ORIGINAL ARTICLE

Correlation of the Risk Factors in Degenerative Lumbar Spondylolisthesis with MRI Imaging

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ABSTRACT

Introduction: Degenerative spondylolisthesis burdens the future economy. Elderly individuals with this condition suffer from back pain, limb paralysis, reduced activity, and diminished quality of life. Surgery offers relief but is risky and expensive. As healthcare improves, the aging population grows, and spondylolisthesis incidence rises. Early detection and risk factor management are vital for prevention. Therefore, this study aimed to evaluate the correlation of the risk factors for degenerative lumbar spondylolisthesis. **Methods:** A retrospective observational study was done in Dr Soetomo General Academic Hospital, Surabaya from January 2018 to December 2019. Forty-five subjects with degenerative spondylolisthesis diagnosed by MR Imaging enrolled in this study. Intervertebral disc, facet joint, multifidus muscle, and ligamentum flavum at level L1 until level L5 were examined using MR imaging. Correlation analysis was measured using the Spearman correlation test and risk factor analysis was measured using the logistic regression test. **Results:** There are significant correlations between intervertebral disc degeneration, facet joint osteoarthritis, multifidus muscle fatty infiltration, and thickening of ligamentum flavum with degenerative spondylolisthesis. The risk factors at levels L3-4 and L5-S1 are intervertebral disc degeneration and L4-5 is multifidus muscle fatty infiltration and facet joint osteoarthritis. **Conclusion:** This study confirmed the risk factors that correlated with degenerative lumbar spondylolisthesis.
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Keywords: Degenerative spondylolisthesis, Intervertebral disc, Facet joint, Multifidus, Ligamentum flavum

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INTRODUCTION

Around the age of 40, humans start to lose their lean tissue (muscles and bones). The spine also undergoes anatomical and morphological changes called degenerative processes. The initial degenerative process is disc degeneration which will cause secondary deterioration of the facets, ligaments, and muscles (1,2). This process also has a major effect on the spine, causing the slip of one vertebral body over the one below which we called spondylolisthesis (3,4).

Degenerative spondylolisthesis is an example of spinal instability resulting from progressive degeneration related to ageing (ageing-related degeneration). Lumbar spondylolisthesis is considered to be a significant source of back pain and disability. This disease can progress into spinal stenosis and result in neurogenic symptoms, such as leg pain, numbness, or weakness. It can cause an accumulating clinical-dysfunctional impact that ultimately impacts quality of life. (5)
A large population study of elderly Chinese people in Hongkong showed that degenerative spondylolisthesis prevalence was 25.0% in women and 19.1% in men with female : male prevalence ratio was 1.3:1 (4,5).

Most patients are managed with conservative therapy. However, surgical method is the only option when the conservative therapy was unsuccessful. Over 300,000 lumbar spine fusions are performed in the USA each year and this number is increasing. Many of these fusions are performed to correct the instability associated with degenerative spondylolisthesis (5,6). Zhu R, et al (2017) stated that the major local reasons that probably lead to the development of degenerative vertebral slippage may be disc degeneration, arthritis of the facet joints, malfunction of the ligamentous stabilizing component, and ineffective in muscular stabilization (7).

Degeneration of intervertebral disc, facet joint osteoarthritis, and thickening of ligamentum flavum

has been identified as the cause of degenerative spondylolisthesis (8,9). The multifidus muscle fatty infiltration also causes a reduction in spine muscle tension and loses its effective control mostly at the level of L4-5, causing lumbar instability (10,11). However, there is also no regional data about degenerative spondylolisthesis that has ever been reported yet. This study aimed to investigate the correlation and risk factors for degenerative lumbar spondylolisthesis.

MATERIALS AND METHODS

Population and sample

The inclusion criteria of our study were patients aged 40 years and above that diagnosed with lumbar spondylolisthesis. Shilpa A, et all (2018) state that after the age of 40, people start losing their lean tissue (muscles and organs), bones and water (12). Exclusion criteria were: accident or trauma involving the spine, previous spine surgery , congenital spine defect and spine tumour. From January 1st 2018 to December 31th 2019 there were 259 patients who underwent MR Lumbar Imaging. There were 297 patients diagnosed with spondylolisthesis but only 45 patients that meets our criteria and were included as our sample. In every sample we collected data for each level of lumbar vertebra from 1st-5th level of vertebra (total 225 levels of lumbar vertebra were evaluated).

MR Protocol

The evaluation was performed on a 3T MRI scanner (Siemens MAGNETOM Skyra, Siemens AG German) with imaging sequences; axial T1-weighted (TR 550-650/TE 8.28 ms), axial T2-weighted (TR 42500-4400/ TE 106.5 ms), sagittal T1-weighted (TR 245-260/TE 19.8 ms) and sagittal T2-weighted (TR 1500-1650/TE 102.6 ms).

Image interpretation

Images were evaluated by a radiologist with over 20 years of academic experience as a consultant in musculoskeletal/ bone and joint radiology. The images are processed in workstation AW VolumeShare 5 from GE Healthcare. The intervertebral discs were analysed in sagittal T2-weighted images. Multifidus muscles were analysed in axial T1-weighted images. Facet joints and ligamentum flavum were analysed in axial T2-weighted images.

Intervertebral disc

Intervertebral disc degeneration was evaluated according to the Pfirrmann grading scale, which represents the progression of disc degeneration. A study about this classification conducted by Urrutia J, et all (2016) showed that the Pfirrmann classification demonstrated an adequate agreement among different observers and by the same observer on separate occasions. Furthermore, it allows communication between radiologists and spine surgeons (13).

Facet joints

Facet joints were evaluated according to the Pathria grading scale, which indicates the severity of facet joint osteoarthritis. This grading scale widely uses for radiographic evaluation in facet joint degeneration. A study by Zhou X, et all (2016) found that current radiographic techniques (Pathria grading scale) had moderate accuracy and reliability for assessing facet joint degeneration (14).

Multifidus muscles

Fatty infiltration of the multifidus muscles was evaluated according to the Goutallier classification. A reliability study conducted by Soares RO, et all (2021) found that the Goutallier Classification System showed moderate interobserver and almost perfect intraobserver agreement in the evaluation of the fat infiltration rate of the multifidus muscle (15).

Ligamentum flavum

Ligamentum flavum thickness was measured at the thickest area, mid of facet joint level (16).

Statistical analysis

The data was analysed using SPSS 23. Correlation analysis was measured using the Spearman correlation test and risk factor analysis was measured using the logistic regression test to identify the risk factor for degenerative spondylolisthesis at each level of the lumbar vertebra.

Ethical consideration

This study has met the ethical principles of and received approval from the Research Ethics Committee of Dr. Soetomo General Academic Hospital, Surabaya. Reference number: 0291/LOE/301.4.2/I/2021

RESULTS

A total of 45 subjects were included in this retrospective study. There were 27 males and 18 females with an age range between 40 to 79 years with an average of 61.93 years. There are 41 cases with single-level listhesis and 4 cases with double-level listhesis. Listhesis mostly found at level L4-5 (35, 71.4%), L5-S1 (9, 18.4%) and L3-4 (5, 10.2%).

We evaluated the characteristic of degenerative spondylolisthesis from 225 levels of lumbar vertebrae from L1 to L5 including the level of spondylolisthesis, disc degeneration, facet joint osteoarthritis, multifidus muscles fatty infiltration and thickening of ligamentum flavum on each level vertebra (Table I).

Intervertebral disc

All intervertebral discs have degenerated with various degrees of degeneration with most findings being grade III (80, 35%) and grade IV (56, 24.9%) (Figure 1).

Table I: Frequency and distribution for each variable

Variable	Level/Grade	Frequency and percentage
Level of spondylolisthesis	L3-L4	5 (10.2%)
	L4-L5	35 (71.4%)
	L5-S1	9 (18.4%)
	Total	49 (100%)
Intervertebral disc degeneration	Grade I	0 (0%)
	Grade II	55 (24.4%)
	Grade III	80 (35.6%)
	Grade IV	56 (24.9%)
	Grade V	34 (15.1%)
	Total	225 (100%)
Facet Joint Osteoarthritis	Grade I: Normal	52 (22.7%)
	Grade II: Mild	97 (43.1%)
	Grade III: Moderate	50 (22.2%)
	Grade IV; Severe	27 (12.0%)
	Total	225 (100%)
Multifidus muscle atrophy	Normal	40 (17.8%)
	Grade 1	69 (30.6%)
	Grade 2	88 (39.1%)
	Grade 3	22 (9.8%)
	Grade 4	6 (2.7%)
	Total	225 (100%)
Thickening of Ligamentum Flavum	Right	Mean: 3.2 mm; Max 6.7 mm
	Left	Mean: 3.1 mm; Max 6.6 mm

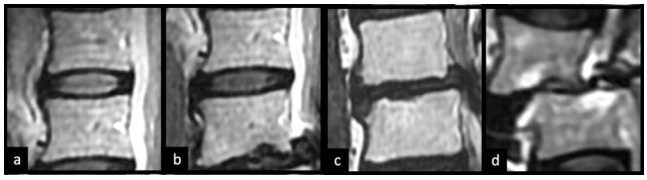

Figure 1: Grade of disc degeneration based on Pfirrmann grading scale (range II to V); Grade I, the healthy disc is not included in this figure. (a) Grade II: clear nucleus, hyperintense, normal height. (b) Grade III: nucleus unclear, mild hypointensity, slightly decreased height. (c) Grade IV: loss of nucleus, hypointense, significantly decreased height. (d) Grade V: collapsed disc space

Facet Joint

Facet joint osteoarthritis was found mostly in grade II (97, 43.1%) and grade I (51, 22.7%) (Figure 2).

Multifidus muscles

Goutallier classification showed that muscle fatty infiltration wasmostly grades 2 (88, 39.1%) (Figure 3).

Ligamentum flavum

This study also found the thickening of ligamentum flavum with the maximum thickness of right ligamentum flavum 6.7 mm and left ligamentum flavum 6.6 mm (Figure 4).

A positive correlation was found in all variables. Intervertebral disc degeneration, facet joint osteoarthritis, and multifidus muscle fatty infiltration have a moderate correlation with degenerative spondylolisthesis and ligamentum flavum only has a weak correlation with degenerative spondylolisthesis (Table II). The risk

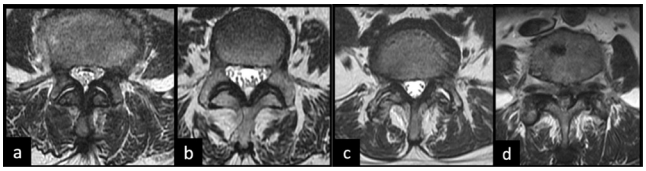

Figure 2: Grade of facet joint osteoarthritis based on pathria grading scale; (a) Grade I: normal. (b) Grade II: mild osteoarthritis. (c) Grade III: moderate osteoarthritis (sclerosis or moderate osteophyte). (d) Grade IV: severe osteoarthritis (marked osteophyte, joint irregularity, and deformity)

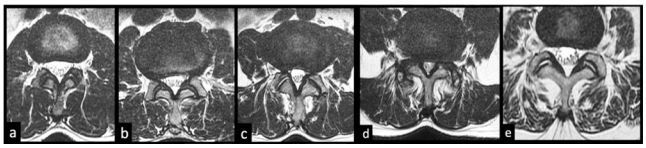

Figure 3: Grade of multifidus muscle fatty infiltration based on goutallier grading (range 0 to 4) on axial T1-weighted image. (a) Grade 0: normal muscle tissue. (b) Grade 1: fat streaks. (c) Grade 2: more muscle than fat. (d) Grade 3: equal amounts of fat and muscle tissue. (e) Grade 4: more amount of fat than muscle.

Figure 4: Measurement of ligamentum flavum using axial T2-weighted image at the thickest area, mid of facet joint.

Table II: Correlation between spine degenerative factors and degenerative spondylolisthesis

Factors	ρ [a]	Interpretation
Intervertebral disc	0.512**	Moderate
Facet joints	0.540**	Moderate
Multifidus muscle	0.431**	Moderate
Right ligamentum flavum	0.388**	Weak
Left ligamentum flavum	0.395**	Weak

[a]Correlation coeffient
**$P < 0,01$

factor at levels L3-4 and L5-S1 was intervertebral disc degeneration and L4-5 was multifidus muscle fatty infiltration and facet joint osteoarthritis (Table III).

Table 3. Risk factors for degenerative spondylolisthesis

Level vertebrae	Risk factors	*OR*[a]
L3-4	Intervertebral disc degeneration	5.61
L4-5	Multifidus muscle fatty infiltration	8.58
	Facet Joint osteoarthritis	11.1
L5-S1	Intervertebral disc degeneration	5.56

[a]Odd Ratio

DISCUSSION

The human body is composed of fat, muscles, bones and water. Around the age of 40, people start losing their lean tissue (muscles and bones) (12). This degenerative process begins after the first ten years of life and has a major effect on the spine (17). All tissues that maintain the spine's alignment and prevent the spine from slipping are affected by this process and resulting in the slip of one vertebral body over the one below that called spondylolisthesis (2). Spondylolisthesis caused by degenerative process occurs mostly at level L4–5, as degeneration has the greatest effect on spinal loads and mobility in this region (18). There are some explanations that could be the reason why intervertebral disc degeneration, facet joint osteoarthritis, and multifidus fatty infiltration have moderate correlation with degenerative spondylolisthesis.

The degeneration of the intervertebral disc in the lumbar region starts in the first decade of life and peaks during one's thirties (19). Disc degeneration is considered the initiating event that results in secondary deterioration of the facets, ligaments and muscles (1). In this process, the nucleus pulposus and annulus fibrosus start to lose their structural integrity, resulting in structural weakness and inability to maintain anatomical alignment, causing instability and spondylolisthesis (20).

The degenerative process in facet joint cartilage can begin as early as 15 years of age (21). The explanation for this might be that the degeneration in the facet cartilage will alter the mechanical function of the facet joint. Many studies have shown that facet morphology affects the progression of degenerative spondylolisthesis (22).

The multifidus muscle is the last factor that holds the spine alignment specifically at level L4-5 (8). The multifidus muscle starts to degenerate after the age of 30, and this process is even faster after the age of 60 (23). Multifidus muscle that is infiltrated by fat will lose its ability to effectively control spine tension, ultimately causing lumbar instability (11).

Ligamentum flavum start to degenerate at the age of 20 and tends to thicken with increasing age (21,23,24). The function of ligamentum flavum is to maintain body posture and preserve normal spine curvature (25). Repeated flexion-extension motion may lead to thickening of the ligamentum flavum (26).

We also investigated the risk factors for degenerative spondylolisthesis. Spondylolisthesis mostly occurs at level L4–5, the same level that is affected by facet joint osteoarthritis (16). A sagittal facet orientation at level L4-5 along with a degenerative process will cause facet joint osteoarthritis and alter the motion of the facet joints (27). Nevertheless, the more sagittal the orientation, the lessen amount of anterior restraint from the facet joint would be and thus can result in anterior slippage of the lumbar vertebra (24). Multifidus muscle is also an important factor to maintain spinal stability (23). This finding is similar with study conducted by Kalichman (2017) who found that there was a significant association between L4 multifidus/ erector spinae density and facet joint osteoarthritis at L4-5. Facet joint osteoarthritis and higher grades of fatty infiltration in the multifidus at level L4 also have a significant association with spondylolisthesis at the same level (28). This result is also confirming the previous biomechanical in vitro study conducted by Wilke (1995). He tested four different paraspinal muscles (multifidus, iliocostalis, longissimus and psoas major) at level L4-5 in seven human cadaveric lumbosacral spines and found that multifidus muscle group had the strongest influence in maintaining spine stability at level L4-5 (10).

We also found that the risk factor for degenerative spondylolisthesis at level L3-4 and L5-S1 are intervertebral disc degeneration. Even though facet joint at level L3-4 has the same sagittal facet joint orientation as L4-5, level L3-4 is more stable due to the specific anatomy of quadratus lumborum muscle and lesser effect on spinal loads. Even bodyweight had the greatest effect on spinal loads at the L4-5 and L5-S1, the spinal level at L5–S1 was more stable than L4-5 due to lesser flexion-extension motion range (29). The stability level L5-S1 is provided by large transverse processes supported by strong iliolumbar and possibly ventral sacroiliac ligaments (25,30,31). The oblique orientation of the lumbar facets also contributes to resistance to intervertebral shear force at this level (30). From our finding, we suggest that spondylolisthesis that occurs at level L4-5 really depend on the degenerative process of the facet joint and multifidus muscle.

There are several limitations to this study. First, we only analysed patients with degenerative spondylolisthesis, excluding patients with degenerative spine disease without spondylolisthesis as the control group. Second, we did not perform an analysis to investigate other factors that restrain level L5-S1. Further study should be performed with prospective approach and control groups particularly at level L4-5 and L5-S1 to confirm this finding.

CONCLUSION

This study showed that degenerative lumbar spondylolisthesis is commonly seen at level L4-5. Intervertebral disc degeneration, facet joint osteoarthritis, multifidus muscle fatty infiltration and thickening of ligamentum flavum have weak to moderate correlation with degenerative spondylolisthesis. The risk factors for degenerative spondylolisthesis at level L4-5 are facet joint osteoarthritis and multifidus muscle fatty infiltration. The risk factor at levels L3-4 and L5-S1 is intervertebral disc degeneration.

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