Original Article

HEALTH SCIENCES
MEDICINE

DOI: 10.32322/jhsm.973905
J Health Sci Med 2021; 4(6): 845-852

Radiological evaluation of spinal canal, dural sac, epidural fat and superior articular process in diagnosis of lumbar spinal stenosis

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Cite this article as: Çankal F, Patat D, Şirinoğlu T. Radiological evaluation of spinal canal, dural sac, epidural fat and superior articular process in diagnosis of lumbar spinal stenosis. J Health Sci Med 2021; 4(6): 845-852.

ABSTRACT

Aim: The aim of our study; to investigate the location of hypertrophy in the epidural adipose tissue in the lumbar spinal stenosis clinic, to compare the area measurements of the spinal canal and dural sac in patients with a preliminary diagnosis of lumbar spinal stenosis or radiculopathy, and to determine the place of the superior articular process area measurement in the diagnosis of spinal stenosis.

Material and Method: 180 patients aged 50-69 years who underwent Lumbar Magnetic Resonance Imaging were divided into two groups according to the prediagnosis of lumbar spinal stenosis or radiculopathy and retrospectively analyzed. Spinal canal, dural sac, epidural fat, and superior articular process areas were measured. Statistical relationships of the findings were investigated.

Results: There was no difference between the stenosis groups of these patients in terms of age and gender (respectively p=0.078; p=0.564). There is a significant difference in terms of the spinal canal, dural sac, superior articular process, and epidural fat widths between spinal stenosis and radiculopathy (p<0.001; p<0.001; p<0.001; p=0.033, respectively). Superior articular process, spinal canal, dural sac, and epidural fat cross-sectional areas were each found significant for their use as a diagnostic test for diagnosing lumbar spinal stenosis (p<0.001; p<0.001; p<0.001; p=0.034, respectively).

Conclusion: Spinal stenosis is a problem that greatly affects the quality of life of patients. Measuring only the width of the spinal bony canal does not provide sufficient information in the diagnosis of spinal stenosis. In our study, hypertrophy of the superior articular process was the strongest finding in the diagnosis of lumbar spinal stenosis. Hypertrophy of epidural adipose tissue has also been shown to be a risk factor for lumbar spinal stenosis. In radiological evaluations, other structures that narrow the canal should also be carefully examined.

Keywords: Spinal stenosis, dural stenosis, epidural fat, magnetic resonance imaging

INTRODUCTION

The prevalence of lumbar spinal stenosis (LSS) varies between 1.7-13.1% in the population (1). LSS is the most common cause of disability in elderly and middle-aged patients (2). It causes neurogenic intermittent claudication, radicular pain, and sensory and motor disturbance in the lower extremities. Sciatica may also present itself with neurogenic claudication and low back pain complaints (3). Complaints increase with walking (4). However, radiological LSS is not always clinically present (5,6).

Indications for surgery due to LSS are increasing especially in the over 65 age group (7,8). LSS patients benefit from spinal decompression surgery, but non-surgical interventions are preferred primarily (9).

Spinal stenosis is evaluated in three types. The type in which the spinal canal is affected is called central stenosis, the type in which the intervertebral neural foramina are affected is called foraminal stenosis, and the type in which the lateral recesses are affected is called lateral stenosis. (3,10). It is important to determine the location of the LSS in the approach to the patient with neural compression (11).

Spinal stenosis was originally defined as any narrowing of the spinal canal, nerve root canals, or intervertebral foramina (12). It can be congenital, acquired, or mixed (13). Congenital causes are primarily short pedicle structure or facet joint abnormalities. Acquired

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Received: 24.07.2021 **Accepted:** 15.08.2021

conditions are injuries, bone tumors, hematomas, abscess, metabolic diseases such as acromegaly or achondroplasia, iatrogenic conditions, and degenerative diseases (14). It is also known that the width of the spinal canal is affected by genetic factors (10).

Unfortunately, there is currently no standard for the diagnosis of LSS. Diagnosis is made by clinical signs, physical examination, and radiological confirmation (17,18). In the radiology department, the anterior - posterior diameter measurements of the spinal canal and dural sac; and their cross-sectional area (CSA) measurements are the most frequently used methods. (16).

Unfortunately, there is currently no standard for the diagnosis of LSS. Diagnosis is made by clinical signs, physical examination, and radiological confirmation (17,18). In the radiology department, cross-sectional area (CSA) measurement of the spinal canal and dural sac diameter and anterior-posterior diameter measurement are the most frequently used methods (16).

Magnetic Resonance Imaging (MRI) of the lumbar spinal canal is one of the most frequently used methods to evaluate the morphological structure of the spinal canal and nerve roots after physical examination of people who have difficulty in movement due to complaints such as low back pain and loss of strength in the lower extremities. It is known that MRI provides useful images for back pain and other pathologies of lumbar origin (19). Using MRI, we can easily visualize degenerative changes and spinal canal dimensions (20). MRI is the gold standard for the lumbar spinal canal (10).

In the literature, the ligamentum flavum is mentioned as an important structure that narrows the spinal canal (21). Fluid increase in the facet joint is also a condition that narrows the dural sac (22).

Epidural fat is the adipose tissue that fills the space between the dura mater and the periosteum of the vertebra. (23) It is more prominent at the level of the upper lumbar vertebrae than at the lower lumbar level (24,25).

Back pain is the most frequently reported symptom associated with spinal epidural lipomatosis (SEL) and often presents long before the other symptoms (26). We could not find specific information about epidural adipose tissue hypertrophy or lipomatosis for spinal stenosis in the literature.

Our study aims to investigate the place of hypertrophy in epidural adipose tissue in the clinic of lumbar spinal stenosis, to compare the measurements of the spinal canal and dural sac CSA in patients with a preliminary diagnosis of lumbar spinal stenosis or radiculopathy, and to determine the place of superior articular process CSA measurement in the diagnosis of lumbar spinal stenosis.

MATERIAL AND METHOD

This study was planned as a retrospective study. At all stages, the 1964 Declaration of Helsinki, national research committee standards, and ethical guidelines were meticulously complied with. This study was approved by Ankara Medipol University Faculty of Medicine, Non-interventional Researchs Ethics Committee (Date: 01.07.2021, Decision No: 27).

Study Plan and Patient Selection Criteria

Between January 2020 and December 2020, a total of 896 examinations that underwent lumbar spinal MRI at the imaging center were evaluated retrospectively. Patients aged between 50-69 years were included in the study in order to have the measurements affected by age-related changes as little as possible. Only the first examination of the patients with more than one examination was included in the study. Patients who had undergone surgery, infection, abscess, fracture, hematoma, and malignant mass were not included in the study group. The patients were examined in two groups according to the reasons for their request as those with narrow lumbar spinal canal and spinal stenosis findings and those with suspected radiculopathy. However, we found it necessary to have a complaint of neurogenic claudication in the patient forms in order to include those presenting with suspected spinal stenosis into the group. Thus, 108 lumbar spinal MRIs were accepted in the study.

MRI examinations were performed using 1.5 T (Tesla) (Signa Explorer, GE Healthcare, USA) MRI scanners.

Routine sequences included in the standard protocol were taken in MRI examinations. The retrieved sequences and their properties are given in **Table 1**.

Table 1. Values mean of routine sequences in Lumbar Spinal MRI

	TR (ms)	TE (ms)	FOV	Matrix	ST (mm)	SS (gap) (mm)
AXIAL T2W	7691	105	20×18	352×224	4.0	1.0
SAGITAL T1W	329	15.2	28×28	320×256	4.0	1.0
SAGITAL T2W	3522	111	28×28	320×256	4.0	1.0
SAGITAL STIR	4209	93.6	28×28	320×224	4.0	1.0

TR: Repetition time, TE: Echo time, FOV: Field of view, ST: Slice Thickness, SS: Slice Spacing, STIR: Short tau inversion recovery.

In the evaluation of images, spinal canal CSA (SCCSA), dural sac CSA (DSCSA), epidural fat CSA (EFCSA), and bilateral L5 superior articular process CSA (SAPCSA) measurements were made at the level of L4-5 intervertebral disc (Figure 1-4). Measurements were predominantly made using axial T2W images, and sagittal images were used for the presence of osteophytes or cystic structures and epidural fat boundaries.

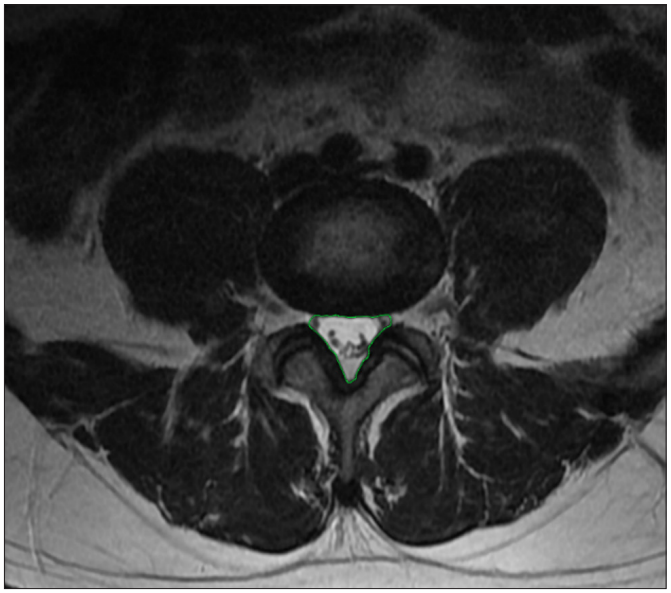

Figure 1. Spinal canal CSA measurement

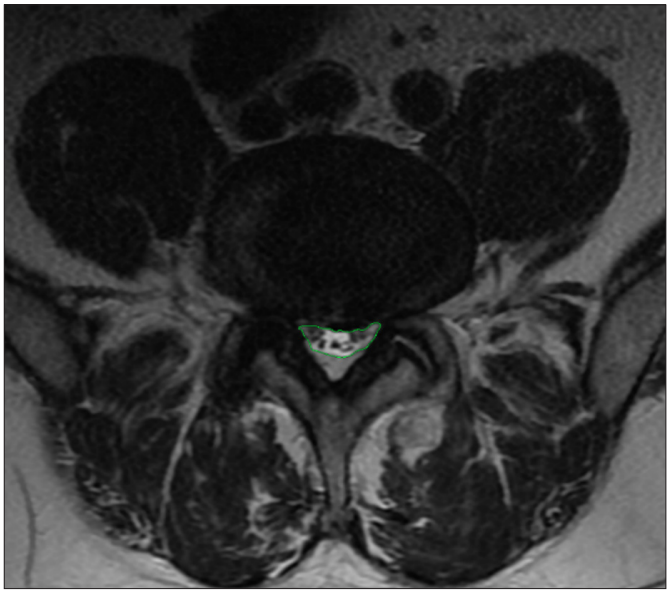

Figure 2. Dural sac CSA measurement

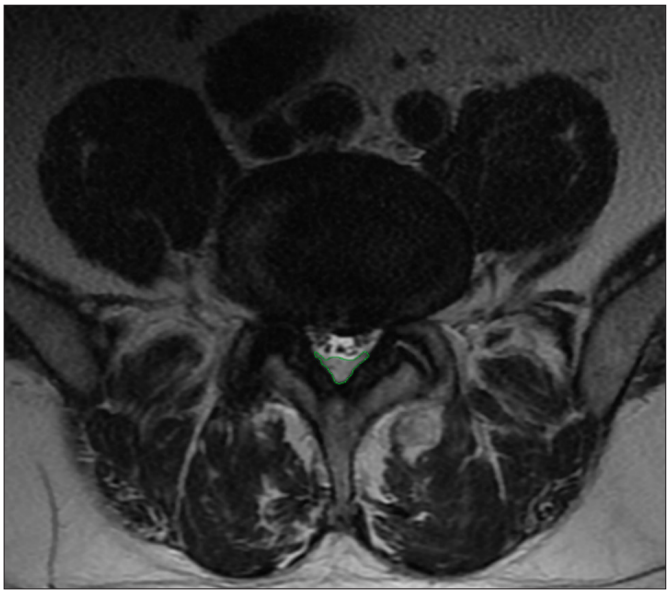

Figure 3. Epidural fat CSA measurement

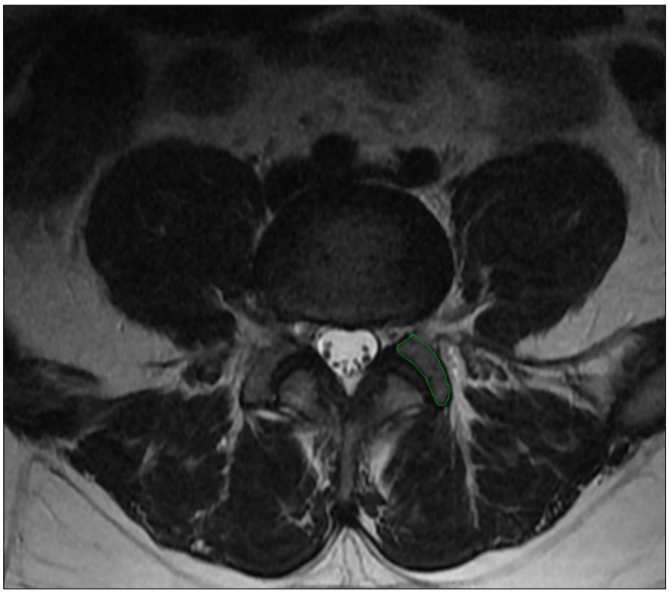

Figure 4. Superior articular process CSA measurement

Images in the collection environment of the center were examined on two separate dates by a radiologist with 22 years of experience using the Picture Archiving and Communication System (PACS). The reliability of the measurements was tested, the intra-observer reliability was found between 0.95-0.98. Results were considered safe and measurements were averaged.

Statistical Analysis

In the study, depending on the assumptions for numerical parameters as descriptive statistics, mean±standard deviation or median (minimum-maximum); Number (n) and percentage (%) for categorical data are given. Student's t test was used if parametric test assumptions were met, and Mann-Whitney U test was used if not, in determining whether there was a difference between groups in terms of numerical variables. ROC (Receiver Operating Characteristic) analysis was performed to test the usability of numerical parameters in estimating stenosis, Area Under Curve (AUC) value and confidence intervals were given, and the cut-off value was found according to Youden index. The analyzes of the study were made in IBM SPSS v22 program. $p<0.05$ was considered statistically significant.

RESULTS

The study consisted of 108 patients, 54 female, and 54 male. The mean age is 57.20±5.191 years. While 54 of the patients had stenosis, 54 did not have stenosis.

There was no difference between the stenosis groups of these patients in terms of age and gender (respectively $p=0.078$; $p=0.564$).

There was no significant difference between men and women in terms of SCCSA, DSCSA, SAPCSA, and EFCSA (p=0.694; p=0.379; p=0.832; p=0.707, respectively).

There is a significant difference in terms of SCCSA, DSCSA, and SAPCSA, and EFCSA between lumbar spinal stenosis and radiculopathy (p<0.001; p<0.001; p<0.001; p=0.033, respectively) (**Table 2**).

SAPCSA, SCCSA, DSCSA, and EFCSA were each found significant for their use as a diagnostic test for diagnosing lumbar spinal stenosis. (p<0.001; p<0.001; p<0.001; p=0.034, respectively) (**Table 3**) (**Figure 5**).

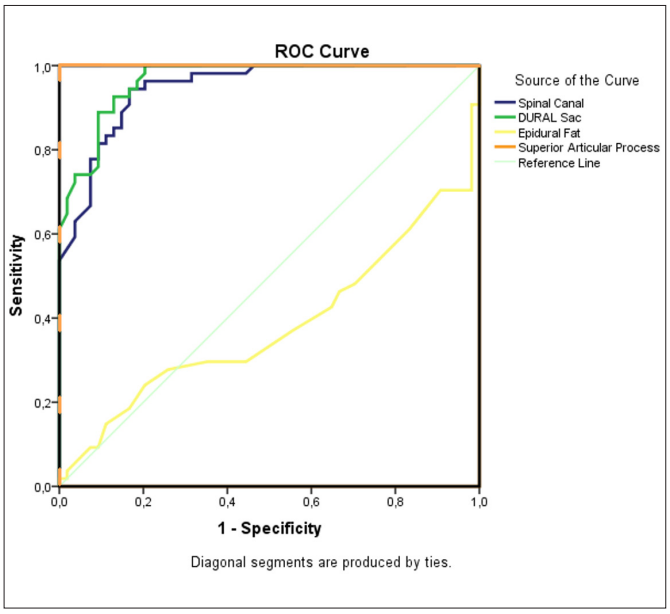

Figure 5. AUC graphs of parameters

Table 2. Comparison in terms of parameters for stenosis

	Spinal Stenosis		P
	Negative (n=54)	Positive (n=54)	
SAP (mm²)	92.93±6.689	119.52±6.068	<0.001[a]
Spinal Canal (mm²)	198.24±40.646	119.98±25.680	<0.001[a]
Dural Sac (mm²)	163.37±41.120	82.87±19.204	<0.001[a]
Epidural Fat (mm²)	14.0(3.0-38.0)	19.0(2.0-42.0)	0.033[b]

[a]:Student's t Test; (Mean±Standard Deviation), [b]: Mann-Whitney U Test; median (minimum-maximum)

DISCUSSION

Jensen et al. (27), in their systemic review of 55 studies, reported that 11% of the general population complies with the clinical diagnostic criteria of LSS, and this rate varies between 25-39% in the clinical population. Radiological findings in spinal stenosis are more extensive than clinical symptoms and signs (3). Some studies have found a relationship between the degree of spinal stenosis and decreased walking distance and leg pain (28,29).

There are also studies in which variations of the spinal canal and its correlation with somatometric parameters in asymptomatic patients have been performed (13). In these studies, it was reported that the spinal canal measurements did not show any change depending on the age or the height of the patient (13).

For the radiological diagnosis of spinal stenosis, there are different opinions about the pathological limits of the anterior-posterior diameter, although they are close to each other. The generally accepted value for absolute stenosis appears to be 11-13 mm. In studies describing dural stenosis as a separate entity, it was determined as normal stenosis above 10 mm, relative stenosis between 8-10 mm, and absolute stenosis below 8 mm (1,10,30-33).

Korse et al. (34) measured the sagittal diameter of the spinal canal at L4-5 level, 10.06 (5-14) mm (5-14) in cauda equina syndrome (CES) and 12.75 (9-20) mm in sciatica, and stated that there was no correlation between MRI findings and CES symptoms.

Pierro et al. (35) described the sagittal diameter of the dural sac as 13.3±2.1 mm at the L4 level and 12.9±2.4 mm at the L5 level, and no difference was found in the dural sac width between males and females. Since Pierro et al. (35) made the measurements from the middle 1/3 of the vertebra, the results may have been different from the literature. However, it is valuable that it indicates a significant difference between the diameter of the dural sac and the diameter of the spinal canal. In the literature review, it is seen that the spinal canal measurement was made at the disc level in some studies and from the corpus level in others, as in this study. In some publications, DSCSA measurement was performed at the levels where the ligamentum flavum is prominent in the figures showing the measurement, while the bone canal was presented as data (1).

Table 3. Identifying diagnostic tests for stenosis

	AUC	95% Confidence Interval	P	Cut-off value	Sensitivity	Specificity
SAP (mm²)	1.00	1.00 – 1.00	<0.001	106.50	1.00	1.00
Spinal Canal (mm²)	0.947	0.909 - 0.984	<0.001	159.50	0.94	0.83
Dural Sac (mm²)	0.965	0.937 – 0.993	<0.001	104.50	0.89	0.91
Epidural Fat (mm²)	0.618	0.510 – 0.727	0.034	23.50	0.30	0.98

Panda et al. (10) measured the sagittal diameter of the spinal canal at L4-5 level as 14.66-16.5 mm in the control group; It was found between 10.92-12.99 mm in the case group. In the same study, he states that there is no difference in age between the discopathy patient group and the control group in the measurements he made at all levels according to age groups.

In the literature, it is said that DSCSA is a more sensitive method for spinal stenosis (16). Most studies that present data on spinal canal width are either on symptomatic patients or as comparative studies. According to the data of this study, a DSCSA less than 75 mm² was determined as absolute spinal stenosis (ASS), and a DSCSA between 75-100 mm² was determined as relative spinal stenosis (RSS). In previous studies, anteroposterior diameter measurement in the sagittal plane was preferred rather than area measurement. Today, we think that area measurement should be preferred, since MR images of patients are made almost entirely on computer systems.

Verbiest says neurogenic intermittent claudication is common in both ASS and RSS (30). Other studies also mention a relationship between the degree of dural stenosis and specific symptoms for stenosis, such as walking ability (4). According to this latest study, the DSCSA limit value is given as 53 mm² for walking ability below 100 m, and 69 mm² for walking ability over 500 m. Walking distances and disability indices were used for such studies (36). In this study of Altinel and Yerli, 70 mm² Shönnström criteria (typo belongs to the authors) were used for DSCSA, and no reference was given as to where these criteria were taken from. In this study, a close relationship was found between the severity of the narrowing and the complaints and findings of the patients (36). Sirvancı et al. (6) examined the results of 63 patients who had undergone surgery for stenosis and found DSCSA at all levels between 18-232 mm² and did not detect a correlation between the Oswestry Disability Index and radiological images. Hurri et al. (37), on the other hand, defends the existence of this relationship. In our study, there is a significant relationship between lumbar spinal stenosis clinic and canal diameter. While the mean SCCSA was 119.98 mm² at the L4-L5 level in patients presenting with spinal stenosis clinic, the mean SCCSA was measured as 198.24 mm² in patients with clinical signs due to discopathy at other levels. DSCSA was 82.87 mm² and 163.37 mm², respectively. Both the spinal canal and dural sac narrowing were statistically significant ($p<0.001$, $p<0.001$). However, since Sirvancı et al.'s study includes only patients with clinical data and the decision to operate, it may not be accurate to compare with our results (6). Jail et al. (38), in their study using disability indexes, found DSCSA between 35-50 mm² in patients with neurogenic claudication and 164 mm² in patients with mild low back pain and reported a significant statistical difference.

Premchandran et al. (39) measured the DSCSA at the level of the vertebral corpuscles of the patients who were taken out of the clinic and did not have fractures or kyphoscoliosis, with the L4 level of 196.36±44.12 in women; 226.57±51.29 in men; L5 level was 187.11±59.76 in women; published as 215.92+-51.35 in men. Unfortunately, there was no information that the data shared in this study was mm², although we interpreted it that way. Rapala et al. also measured the vertebral corpus levels, and they described DSCSA as 267.70 mm² at the L4 level and 303.99 mm² at the L5 level (40). Our findings also support these studies.

In early CT studies, 10 mm for the ASS and 12 mm for the RSS was used as the lower limit of the sagittal diameter of the spinal canal, and the lower limit was 145-150 mm² for the DSCSA. However, in recent studies, the lower limit of 75 mm² is accepted as the lower limit of 100 mm² relative SS, and it has been reported that symptoms may occur below 130 mm² (5,6,29,41,42). Schönström et al. (43) defends 100 mm² as the critical size. In the literature, there are parameters such as normal canal width not less than 145 mm², anterior-posterior diameter greater than 11.5 mm, ligamentum flavum thickness not exceeding 5 mm, and interpeduncular distance above 16 mm in the evaluation of spinal canal stenosis (13).

The old data on DSCSA normal size are as follows: Ulrich et al. (44) argue that stenosis below 145 mm², Hamanishi et al. (45) argue that it can be called stenosis below 100 mm².

Although Danielson et al. obtained significant results with the axial loading technique used in MRI and computed tomography (CT) examinations, this examination has not become widespread in practice. In the same study, they showed that the diameter of the spinal canal increased in flexion and decreased in extension (46). In the axial loading technique, compression is applied to the patients or cadavers from the sole of the foot, so that the vertebrae are exposed to an axial force as when standing. This technique was first described by Schönström and Hansson (47), and in cadaver studies, it was determined that 40-50 mm² difference occurred when force was applied compared to when it was not applied. In addition, it is stated in this study that compression may occur in the nerve roots with diameters below 75 mm².

In another dynamic study, it was reported that the sagittal diameter of the spinal canal increased in extension in 33% of patients and decreased in flexion in most patients (3). In the same study, it is stated that there is no significant relationship between the severity of clinical symptoms and the degree of radiological narrowing.

Lim et al. (16) made measurements from several levels. In this study, bone canal and dural sac diameters were measured separately, and DSCSA measurement was found to be more sensitive for the diagnosis of LSS. In our study, all data were found to be significant.

Another recent consideration for the diagnosis of spinal stenosis is the measurement of SAPCSA (2,48,49). This view is quite logical. Because facet hypertrophy may already be the cause of spinal stenosis alone (50). It is said that this measurement can also be a guide before endoscopic spinal surgery (51). An et al. (48) mention that they examined patients over the age of 60 in their study because there were minimal cartilage changes in the superior articular process before the age of 45. The most definitive result of our study was the significant relationship between SAPSCA measurements and the diagnosis of spinal stenosis ($p<0.001$). The power of this data in diagnosis came as a surprise to us. However, it draws attention to the place of facet joint hypertrophy in the etiology of spinal stenosis. However, it would be appropriate to evaluate it with studies involving more patients. It has been determined that the increase in fluid in the facet joint narrows the dural sac, which becomes evident in axial loading shots (22). Besides the facet joint, the ligamentum flavum is an important structure that narrows the spinal canal (21). We think that it would be more useful to use DSCSA to describe the contractions where the increase in size is prominent in these structures.

Shizas et al. (5) introduced a new classification in which the distribution style of the roots in the neural sac is in the foreground. In this classification, epidural fat is prominent in the posterior in grade C stenosis. This is the first study based on shape in the diagnosis of stenosis. We think that it should be supported by new studies. On the other hand, as suggested by Lim et al. (16), it may be useful to evaluate the presence of CSF obliteration by looking at the shape of the dural sac.

Patients with spinal epidural lipomatosis may be asymptomatic but often present with symptoms secondary to nerve or spinal cord compression (52). Cases, where the EF thickness is over 7 mm, are considered as spinal epidural lipomatosis (26,53).

In studies conducted for EF, measurement was preferred at the thoracic (especially T7) level (54,55). We did not study epidural lipomatosis. Our measurements were made at the L4-5 level.

There is also a study that states that the rate of climbing stairs and feeling well in the elderly increases with the increase in the prominence of epidural fat. However, this association was not found in patients with low back pain in the same study (23). Although it lagged behind other data in our study, there was a significant difference in hypertrophy of epidural adipose tissue between patients with lumbar spinal stenosis clinic and the other group ($p=0.033$). Sions et al. measured the epidural fat thickness as 4.4 mm in their study. Since we measured the area, we could not find the opportunity to compare. In our measurements, the mean EFCSA was 19 mm^2 in patients with lumbar spinal stenosis, and 14 mm^2 in the other group. It may be difficult to evaluate epidural adipose tissue on T2W images taken from the intervertebral disc level for discopathies (**Figure 6**). We recommend using sagittal T1 images for this.

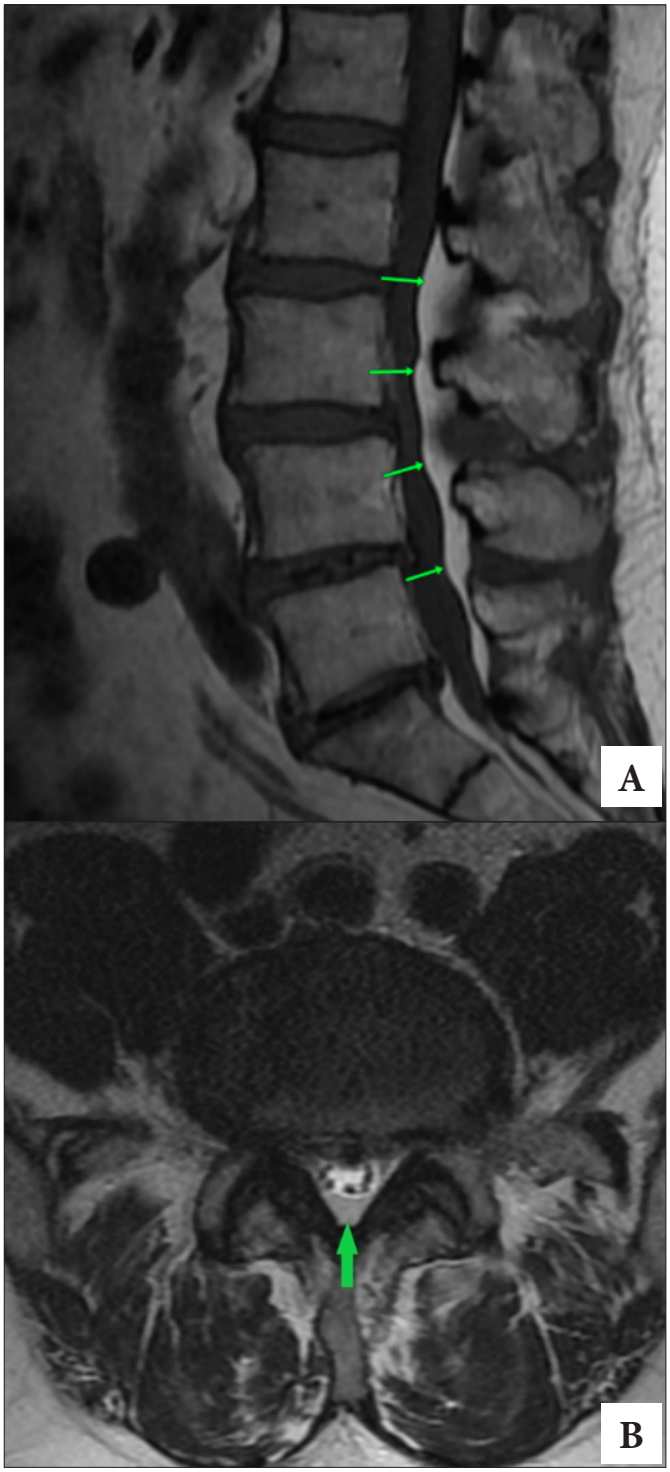

Figure 6. Posterior epidural fat is evident. Images of the same patient (**A**- sagittal T1W, **B**- axial T2W)

In our literature review, we found that epidural fat was not evaluated in detail in studies investigating SCCSA and DSCSA. In our study, we tried to find out whether volume changes in epidural fat tissue contribute to LSS formation. We found 23.50 mm² as the cut-off value.

CONCLUSION

Lumbar spinal stenosis is a problem that greatly affects the quality of life of patients. Measuring spinal bone canal width alone does not provide sufficient information in the diagnosis of spinal stenosis. For the diagnosis of dural stenosis, which is at the forefront of the emergence of symptoms, other structures that narrow the canal should be carefully examined in MRI evaluations. Since hypertrophy in the epidural adipose tissue is a condition that can lead to the finding of dural stenosis, we think that it should be especially evaluated. In addition, we would like to confirm that the diameter of the superior articular process is a valuable finding in the diagnosis of lumbar spinal stenosis.

ETHICAL DECLARATIONS

Ethics Committee Approval: This study was approved by Ankara Medipol University Faculty of Medicine, Non-interventional Researchs Ethics Committee (Date: 01.07.2021, Decision No: 27).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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