <0.3 cm (definitive stenosis).

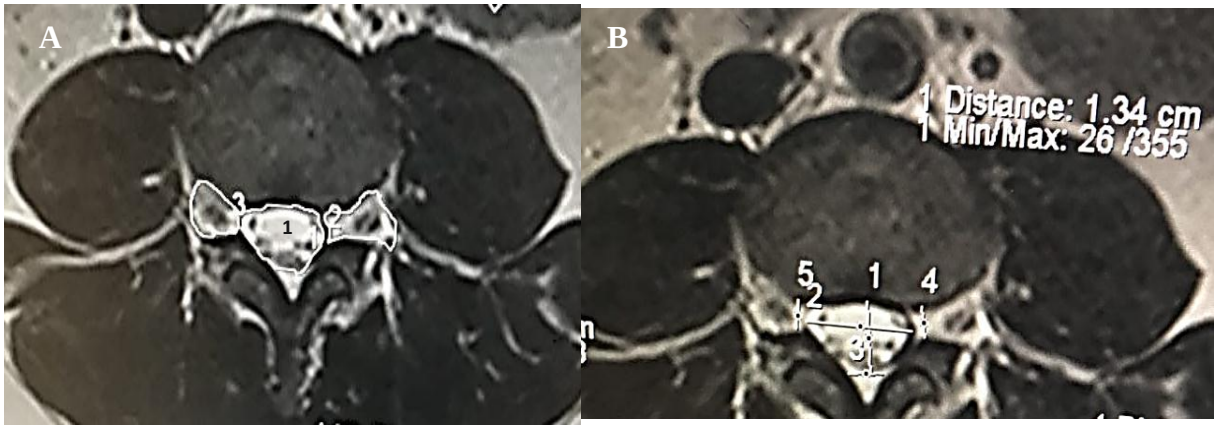

Figure 1. A- spinal canal areas measurement: 1. CSA of dural sac; 2,3. Cross-sectional area of lateral recesses. B- 1. AP diameter of dural sac; 2. Transverse diameter of dural sac; 3. Ligamentous interfacet distance; 4,5. Depth of the lateral recesses

Ethical considerations

Verbal informed consent obtained from all patients

Statistical analysis

Data analysis was performed using Statistical Package for Social Sciences (SPSS) Version 22.0 for Windows. Mean and standard deviation

(SD) were calculated for all variables. The chi square test was used for categorical scales and Pearson correlation was used for continuous variables. ANOVA has been used to find the significance of study parameters between three or more groups. SR ratio as index for measuring the degree of stenosis were calculated. P-values <0.05 were considered statistically significant.

Results

During the study period, 41 selected patients who underwent LSS MRI at the MRI department of Al-Imamein Kadhimein Medical City were included in the study. Of them 14 (23.1%) were male and 27 (65.9%) were female. The age of the patients ranged from 29 to 75 years with mean age±SD was 51.46±12.62 years.

Of those 41 patients, a total of 205 intervertebral discs were analyzed for lumbar stenosis. The CSA of the dural sac at mid-vertebral level varied between 0.8 and 3.0 cm^2, and the CSA of the dural sac at each disc level varied between 1.36 and 3.97 cm^2 in supine position. The mean and SD of CSA of each level were shown in table 1. The mean and SD of AP diameter, transverse Diameter, CSA of the lateral recesses, and LRD at intervertebral discs levels were shown in table 2.

Table 1. Range, minimum, maximum, Mean and SD of the CSA of the dural sac at mid-vertebral and intervertebral disc levels in cm

Level	Range	Minimum	Maximum	Mean	SD
L1	1.97	2.00	3.97	2.83	0.49
L1-L2	1.57	1.40	2.97	2.24	0.35
L2	1.90	1.79	3.69	2.61	0.48
L2-L3	1.63	1.19	2.82	1.93	0.43
L3	2.02	1.82	3.84	2.37	0.43
L3-L4	1.77	.87	2.64	1.73	0.41
L4	1.57	1.56	3.13	2.19	0.40
L4-L5	2.16	.84	3.00	1.62	0.53
L5	2.50	1.36	3.86	2.3	0.53
L5-S1	2.05	0.80	2.85	2.00	0.62

Table 2. Mean and SD of AP diameter, Transverse Diameter, CSA of the lateral recesses, and LRD at intervertebral disc levels of the lumbar spine in cm

	AP Diameter Mean±SD	Transverse Diameter Mean±SD	CSA of left lateral recess Mean±SD	CSA of right lateral recess Mean±SD	Left LRD Mean±SD	Right LRD Mean±SD	LID Mean±SD
L1-L2	1.40±0.18	2.11±0.24	0.98±0.31	0.93±0.29	0.59±0.18	0.65±0.2	0.81±0.12
L2-L3	1.28±0.21	2.02±0.26	0.92±0.33	0.85±0.31	0.45±0.15	0.50±0.19	0.80±0.13
L3-L4	1.21±0.22	1.89±0.23	0.86±0.4	0.87±0.4	0.33±0.17	0.37±0.15	0.78±0.15
L4-L5	1.14±0.29	1.79±0.25	1.02±0.52	0.95±0.48	0.27±0.15	0.30±0.15	0.89±0.22
L5-S1	1.25±0.26	1.90±0.36	1.10±0.62	1.06±0.55	0.36±0.16	0.39±0.18	1.04±0.29

AP: anterior-posterior; CSA: cross-sectional area; LRD: lateral recess depth; LID: Ligamentous interfacet distance. Of the 290 evaluated levels, 59 revealed moderate and 80 revealed severe central stenosis

Regarding the disability score of the ODI, out of the 41 patients, 11 patients (26.8%) showed mild disability; 8 patients (19.5%) showed moderate disability, 12 patients (29.3%) showed severe disability; 6 patients (14.6%) were crippled and 4 patients (9.8%) were bedridden.

In terms of validity, the disability score of the ODI was highly correlated with the CSA of the dural sac at the intervertebral discs of L1-L2, L2-L3, L3-L4, and L4-L5 (P-value = 0.01, 0.04, 0.01, and 0.02) consequently. There is no significant correlation between the disability score of the ODI and CSA of lateral recess or LID at any level, P-value > 0.05.

Of the 205 evaluated levels, 58.5% showed no stenosis, 35.6% showed mild central stenosis, and 5.9% showed moderate central stenosis, none of the evaluated levels shows severe central stenosis. This study shows a highly significant correlation between stenosis ratio and the disability score of the ODI (P-value is 0.015), as shown in table 3.

Table 3. Relation of stenosis ratio to ODI at intervertebral disc levels of the lumbar spine

	No stenosis		Mild stenosis		Moderate stenosis		Total
	No.	%	No.	%	No.	%	
Minimal Disability	42	35	12	16.4	1	8.3	55
Moderate Disability	15	12.5	21	28.8	4	33.3	40
Severe Disability	35	29.2	23	31.5	2	16.8	60
Crippled	17	14.2	9	12.3	4	33.3	30
Bed-bound	11	9.1	8	11	1	8.3	20
Total	120	100	73	100	12	100	205

The chi-square statistic is 18.95. The p-value is 0.015. The result is significant at $p < 0.05$

In these 41 patients, a total of 410 lateral recesses were analyzed for nerve root compression. Of the 410 evaluated lateral recesses, 30.7% showed no stenosis, 42% showed relative stenosis, and 27.3% showed definitive stenosis. This study shows a significant correlation between the grade of nerve root compression and the disability score of the ODI (P-value is 0.041), as shown in table 4.

Table 4. Relation of the severity of lateral stenosis to ODI at intervertebral disc levels

	No stenosis		Relative stenosis		Definitive stenosis		Total
	No.	%	No.	%	No.	%	
Minimal Disability	45	35.7	43	25	23	20.5	111
Moderate Disability	20	15.9	39	22.7	21	18.7	80
Severe Disability	28	22.2	51	29.7	41	36.6	120
Crippled	20	15.9	19	11	20	17.9	59
Bed-Bound	13	10.3	20	11.6	7	6.3	40
Total	126	100	172	100	112	100	410

The chi-square statistic is 16.02. The p-value is 0.041. The result is significant at $p < 0.05$

The disability score of the ODI was significantly associated with the AP diameter of the intervertebral discs of L2-L3 (P-value 0.004) and L3-L4 (P-value 0.03). There is no significant correlation between the disability score of the ODI and AP diameter at the other levels (P-value >0.05), as shown in table 5.

Table 5. Relation of AP diameter to of the ODI at intervertebral disc levels of the lumbar spine in cm

	Minimal Disability		Moderate Disability		Severe Disability		Crippled		Bed-bound		p value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
L1-L2	1.45	0.11	1.27	0.20	1.27	0.20	1.37	0.05	1.41	0.16	0.13
L2-L3	1.40	0.17	1.21	0.18	1.38	0.17	1.20	0.29	1.02	0.06	0.004*
L3-L4	1.33	0.16	1.05	0.23	1.30	0.16	1.18	0.30	1.08	0.26	0.03*
L4-L5	1.15	0.40	1.19	0.33	1.20	0.29	1.09	0.18	0.99	0.05	0.78
L5-S1	1.24	0.33	1.34	0.17	1.22	0.25	1.27	0.23	1.24	0.36	0.9

*Significant

There is no significant correlation between the disability score of the ODI and transverse diameter of the intervertebral discs at all levels except at L3-L4 level show significant correlation (P-value > 0.04), as shown in table 6.

Table 6. Relation of transverse diameter to the ODI at intervertebral disc levels of the lumbar spine in cm

	Minimal Disability		Moderate Disability		Severe Disability		Crippled		Bed-bound		P-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
L1-L2	2.16	0.30	2.09	0.22	2.14	0.25	2.00	0.12	2.10	0.28	0.78
L2-L3	2.10	0.19	1.97	0.35	2.04	0.26	1.87	0.12	2.08	0.40	0.48
L3-L4	2.03	0.29	1.85	0.14	1.92	0.15	1.67	0.29	1.84	0.18	0.04*
L4-L5	1.86	0.17	1.73	0.43	1.82	0.25	1.70	0.21	1.81	0.15	0.74
L5-S1	2.03	0.39	1.94	0.29	1.85	0.34	1.90	0.49	1.62	0.30	0.41

*Significant

Discussion

Several quantitative radiological criteria have been used to define LSCS. Measurement of AP diameter and the CSA of spinal canal with variable levels are the most frequently applied criteria for central LSCS; depth of the lateral recess for lateral stenosis [10].

Genevay et al. [13] in their study noticed that the researchers had a variety of combinations of clinical symptoms, signs, and radiological criteria to study LSCS. However, the degree of narrowing of the spinal canal that considered symptomatic for LSCS is not clear, but it is still needed to ensure appropriate care for the patients and successful treatment plan [14].

Regarding the choice of ODI instrument to measure the level of disability, as described previously by other studies, it has been proven to be the 'gold standard' to quantify disability in a patient with low backache [15] as it is simple, condition specific, reliable, and valid instrument for the assessment of disability in

patients with lower back pain with the benefit of easy comprehension and compliance for the patient. It takes less than five minutes to complete and one minute to be scored, without the need for training, equipment or any cost requirements; it comprises a wide range of function, pain and role limitation [9].

This study shows that the disability of the patients assessed by ODI correlates significantly with the CSA at the intervertebral disc at 4 levels (L1-L2, L2-L3, L3-L4, and L4-L5) (P-value = 0.01, 0.04, 0.01, and 0.02) respectively. This was in concordance with several studies [16-20]. Ragupathi et al. [16] noted a significant association between CSA of dural sac and the disability of the patients assessed by ODI. Kanno et al. [17] noted a significant correlation between the CSA of dural sac in axial loaded MRI and severity of clinical symptoms in patients with LSCS. This study disagrees with Schizas et al. [21] and Sirvanci et al. [8] studies, they found no correlation between CSA of dural sac and ODI (measured on axial MRI), also disagrees with Lohman et al. study which show no relation between CSA of the spinal canal measured on Computed Tomography and clinical symptoms [15]. The current study shows non-significant correlation between CSA of dural sac at the L5-S1 level and ODI, this may be due to the fact that the anatomical and functional aspects of this level of spinal column differs significantly from other levels of the lumbar spine. Functionally, it is consider as junction between the lumbar and sacral vertebrae, act as a joint separating lumbar and sacral vertebrae, anatomically, L5 is significantly different in morphology, with its body being much deeper in front than behind, which allows for articulation with the sacrovertebral prominences. The spinous process is smaller, there is a wider interval between the inferior articular processes, and the transverse processes are thicker and spring from the body as well as the pedicles [22].

The current study shows a non-significant correlation between the disability score of the ODI and the ILD of the intervertebral disc levels. This agrees with Pawar et al. study [23]. Moreover, this study shows a non-significant correlation between the disability score of the ODI and the CSA of the lateral recesses at any level.

The current study shows that the disability of the patients assessed by ODI correlates significantly with the severity of central stenosis (P-value 0.015) and the severity of lateral stenosis (P-value 0.041) of the lumbar spine. This agrees with Hurri et al. study, [24] but disagrees with Sirvanci et al. [8] and Schizas et al. studies [21] they found no correlation between severity of lumbar stenosis (measured on axial MRI) and ODI. Although various authors had reported a non-significant correlation between radiologically detected stenosis and severity of clinical findings, patients with narrower lumbar spinal canals expected to be more liable to develop symptoms of LSCS. Sirvanci et al. [8] shows the correlation with only moderate to severe grade of central stenosis however, the current study shows the correlation with only mild to moderate grade of central stenosis as none of the patients present with severe central stenosis through-out the study period.

This study shows a significant correlation between the disability score of the ODI and the LRD for all levels with (P-value 0.041). This agrees with Pawar et al. study [23] who noted a significant correlation between LRD of all levels (except L1 on right side and L1 and L2 on left side) and clinical symptoms.

This study shows significant correlation between the disability score of the ODI and the AP diameter of the intervertebral discs for just two levels; L2-L3 (P-value 0.004) and L3-L4 (P-value 0.03), non-significant correlation at the other levels (P-value > .05), and non-significant correlation of the average of AP diameter of all intervertebral disc levels with the disability score of the ODI (P-value >0.05). This agrees with Kumar et al. [25] study, they noticed a significant correlation between AP diameter of intervertebral disc of 2 levels (L4-L5, L5-S1) with clinical symptoms. This study disagrees with Ragupathi et al. [16] study, they noticed a significant correlation between AP diameter with ODI scoring at all intervertebral disc levels, also disagrees with Geisser et al. [26], they

noted a non-significant correlation of the AP diameter at all intervertebral disc levels

This study shows a significant correlation between the disability score of the ODI and the transverse diameter of the intervertebral disc for just one level L3-L4 (P-value 0.04), and non-significant correlation at the other levels (P-value >0.05). This disagrees with Kumar et al. (25) study, they noticed a significant correlation between transverse diameter at intervertebral disc of 3 levels (L2-L3, L3-L4, and L4-L5) with clinical symptoms, also disagrees with Ragupathi et al. [16] study, they noticed a significant correlation between transverse diameter with ODI scoring at 4 intervertebral disc levels.

Strength of the study

The strength of the current study is to use combined samples of patients diagnosed with LSCS, compromise those who were planning for surgery, and those who were not. Therefore, it could validate the measures that used in assessing ODI in patients with LSCS. The other important aspect of the study is that: the combined results of central and lateral stenosis would correlate better to the ODI and this may explain the disagreement with other studies [9,21].

Limitation of the study

There are some limitations to this study. Firstly, low back pain related disability is systemic symptom, may be due to a variety of causes. It could be due to LSCS as well as renal calculi or infections. The other limitation is pain tolerance may change with each patient, as some patients can tolerate even more severe pain while other may not be able to tolerate a minimal pain.

Conclusion

Although the CSA of dural sac of 4 levels, SR of all levels, LRD of all levels, and AP diameter of 2 level were all significantly associated with LSCS. SR and CSA of dural sac at intervertebral disc were more sensitive parameter for LSCS than other parameters. There is significant correlation between MRI measurements of spinal canal and levels of disability measured by ODI in patients with LSCS, the degree of stenosis correlates to the severity of disability scored measured by ODI.

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Author contribution

Dr. Al-Jaberi and Dr. Kanaan: Conception and design of study, acquisition of data and revising the manuscript critically for important intellectual content. All three authors participated in analysis and/or interpretation of data, drafting the manuscript.

Conflict of interest

There are no conflicts of interest.

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