European Review for Medical and Pharmacological Sciences 2023; 27: 9091-9100

The correlation between clinical symptom and morphological parameters on magnetic resonance imaging in patients with spondylolisthesis levels L4/L5 and L5/S1

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Abstract. – OBJECTIVE: Spondylolisthesis is one of the common causes of spinal pain. There is currently a lack of studies on the correlation between magnetic resonance imaging (MRI) and clinical symptoms of patients with spondylolisthesis. This study is aimed to find the correlation between clinical symptoms of L4/L5, L5/S1 lumbar spondylolisthesis, and imaging parameters on MRI.

PATIENTS AND METHODS: A retrospective study on 100 patients who were diagnosed with lumbar spondylolisthesis at the L4/L5, L5/S1 levels from August 2022 to February 2023. Parameters on MRI are measured the cross-sectional area of the dural sac (DSA), the cross-sectional area of the spinal canal (SCA), the ligamentum flavum cross-sectional area (LFA), and ligamentum flavum thickness (LFT), anterior-posterior diameter (APD), sliding distance (SD) at the spondylolisthesis level. Clinical symptoms were investigated according to the Visual Analogue Scale (VAS) for grading of pain and the subjective disability was assessed by the Oswestry Disability Index (ODI).

RESULTS: There was no statistically significant difference between SD, APD, SCA, DSA, LFA, and LFT between the mild and moderate pain VAS and severe pain VAS groups. No correlation was found between VAS and SD, APD, SCA, DSA, LFA, and LFT. There is a negative correlation between ODI and APD, SCA, and DSA. The statistically significant difference in APD, SCA, and DSA indexes in the two groups with mild/moderate disability (ODI ≤40%) and the group with severe disability (ODI >40%).

CONCLUSIONS: A higher DSA and SCA, APD are associated with lower ODI. Decreased APD, SCA, and DSA are all suggestive of decreased spinal function. However, the MRI findings did not correlate with the patient's clinical pain level.

Key Words:
Spondylolisthesis, Clinical and imaging, Visual Analogue Scale, Oswestry Disability Index (ODI).

Introduction

Lumbar spondylolisthesis is an abnormal forward or posterior movement of the vertebral body along with the pedicle, transverse process, and superior articular facet[1]. It includes many causes such as degenerative, isthmus, trauma, postsurgical, pathological, and dysplasia, of which degeneration is the most common cause[2]. Lumbar degenerative spondylolisthesis is most common at L4/L5, then L5/S1[3]. The progression of this disease leads to nerve root compression, and spinal stenosis, if not detected and treated in time, can cause many serious neurological complications, the most severe being lower limb paralysis[4].

The diagnosis of lumbar spondylolisthesis should be based on clinical symptoms such as low back pain, and signs of nerve root compression combined with imaging parameters like X-ray, computed tomography (CT), and magnetic resonance imaging (MRI). MRI is a non-invasive imaging modality for the evaluation of nerve compression, spinal structures such as discs, facet joints, ligaments, bone structures, and root compression, spinal stenosis[5].

In the literature, there have been a number of studies[6,7] on imaging characteristics on MRI of patients with spondylolisthesis and clinical relationship through single or combined characteris-

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tics such as paravertebral muscle area, percentage slip, pelvic parameters such as pelvic incidence, pelvic tilt, sacral slope, lumbar lordosis, L5 incidence. Several reports[8-13] have found a correlation, although with controversies, between the clinical symptoms of patients with spinal pain and imaging parameters by different diagnostic means. Therefore, we conducted a study to evaluate the correlation between parameters on MRI with clinical symptoms in patients with spondylolisthesis at the L4/L5 and L5/S1 levels.

Patients and Methods

Patient Collection

A retrospective study was conducted on 100 patients at Viet Duc Hospital between August 2022 to February 2023. The inclusion criteria were as follows: spondylolisthesis at the L4/L5 and L5/S1 level on MRI 1.5 Tesla, complete medical records including pain intensity by visual analog scale (VAS), and subjective disability was assessed by the Oswestry Disability Index (ODI). Exclusion criteria included any related diseases affecting the pain level and quality of the spine. The study was approved by the Medical Ethics Committee of Hanoi Medical University (reference number: 4084/QĐ-ĐHYHN dated September 30, 2022). Informed consent was waived by the Medical Ethics Committee of Hanoi Medical University for the study's retrospective nature, and the analysis used anonymous clinical data.

The patient's pain symptoms were assessed according to VAS on a score of 0-10, 0 points for no pain, and 10 points for the worst pain possible[14]. Quantifying disability for low back pain was assessed according to the ODI with a questionnaire consisting of 10 topics: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. Each topic will be scored 0 points (no influence), and 5 points (the most severely affected), and the total score is calculated as a percentage. The index is scored from 0 to 100% and interpreted as follows: 0-20%, minimal disability; 21-40%, moderate disability; 41-60%, severe disability; 61-80%, crippled; 81-100%, bed-bound patiens[15].

With the VAS scores, patients were divided into 2 groups: group 1: VAS ≤6 (mild/ moderate pain) and Group 2: VAS >6 (severe pain). With the ODI, patients were divided into 2 groups: group 1: ODI ≤40% (mild/ moderate disability) and group 2: ODI >40% (severe disability).

MRI Technique

The images from the MRI were retrospectively reviewed by two musculoskeletal radiologists with 2 and 7 years of experience in musculoskeletal radiology who had no previous knowledge of the pathologic diagnosis.

All MRI scans were performed using either a Siemens 1.5 T Magnetom Essenza (Siemens, Berlin, Germany) or a Philips Ingenia 1.5 T (Philips Healthcare, Best, Netherlands) using basic sequences. The parameters of these sequences are described in Table I.

Imaging Parameters

On MRI, we evaluated anterior-posterior diameter (APD), the cross-sectional area of the spinal canal (SCA), the cross-sectional area of the dural sac (DSA), ligamentum flavum cross-sectional area (LFA), and ligamentum flavum thickness (LFT), sliding distance (SD). The workflow of this study was introduced in Figure 1.

On the axial T2W, we measured indexes, including the SCA, DSA, LFA, and LFT, at the position of the spondylolisthesis (Figure 2). On the sagittal T1W, we measured indexes, including the APD, and SD, at the position of the spondylolisthesis (Figure 3).

DSA was measured along the posterior border of the spinal canal extending towards the bilateral facet joint edge. SCA was measured according to the spinal cord cross-sectional boundary at the narrowest spondylolisthesis level. LFA was measured according to the area of the ligament flavum

Table I. Lumbar MRI parameters.

Parameters	Repetition time, ms	Echo time, ms	Slice thickness, mm	Field of view, mm	Matrix
Sagittal T1W	400-600	10	4	350-350	320x320
Sagittal T2W	2,800-3,000	54	4	350-350	320x320
Sagittal STIR	3,000-3,200	54	4	350-350	320x320
Axial T2W	2,800-3,000	119	4	250-290	256x256

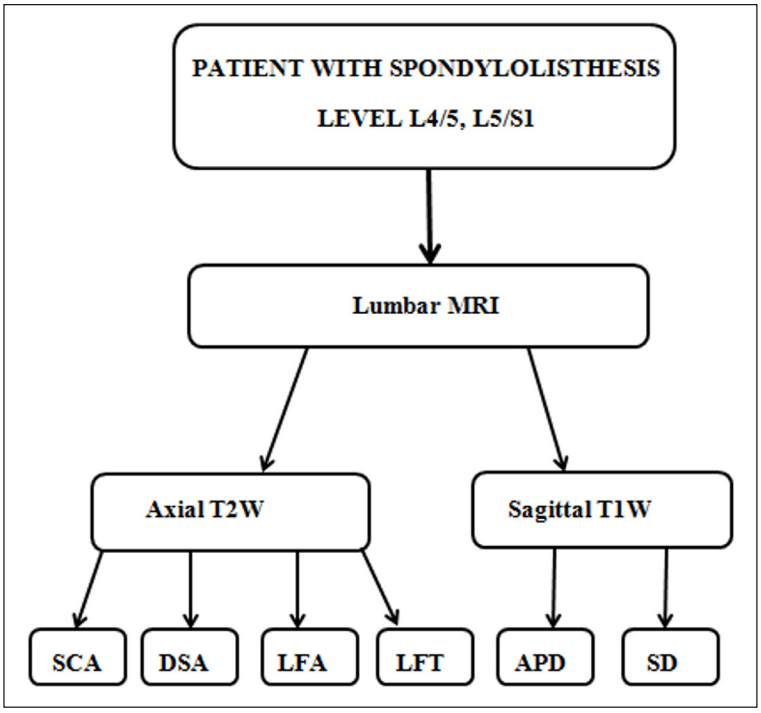

Figure 1. Flow diagram of this study.

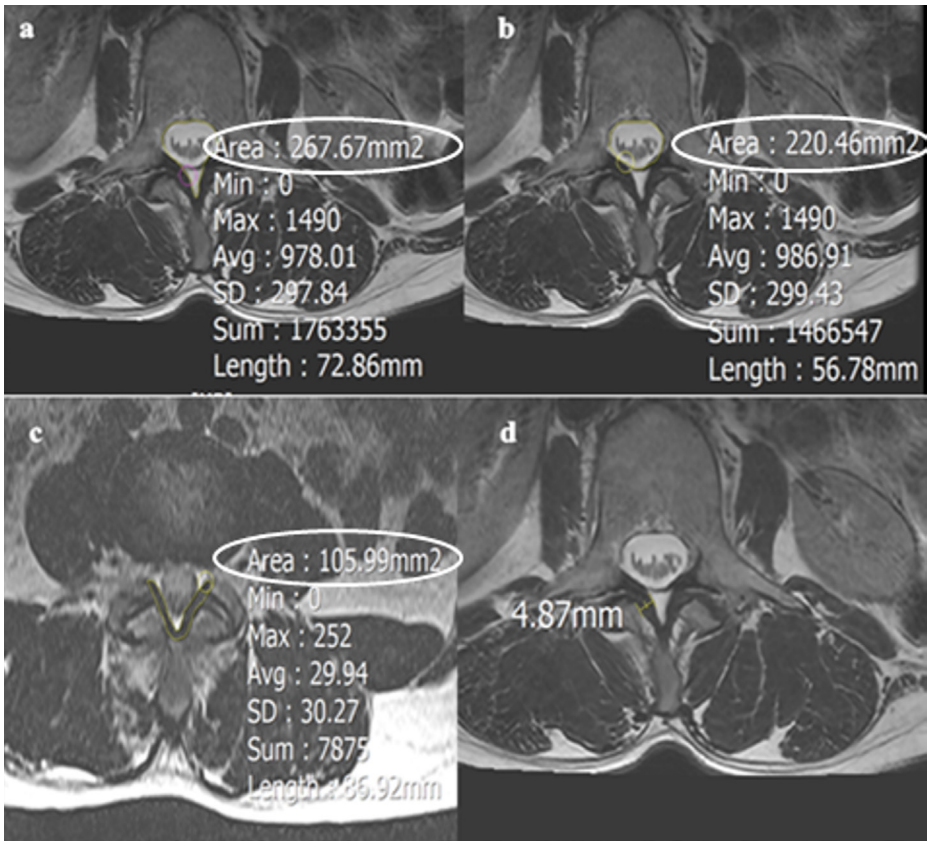

Figure 2. Measurement of morphologic parameters on axial T2W images at the spondylolisthesis level. **a**, Cross-sectional area of the spinal canal. **b**, Cross-sectional area of dural sac. **c**, Ligamentum flavum cross-sectional area. **d**, Ligamentum flavum thickness.

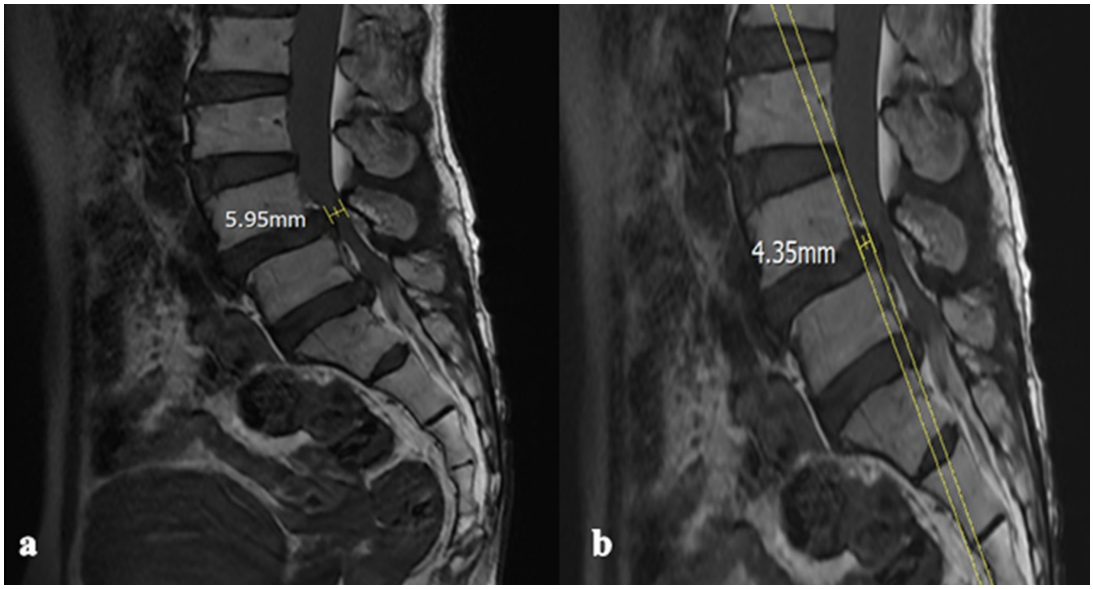

Figure 3. Measurement of morphologic parameters on the Sagittal T1W images at the spondylolisthesis level. a, Anteroposterior diameter. b, Sliding distance.

at the narrowest spondylolisthesis level. LFT was measured at the thickest point at the position of the spondylolisthesis. APD was measured midline from the posterior border of the vertebral body to the anterior margin of the posterior arch at the narrowest level at the position of the spondylolisthesis. SD is measured as the displacement of the upper vertebrae relative to the lower vertebrae.

Statistical Analysis

Statistical analysis was performed using SPSS 20.0 software (IBM Corp., Armonk, NY, USA) with conventional medical statistical algorithms. Quantitative variables are presented as the mean ± standard deviation. We compared the mean (SCA, DSA, LFA, LFT, SD, APD) between two groups VAS and ODI (group 1 and group 2), using an unpaired Mann-Whitney test. The relationship between the morphological parameters (SCA, DSA, LFA, LFT, SD, APD) and clinical symptoms through VAS and ODI were analyzed using Spearman's rank correlation test. $p<0.05$ was considered to indicate a statistically significant difference.

Results

A total of 100 patients with a definitive diagnosis of L4/L5, L5/S1 spondylolisthesis were included, of which 24 men and 76 women.

There was no statistically significant difference in SD, APD, SCA, DSA, LFA, and LFT indexes between the male and female groups with $p>0.05$ (Table II).

Table II. MRI characteristics.

Sex / Morphological parameters	Male	Female	Total	p
SD (mm)	4.4±2.0	4.7±2.1	4.6±2.0	p=0.431
APD (mm)	9.4±3.0	8.8±3.7	8.9±3.5	p=0.381
SCA (mm^2)	177.4±109.2	147.5±82.9	154.7±90.3	p=0.272
DSA (mm^2)	100.2±58.2	87.3±54.8	90.4±55.6	p=0.321
LFA (mm^2)	120.1±51.8	95.9±33.7	101.7±39.9	p=0.072
LFT (mm)	3.6±1.1	3.1±0.9	3.3±1.0	p=0.109
VAS	4.7±1.8	5.2±2.1	5.1±2.0	p=0.197
ODI (%)	29.8±19.1	34.1±18.3	33.0±18.5	p=0.212

SD: sliding distance, APD: anterior-posterior diameter. SCA: cross-sectional area of the spinal canal, DSA: cross-sectional area of dural sac (DSA), LFA: ligamentum flavum cross-sectional area, LFT: ligamentum flavum thickness. VAS: Visual Analogue Scale. ODI: Oswestry Disability Index.

Table III. The relationship between morphologic parameters and VAS.

		SCA (mm^2)	DSA (mm^2)	APD (mm)	SD (mm)	LFA (mm^2)	LFT (mm)
Mean ± standard deviation	VAS≤6	159.9±93.7	90.5±51.9	9.2±3.7	4.7±1.9	102.3±42.9	3.2±1.0
	VAS>6	146.4±85.1	90.2±61.8	8.6±3.2	4.6±2.3	100.7±35.2	3.3±0.9
p		*p*=0.613	*p*=0.734	*p*=0.529	*p*=0.515	*p*=0.818	*p*=0.774

SD: sliding distance, APD: anterior-posterior diameter. SCA: cross-sectional area of the spinal canal, DSA: cross-sectional area of the dural sac, LFA: ligamentum flavum cross-sectional area, LFT: ligamentum flavum thickness. VAS: Visual Analogue Scale.

Table IV. The relationship between morphologic parameters and ODI.

		SCA (mm^2)	DSA (mm^2)	APD (mm)	SD (mm)	LFA (mm^2)	LFT (mm)
Mean±standard deviation	ODI≤40	169.5±92.0	99.6±55.0	9.4±3.6	4.7±2.1	100.9±41.9	3.2±0.9
	ODI>40	124.5±79.8	71.6±52.8	7.9±3.1	4.6±2.0	103.4±36.1	3.5±1.0
p		*p*=0.027	*p*=0.010	*p*=0.045	*p*=0.703	*p*=0.649	*p*=0.245

SD: sliding distance, APD: anterior-posterior diameter. SCA: cross-sectional area of the spinal canal, DSA: cross-sectional area of the dural sac, LFA: ligamentum flavum cross-sectional area, LFT: ligamentum flavum thickness. ODI: Oswestry Disability Index.

The relationship between morphologic parameters on MRI and VAS is presented in Table III. No statistically significant differences in the SCA, DSA, LFA, LFT, APD, and SD between the groups with mild/moderate pain (VAS ≤6) and the group with severe pain (VAS >6).

The relationship between morphologic parameters on MRI and ODI is presented in Table IV. In the group of patients with severe disability (ODI >40%), the mean values of the APD, SCA, and DSA were smaller in the group with mild/moderate disability (ODI ≤40%) with $p<0.05$. No statistically significant differences in the LFA, LFT, and SD between the two groups of patients with severe disability (ODI >40%) and mild/moderate disability (ODI ≤40%) (Table IV).

The Relation Between the Morphologic Parameters and VAS

There were no statistically significant correlations detected between the VAS score and the SD, APD, SCA, DSA, LFA, and LFT with $p>0.05$ (Table V).

The Relation Between the Morphologic Parameters and ODI

A statistically significant linear association was found between ODI and the SCA (r=-0.259, $p=0.009$); DSA (r=-0.275, $p=0.006$) and APD (r=-0.242, $p=0.015$) showing that the smaller CSA, DSA, APD, the higher the ODI (Table V and Figure 4). There were no statistically significant correlations detected between ODI and the SD, LFA, and LFT with $p>0.05$ (Table V).

Discussion

Through the study, we found that the parameters of MRI reflect the clinical relevance of patients with spondylolisthesis. Specifically, in patients with spondylolisthesis, the imaging signs on MRI reflect the degree of spinal dysfunction in different areas expressed through the patient's ODI score. Also, it was shown that the pain scale on clinical VAS has no relationship in terms of imaging on MRI.

Table V. The relation between the morphologic parameters and clinical symptoms.

Clinical symptoms	Morphological parameters
VAS	There is no correlation with SD, APD, SCA, DSA, LFA, LFT, SD with corresponding *p*: *p*=0.438; 0.339; 0.416; 0.286; 0.769; 0.315.
ODI	SCA (r=-0.259, *p*=0.009) DSA (r=-0.275, *p*=0.006) APD (r=-0.242, *p*=0.015) There is no correlati on with LFA, LFT, SD with *p*=0.792; 0.197; 0.320.

SD: sliding distance, APD: anterior-posterior diameter, SCA: cross-sectional area of the spinal canal, DSA: cross-sectional area of the dural sac, LFA: ligamentum flavum cross-sectional area, LFT: ligamentum flavum thickness, VAS: Visual Analogue Scale, ODI: Oswestry Disability Index.

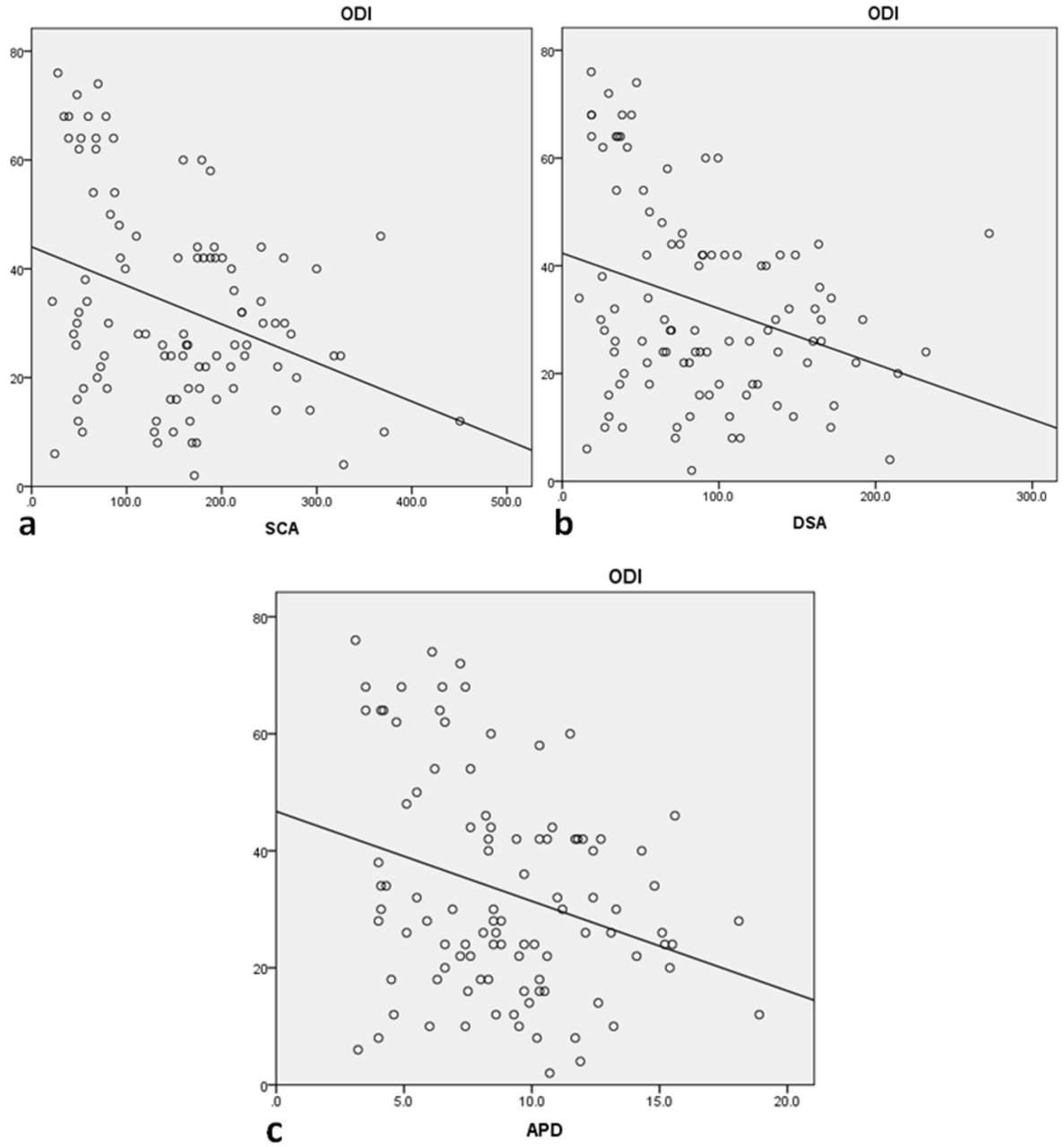

Figure 4. The correlation between ODI and SCA (**a**), ODI and DSA (**b**), ODI and APD (**c**).

Spondylolisthesis can be caused by different etiologies, including isthmic, traumatic, degenerative, pathologic, dysplastic, and postsurgical; among these, the most commonly reported are degenerative spondylolisthesis and isthmic spondylolisthesis[2]. The diagnosis of spondylolisthesis can be easily diagnosed on X-ray film with 4 position[16]. However, MRI is a valuable non-invasive imaging modality to evaluate nerve compression, spinal structures such as discs, facet joints, ligaments, bone structures, and compression nerve roots, spinal canal, lesions not detected on routine X-ray[5]. The relationship between clinical symptoms of patients with spondylolisthesis and imaging is not much evaluative data, a few studies[6,7] on imaging features on MRI of patients with spondylolisthesis and the clinical relationship across the single or combined characteristics such as psoas cross-sectional area, slippage rate, pelvic parameters such as pelvic incidence, pelvic tilt, sacral

slope, lumbar lordosis, L5 incidence. However, a few reports have found a relationship between the clinical symptoms of patients with spinal pain and imaging parameters by different diagnostic means, although, between different reports, there are many controversies regarding imaging and clinical disproportion[8-13]. In the case of significant spinal stenosis, the patient may have few or no clinical symptoms, in contrast, the patient may have clinical symptoms of spinal stenosis, but the imaging findings are not significant[17].

In our study, in the group of patients with severe disability (ODI >40%), the mean values of the APD, SCA, DSA were smaller in the group with mild/moderate disability (ODI ≤40%) with $p<0.05$. There was a statistically significant difference in APD, SCA, and DSA between the group of patients with spondylolisthesis with mild/moderate disability (ODI ≤40%) and the group with severe disability (ODI >40%). Also found a negative correlation between ODI and SCA, DSA, and APD with correlation coefficients respectively r=-0.259; r=-0.275, and r=-0.242 with $p<0.05$. This suggests that in patients with spondylolisthesis, the smaller the SCA, DSA, APD, the greater the possibility of nerve compression in the patient, which can cause more clinical symptoms. Our results are also consistent with some previous studies[18-20]. A study by Delamarter et al[18] found that motor and sensory disturbances can be enhanced with 50% or greater constriction of the cross-sectional area of the spinal canal. In addition, a cadaveric study by Schönström and Hansson[19] demonstrated that the dural sac is a relevant measure of nerve root compression in the spine, which indicates that the cross-sectional area of the dural sac, when less than 75 mm^2 may affect the normal function of the cauda equine nerve roots, reducing the size of the dural sac and cause impaired circulatory and/or neural function of the cauda equina. They also suggest that the smaller the spinal cord area, the higher the pressure among the nerve roots in the cauda equine[20]. Ogikubo et al[4] have shown that the cross-sectional area of the dural sac at the most constricted level was found to be a strong predictor of preoperative walking ability, leg and back pain, and health-related quality of life, the smaller the minimum cross-sectional area, the shorter the walking ability, the worse the pain intensity, and the poorer the quality of life. Nava-Bringas et al[21] showed that there is a correlation between ODI and slippage with a correlation coefficient of r=0.576. Gupta et al[9] have shown that the mid-sagittal diameter of the thecal sac showed a moderate negative correlation with ODI. Sigmundsson et al[22] also showed that there was a poor correlation between ODI and dural sac area, spondylolisthesis patients more often had small dural sac areas.

No statistically significant difference was found in the LFT, LFA, and SD between the two groups of patients with spondylolisthesis with mild/moderate disability (ODI ≤40%) and the group with severe disability (ODI >40%), as well as no correlation of parameters LFT, LFA, SD with ODI. The results of this study are similar to those of the literature. Zheng et al[6] have shown that slippage rate was not associated with ODI in patients with spondylolisthesis. Kim et al[23] also found no correlation between SD and ODI. However, the study of Kim et al[23] in patients with spinal stenosis, found a correlation between ODI, LFA, and LFT, suggesting that larger LFA and LFT values are associated with higher ODI values. However, their study was performed on patients with spinal stenosis, while our study was performed on patients with spondylolisthesis. In patients with spondylolisthesis, the vertebrae can slide forward or backward, which can be caused by different reasons such as degeneration, isthmic, or congenital, trauma, etc. The causes of spondylolisthesis due to isthmic, congenital, or vertebrae slide forward without spinal stenosis, are unlikely to be the cause of nerve root compression and are not the cause of the patient's clinical symptoms. Therefore, MRI parameters such as SD, LFT, and LFA may not reflect the degree of nerve compression causing clinical symptoms in patients with spondylolisthesis in our study. We consider the pathophysiology of spondylolisthesis to be complex, and although nerve root compression is a major contributor to the patient's main symptoms, inflammatory effects, and several other causes, such as psychological and sensory factors, which also influence both pain intensity and discomfort, cause different clinical symptoms[24].

On the other hand, the study did not find any statistically significant difference between the SD, APD, SCA, DSA, LFT, and LFA between the group of patients with spondylolisthesis with mild/moderate pain (VAS ≤6) and the group with severe pain (VAS >6). Furthermore, there were no statistically significant correlations detected between the VAS and the SD, APD, SCA, DSA, LFA, and LFT. This is also consistent with the results of several studies[22,23]. Kim et al[23] showed that no statistically significant correlation was found between VAS and DSA, SCA, LFA, and

LFT. Sigmundsson et al[22] did not find any correlation between leg and back pain scores and the size of the dural sac area. Lohman et al[25] also indicated that no association was found between VAS in patients with spinal stenosis and dural sac areas measured on computed tomography. However, Ogikubo et al[4] have shown the minimum cross-sectional area was a strong predictor of preoperative walking ability leg, and back pain, and was directly related to the quality of life of patients with central spinal stenosis, the smaller the minimum cross-sectional area. We believe that pain is a subjective feeling of the patient, and the pain threshold of each patient is different. There are patients who suffer from persistent dull pain, but an acute episode of pain prompts the patient to go to the hospital for a check-up. As well as there are many factors that cause pain for patients in patients with spondylolisthesis, such as herniated disc compressing the nerve, narrowing of the intervertebral foramen, compressing the nerve in the foramen, or tearing the annulus fibrosus, disc degeneration, facet joint effusion, can cause subjective pain sensations for different individuals. The fact that nearly all lumbar structures can cause low back pain may be a possible explanation[26,27]. Therefore, the VAS scores only reflect the patient's pain level from 0 to 10 points, it will not be as objective as the ODI to quantify disability with a questionnaire consisting of 10 topics: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, traveling. It may be the reason that the clinical assessment of pain level through the VAS scale does not correspond to the image on the MRI. Thus, the use of clinical assessment scales covering many areas, such as ODI, is more valuable for comparing clinical symptoms of imaging-compatible patients on MRI.

With our research showing that pain level is a subjective factor of each individual, there are many causes of acute pain over a patient's chronic pain episode, as well as not reflecting the correct degree of nerve compression in patients with spondylolisthesis. We believe that by using the ODI scale to assess clinically patients with spondylolisthesis, there will be a correlation between the extent of damage on imaging and the patient's clinical symptoms in many different areas of life. We recommend that clinicians examining patients with spondylolisthesis use the ODI score for spondylolisthesis rather than using the VAS pain scale.

Limitations

There are several limitations in this study. Firstly, our study evaluated data collection on routine MRI, the patient was in the lying position, but spondylolisthesis is an unstable disease of the spine, the conventional MRI only assesses the state of the spine and inevitably has limitations. There are several imaging techniques to solve these problems, such as dynamic magnetic resonance or gravity-bearing magnetic resonance[28]. Gravity magnetic resonance is a method of imaging with the patient's weight-bearing position, such as upright or weight-bearing, dynamic-kinetic, so it is easier to detect injuries of the lumbar spine. Second, the patients in our study who come to the hospital are mostly patients with clinical symptoms, we measure and evaluate groups of patients who have symptoms, without a control group. Third, we measured the data on the same system using the same measurement methods to collect the data, but individual anatomical variations, differences in cutting angles, and levels because of technical reasons, and heterogeneous data may be obtained.

Conclusions

Our study showed that in patients with spondylolisthesis, the APD, SCA, and DSA are important parameters in imaging and correlate with clinical symptoms. Decreased anteroposterior diameter, spinal canal cross-sectional area, and dural sac cross-sectional area suggest decreased spinal function. However, the MRI findings did not correlate with the patient's clinical pain level.

Ethics Approval

The study was approved by the Medical Ethics Committee of Hanoi Medical University (reference number: 4084/QĐ-ĐHYHN dated September 30, 2022) and conducted according to the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Informed Consent

Informed consent was waived by the Medical Ethics Committee of Hanoi Medical University for the study's retrospective nature; the analysis used anonymous clinical data.

Authors' Contributions

Nguyen Duy Hung and Nguyen Minh Duc prepared, drafted, and revised the manuscript critically, for important intellectual content. Nguyen Duy Hung and Nguyen Minh Duc contributed substantially to the acquisition, analy-

sis, and interpretation of data. Each author gave final approval to the version of the manuscript submitted for publication and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are not publicly available due to privacy concerns but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

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