RADIOLOGICAL ASSESSMENT OF SPONDYLOLISTHESIS OF LUMBOSACRAL SPINE

Antonio Đopa,
University Hospital Center Mostar

Submited: October 24, 2024
Accepted: November 2, 2024
DOI: https://doi.org/10.48026/issn.26373297.2024.1.15.3

SUMMARY

Introduction: One major injury or frequent minor injuries cause the vertebral body, pedicle and superior articular surfaces to slide forward. This disorder is known as spondylolisthesis and is usually accompanied by symptoms, often proportional to the degree of forward movement. Patients may complain of pain in the lower back that spreads to the thighs, and limited range of motion is possible

Objectives: The aim of this study is to determine the frequency of spondylolisthesis by age and gender in the patients studied at SKB Mostar.

Research methodology: The method of content analysis was used to retrospectively examine X-ray, CT and MRI examinations of patients with the clinical features of lumbar pain syndrome in the period from 1 January 2019 to 1 January 2020 in patients who underwent radiological examination of the LS spine at the Clinical Institute of Radiology of the University Clinical Hospital Mostar. Data were collected from IMPAX at the SKB Mostar Department of Radiology. The input parameters that were observed were: pain syndrome, diagnosis. The output parameters were the radiological findings from the X-ray, CT, and MRI scans.

Results: During the study period, 297 spinal scans were performed, and spondylolisthesis was found in 32 patients, or 11%. The youngest respondent was 8 years old, and the oldest was 85 years old. The average age of the respondents was 64.37 years. The largest number of respondents was in the age group of over 75 years old. Of the tests performed, the most common were CT scans, followed by MRI, and the rarest were X-ray scans. The highest prevalence of spondylolisthesis was found in vertebrae L4-L5 and L5-S1 at 41%. Spondylolisthesis was found bilaterally in 9% of cases at the L3-L4 and L5 vertebrae.

Conclusion: Most often, spondylolisthesis is found in L4-L5 and L5-S1 vertebrae. There was no difference according to gender, and most often subjects older than 75 years had spondylolisthesis.

1. INTRODUCTION

The term spondylolisthesis refers to a pathological condition caused by the forward displacement of the upper part of the vertebra in relation to the lower part. Kilian used the name spondylolisthesis for the first time in 1854, it originated from the Greek words spondylo (spine) and olisthesis (to slip), it was observed as early as in the 18th and 19th centuries. Spondylolysis is a bone defect that probably arises from the trauma of the congenitally abnormal pars interarticularis (aside from the junction of the pedicle with the lamina) of the lower lumbar vertebrae, and is best visualized with oblique radiographs or CT scans. Some people have bilateral damage.

One major injury or frequent minor injuries cause the vertebral body, pedicle and superior articular surfaces to slide forward. This disorder is known as spondylolisthesis and is usually accompanied by symptoms, often proportional to the degree of forward movement. Patients may complain of pain in the lower back that spreads to the thighs, and limited range of motion is possible. Pain is often elicited next to the displaced vertebra (usually L5 on S1 or sometimes L4 on L5), and a step-off may be felt upon deep palpation of the posterior elements above the affected joint. In moderate to severe dislocations, pelvic rotation may occur, along with limited hip flexion due to spasm of the hamstring muscles. A variety of neurological deficits, usually minor, can be found that indicate radiculopathy. In the case of extremely severe spondylolisthesis, the vertebral body may be shortened and the abdomen protruding, due to the extreme displacement of L5 relative to S1 (1).

Few entities in spinal pathology have as much variability in anatomic, clinical, and therapeutic aspects as spondylolisthesis. Some spondylolisthesis progress, some do not; some spondylolisthesis are painful, some are painless. Spondylolisthesis also occurs at a younger age, and not only as a degenerative process in the elderly, and its course and outcomes are different, it is necessary to have exceptional knowledge of clinical and diagnostic indications for the application of the correct method of treatment of this disorder.

Spondylolisthesis is often an incidental radiological finding in asymptomatic patients who have undergone diagnostic evaluation for another issue, and in many cases, no specific treatment is necessary. In most patients with symptomatic spondylolisthesis, conservative therapy is sufficient, and if there are significant difficulties, surgical treatment is considered.

Spondylolysis is usually asymptomatic and can be found accidentally on radiographic examination. If the patient is symptomatic with lower back pain, the pain will generally be worse with back flexion. Visual examination of the child may reveal lumbar hyperlordosis.

Structures that can be easily and quickly determined on the patient's body are taken as orientation points for spinal radiography. The xiphoid process of the sternum determines the optimal position of the upper edge of the image receptor for radiography of the lumbar and lumbosacral spine. The upper margin of the iliac crest is located at the level of the L4 vertebral body and is used as a reference point for the entry of the central ray in radiography of the lumbar and lumbosacral spine.

In the AP projection of the lumbar (lower back) and lumbosacral (lower back-sacral) spine, a supine position is used. The shoulders and hips must be in the same horizontal plane. The

central plane of the body should be aligned with the center of the grid. The arms should be flexed at the elbows and crossed at the chest. The legs are flexed in the hips and knees to flatten the physiological lordosis. The image receptor for the lumbosacral spine is 35x43 cm or 30x40 cm; usually, a narrower collimation of the X-ray beam is sufficient, so a format of 18x43 cm is used, except in cases of scoliosis; the center is positioned at the iliac crest at the level of the L4 vertebra, with the upper margin at the level of the xiphoid. For the lumbar spine, a 24x30 cm image receptor is used, and the center of the receptor is placed 4 cm above the iliac crest. The central ray is perpendicular and enters the median plane at the level of the junction of the iliac crests and the lumbosacral spine. For the lumbar spine, the central ray enters 4 cm cranially. The focus-to-film-distance is at least 120 cm to reduce object distortion.

The profile projection in the traumatized patient is performed so that the patient is on his side, in a clean profile position. The arms are under the head or stretched out above the head. The median plane is parallel to the imaging table. The legs are flexed at the knees and drawn towards the body (Figure 13A). The image receptor for the lumbosacral spine is 30x40 cm or 35x43 cm (in cases of severe scoliosis or hyperlordosis), but an 18x43 cm format is usually sufficient. It is centered on the iliac crest. For the lumbar spine, a film format of 24x30 cm is sufficient. The upper edge of the receptor is positioned at the level of the xiphoid process of the sternum and centered 4 cm cranially from the iliac crests.

The central ray for the lumbosacral spine is directed perpendicularly to the top of the iliac crest (L4), while for the lumbar spine, it is directed 4 cm cranially from the iliac crests. Sometimes it is necessary to angle the central ray 5-10° cranially for a more massive torso in relation to the pelvis, or caudally for a very wide pelvis and narrow shoulders. The central ray always enters at the mid-axillary line, and is recorded in full expiration.

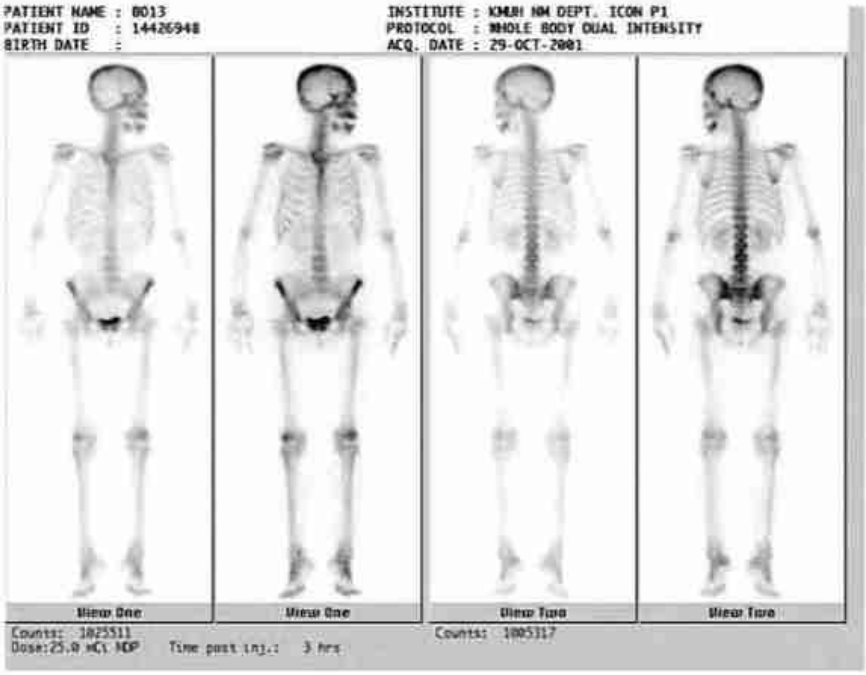
In the lateral projection of the lumbosacral junction, the patient lies on the left or right side. Arms are placed above the head. The legs are flexed at the knees and drawn towards the body. The image receptor is 18x24 cm. The central ray targets the space between L5/S1, which is approximately 5 cm posterior to the anterior superior iliac spine that determines the height of the imaging field. The radiograph must show the vertebral bodies, the spinous and transverse processes, as well as the posterior arches of the L5/S1 vertebrae (2).

Bone scintigraphy is a highly sensitive examination that can detect changes in the bones up to 6 months earlier than X-ray imaging. In some diseases, imaging is performed in two phases (two phase bone scintigraphy) to assess the status of the blood pool, and in certain situations, three phases (triple-phase bone scintigraphy) are conducted when we want to evaluate the perfusion of a specific area of the body or a pathological process (18).

Bone scintigraphy is performed 3 hours after intravenous administration of the radiopharmaceutical using a wide-field gamma camera with a high-resolution collimator. Adults are administered 555-740 MBq (15-20 mCi) of Tc-99m-labeled diphosphonate or polyphosphate compound, while children receive approximately 37 MBq (1 mCi) per 10 kilograms of body weight. Today, methylene diphosphonate (MDP) is most commonly used. Immediately after the injection of the radiopharmaceutical, dynamic scintigrams are recorded at one-second intervals during the first minute, providing a display 14 of perfusion in a specific region of the skeleton during this initial phase. Fifteen minutes after the injection, the second phase follows, which is an early delayed

Print: ISSN 2232-8726
Online: ISSN 2637-3297

scintigraphy that provides a representation of the distribution of the radiopharmaceutical in the vascular spaces, also known as blood pool scintigraphy. The third phase is a conventional static scintigraphy that is performed 3 hours after the injection. Among the quantification methods, we most commonly use the region of interest (ROI), which compares the activity in the region of pathological changes with the activity in the region of healthy bone. This gives us the index of the ratio of activity of the pathological bone changes to that of the normal bone. Bone scintigraphy is applied in nearly all diseases of the skeleton, whether of the bones or joints (19).



Source: www.scintigrafija_skeleta/Images
Figure 4 Bone (skeleton) scintigraphy

Computed tomography (CT) is a diagnostic imaging method that uses X-rays to create images of individual cross-sectional layers of the body. The principle of operation is based on the attenuation of X-rays as they pass through the part of the body being imaged. The attenuation of X-rays is expressed by the absorption coefficient, which depends on the atomic number, the electron density of the tissue, and the energy of the X-rays. After passing through tissues of different densities, attenuated radiation falls on detectors that convert it into an electrical signal proportional to the attenuation of the imaged object. From a series of projections created during the rotation of the X-ray tube and the detector, complex mathematical algorithms with the help of a computer reconstruct the image of the object and display it on the screen in the form of an image matrix composed of pixels. The values of X-ray absorption in thin cross-sectional layers of the patient's body are visually displayed on the TV screen using a grayscale. The resulting image is transferred to storage media.

Source: IMPAX SKB Mostar
Figure 5 CT scan of spondylolisthesis

CT scan is a systematic collection and display of data obtained from numerous projections using X-rays. It is an ideal method of displaying bone structures including vertebral bodies, pedicles, laminae and articular surfaces of small joints.

The resulting image is the result of a process in two separate phases:

1st X-ray scanning

2nd computerized image reconstruction

The collimation of the radiation beam is selected based on the object being examined. If a smaller organ and/or a structure parallel to the X-ray beam is being examined, a beam collimation of 3-5 mm should be used. An even thinner collimation (1-2 mm) is required for a detailed analysis of pulmonary structures in interstitial diseases. Thicker collimation is sufficient for larger parenchymal organs. In multi-layer or multidetector CT (MDCT), thin collimation has become the standard, and thicker layers can be obtained by reconstruction from thinner ones.

Before performing the examination, mental and physical preparation of the patient is required. Mental preparation involves familiarizing the patient with the method and course of the examination, if the patient's condition allows it. Physical preparation involves removing all unnecessary clothing items, garments, jewelry, and other metallic objects from the area of the body being scanned. It is mandatory to take care of the immobilization of the patient. It is important to warn the patient not to move during the imaging and not to swallow. In comatose patients, the use of fixation straps and pads is mandatory. Protection is mandatory and is carried out by placing a lead apron around the patient, ensuring that the area of imaging is not covered (20).

Positioning involves placing the patient in a comfortable position, symmetrical in relation to the substrate with adequate radiation protection. Cushions are placed under the head, knees, or lower legs to ensure the patient's comfort, which will help reduce potential motion artifacts. To avoid artifacts, hands should be removed from the scanning area; it is best if possible to place them overhead. All metal objects should also be removed from the scanning field.

Spiral CT has completely replaced the use of conventional X-ray imaging in cases of spinal trauma. It can also be used in patients who are not otherwise suitable for MRI examination (have a *pacemaker*, are claustrophobic), as well as preoperatively in patients in whom MRI examination is not possible for any reason. Computed tomography lasts much shorter, is cheaper and more accessible to patients. In CT, multiplanar reconstruction is essential, as fractures may sometimes be difficult to visualize on transverse CT sections if the fracture line is parallel to the transverse plane. CT angiography of the thoracic aorta is an integral part of the evaluation of patients with thoracic spine injury (21).

Print: ISSN 2232-8726
Online: ISSN 2637-3297

Routine scans are performed with a thickness of 3 mm, using sagittal, coronal, and axial MPRI (*multiplanar reformatted images)* cross-sections.

Radiological findings play a very important role in determining or excluding pathological conditions and, most importantly, in further deciding on the treatment process. Although conventional radiography, computed tomography and MRI are the gold standard, MRI leads the way as the best technique for spinal imaging due to its high contrast, spatial resolution and the fact that it does not emit ionizing radiation. MRI imaging also provides multi-layer reconstruction and high contrast resolution to characterize various lesions (22).

Manifestations on MRI scans include narrowing of the intervertebral space, loss of disc signal on T2-weighted images (dehydration), fissures, fluid, calcifications, ligamentous changes, bone marrow changes, herniation, osteophyte formation, spondylolisthesis, and spinal canal stenosis (23).

Radiography still represents the first radiological method in the assessment of an injured spine. Since X-rays provide only limited information, all patients with positive X-ray findings, as well as those with negative findings but with a clinical suspicion of spinal injury, require a computed tomography (CT) scan or magnetic resonance imaging (MRI) for a complete evaluation

Source: IMPAX SKB Mostar
Figure 6 MRI before surgery

Source: IMPAX SKB Mostar
Figure 7 X-ray after surgery

Source: IMPAX SKB Mostar
Figure 8 MRI of spondylolisthesis

2. RESEARCH OBJECTIVE

The aim of this study is to determine the frequency of spondylolisthesis by age and gender in the patients studied at SKB Mostar.

3. RESEARCH METHODOLOGY

The method of content analysis was used to retrospectively examine X-ray, CT and MRI examinations of patients with the clinical

features of lumbar pain syndrome in the period from 1 January 2019 to 1 January 2020 in patients who underwent radiological examination of the LS spine at the Clinical Institute of Radiology of the University Clinical Hospital Mostar.

Data were collected from IMPAX at the SKB Mostar Department of Radiology. The input parameters that were observed were: pain syndrome, diagnosis. The output parameters were the radiological findings from the X-ray, CT, and MRI scans.

SPSS for Windows and Microsoft Office Excel 2010 were used for statistical data processing. For the statistical analysis of the obtained data, the SPSS for Windows software system was used (version 13.0, SPSS Inc. Chicago, Illinois, USA) and Microsoft Excel (Office 2010 version, Microsoft Corporation, Redmond, WA, USA).

3.1. Research hypothesis

H1: Spondylolisthesis occurs more often in females

H2 Congenital spondylolisthesis occurs more often at a younger age, and degenerative spondylolisthesis at an older age

4. RESULTS

Of a total of 297 spinal scans during the study period, 32 or 11% were found to have spondylolisthesis.

In the further study, a total of 32 participants were involved, all of whom were confirmed to have spondylolisthesis through CT and MRI examinations. There were no findings of spondylolisthesis in the X-ray examination.

The youngest respondent was 8 years old, and the oldest was 85 years old. The average age of the respondents was 64.37 years.

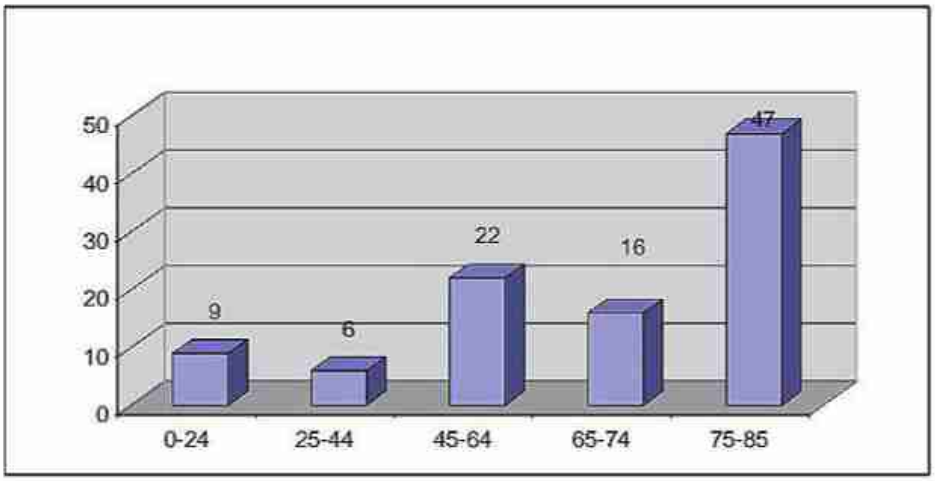


Table 1 Distribution of respondents by age groups

Print: ISSN 2232-8726
Online: ISSN 2637-3297

The largest number of respondents, 47% of them are in the age group older than 75 years. The second most represented age group is 45-64 years, accounting for 22%, followed by 65-74 years at 16%, those under 24 years at 9%, while the least represented age group is 25-44 years, with 6% of participants.

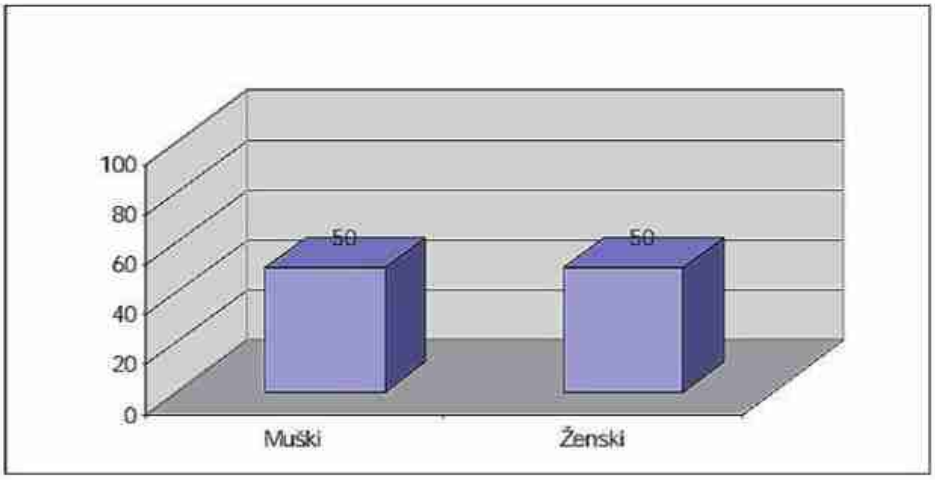


Table 2 Distribution of respondents by gender

In terms of gender, both men and women are equally represented, both groups with 50%.

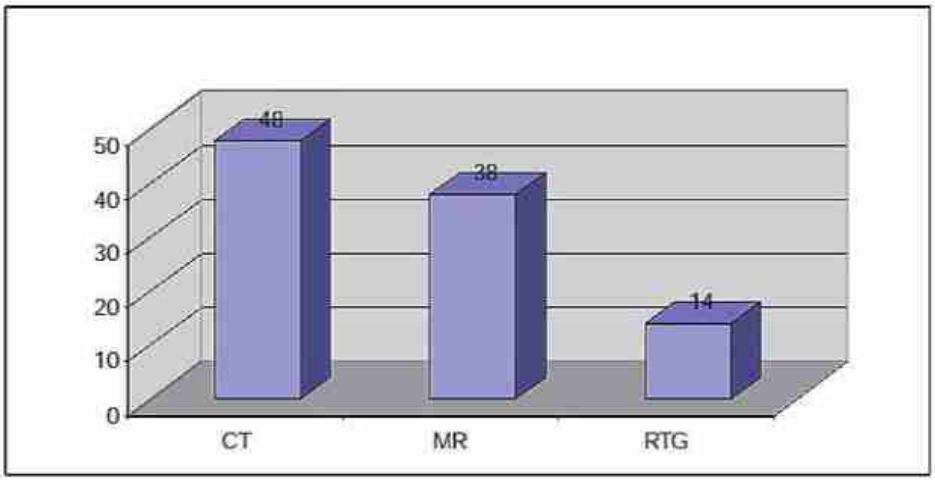


Table 3 Distribution of respondents by type of imaging

Of the performed examinations, the most common were CT scans, accounting for 48%, followed by MRI scans at 38%, while the least performed were X-ray scans, making up 14%.

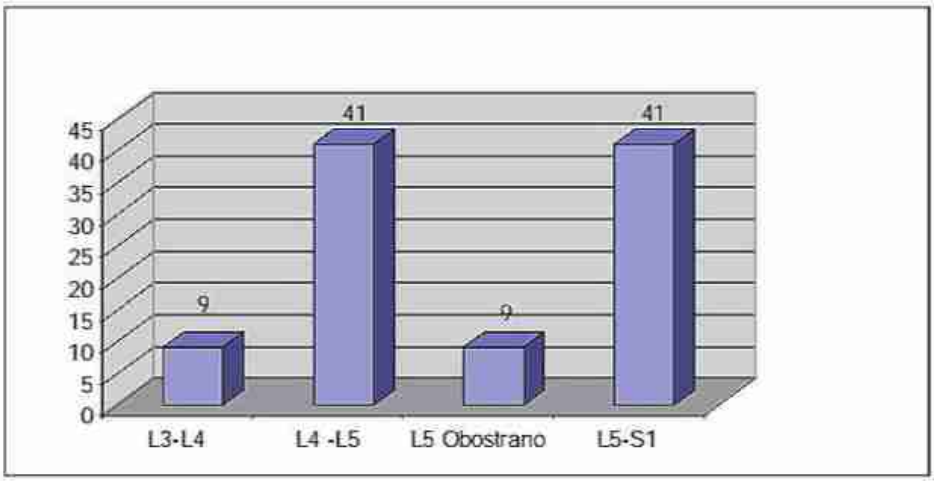


Table 4 Spondylosis by affected spine segments

The highest prevalence, at 41%, was found in the L4-L5 and L5-S1 vertebrae, which are located next to each other. Spondylolysis was found bilaterally in 9% of cases at the L3-L4 and L5 vertebrae.

5. DISCUSSION

Of a total of 297 spinal scans during the study period, 32 or 11% were found to have spondylolisthesis.

In the further study, a total of 32 participants were involved, all of whom were confirmed to have spondylolisthesis through CT and MRI examinations. There were no findings of spondylolisthesis in the X-ray examination.

The youngest respondent was 8 years old, and the oldest was 85 years old. The average age of the respondents was 64.37 years. The largest number of respondents, 47% of them are in the age group older than 75 years. The second most represented age group is 45-64 years, accounting for 22%, followed by 65-74 years at 16%, those under 24 years at 9%, while the least represented age group is 25-44 years, with 6% of participants.

In a professional taxi driver cohort in Taipei (mean age: 44.5 ± 8.7 years, predominantly men), Chen et al reported a spondylolisthesis prevalence of 3.2% (24). Kalichman et al studied 188 adult populations in the community (mean: 52.7 ± 10.8 years) with CT and found that the prevalence of DS was 7.7% (males) versus 21.3% (females) with an F: M = 3: 1 ratio (25). These controversies are complicated by the fact that imaging techniques and radiographic landmarks used for measurements differ in reports, and radiographic magnification is not always taken into account (26).

In terms of gender, our study included both men and women, with each group representing 50%.

Print: ISSN 2232-8726
Online: ISSN 2637-3297

The first hypothesis is H1: Spondylolisthesis occurs more often in females. The results showed that our study did not find a higher frequency of spondylolisthesis in females compared to males, but this is not surprising given the small number of respondents.

The literature review shows that degenerative spondylolisthesis (DS) is highly specific to age and gender and it is relatively rare before the age of 50. In a study on osteoarthritis in Copenhagen, degenerative spondylolisthesis (DS) increases with age in both sexes, while a very small number of individuals (about 4% of all DS cases) had spondylolisthesis at the L4 to L5 level before the age of 50. Kalichman et al (25) also reported that no cases of degenerative spondylolisthesis (DS) were observed in men under the age of 40 or in women under the age of 50. Similar results were observed in the Chen et al study (24). The level of degenerative spondylolisthesis (DS) that was most commonly found was L4–L5, followed by L5–S1 and L3–L4 (approximately 12% each) (27-29).

This proved the second hypothesis: H2: Congenital spondylolisthesis occurs more often at a younger age, and degenerative spondylolisthesis at an older age.

It has been shown that the progression of sliding is slow and not associated with the age at diagnosis or the initial degree of spondylolisthesis. The reduction in disc height at the spondylolytic level occurs at an earlier age and is more severe than in the normal group. Symptoms are associated with radiographic pathology. Risk factors for the occurrence of low back symptoms included more than 25% sliding, spondylolysis at the L4 level, and early disc degeneration. (27).

Of the performed examinations, CT scans were the most common, accounting for 48%, followed by MR scans at 38%, while X-ray examinations were the least frequent at 14%.

Thin-section CT performed with an inverted portal angle is the best modality for defining the bony anatomy of spondylolysis. (30). Magnetic resonance imaging (MRI) is indicated when neurological symptoms and signs are present along with spondylolysis and spondylolisthesis. Compression of the nerve root, abnormalities of the lumbar disc, anomalies of the spinal cord, and neoplasms of the spinal cord or spine are other causes of low back pain that are best evaluated using MRI. MRI can show intraosseous edema in the affected areas in these patients (31).

The highest prevalence, at 41%, was found in the L4-L5 and L5-S1 vertebrae, which are located next to each other. Spondylolysis was found bilaterally in 9% of cases at the L3-L4 and L5 vertebrae.

As reported by Aoki et al. of 580 general population (mean age: 64.4 ± 18.9 years; 336 males / 244 females, 37 patients (6.4%; 26 males and 11 females) had spondylolysis. One patient had spondylolysis at 2 levels. Spondylolysis levels were 1 at L1, 3 at L4 and 34 at L5 vertebrae. Men showed a higher frequency of spondylolysis (7.7%: 26/336 patients) than women (4.5%: 11/244 patients), although no significant difference was observed. Five of the 37 patients had unilateral spondylolysis and the remaining 32 patients had bilateral spondylolysis (32).

The prevalence ratio of lumbar spondylolysis in males to females of 1.4:1.0 had a slightly different ratio compared to our study. This is consistent with reports from the literature that the prevalence of spondylosis is more common in men compared to women (33).

6. CONCLUSION

Of a total of 297 spinal scans during the study period, 32 or 11% were found to have spondylolisthesis.

There were no findings of spondylolisthesis in the X-ray examination.

The youngest respondent was 8 years old, and the oldest was 85 years old. The average age of the respondents was 64.37 years.

The largest number of respondents, 47% of them are in the age group older than 75 years.

In terms of gender, both men and women are equally represented, both groups with 50%.

Of the performed examinations, the most common were CT scans, accounting for 48%, followed by MRI scans at 38%, while the least performed were X-ray scans, making up 14%.

The highest prevalence, at 41%, was found in the L4-L5 and L5-S1 vertebrae, which are located next to each other. Spondylolisthesis was found bilaterally in 9% of cases at the L3-L4 and L5 vertebrae.

Congenital spondylolisthesis occurs more often at a younger age, and degenerative spondylolisthesis at an older age.

9. LITERATURE

1. Ivančević Ž. ed. Principles of internal medicine: Harrison, 3. Croatian edition, Placebo, Split, 2007
2. Gagnet P. et al. *Spondylolysis* and *spondylolisthesis*: A *review* of the *literature*. J Orthop. 2018;15(2): 404–407.
3. Benoist M. Natural history of the aging spine. Eur Spine J. 2003;12(Suppl. 2):S86–9.
4. Kayser R., Mahlfeld K., Heyde C.E., Graßhoff H., Mellerowicz H. Tight hamstring syndrome and extra- or intraspinal diseases in childhood: a multicenter study. Eur Spine J. 2006;15(4):403–408.
5. Hirano A., Takebayashi T., Yoshimoto M. Characteristics of clinical and imaging findings in adolescent lumbar spondylolysis associated with sports activities. J Spine. 2012;1:124.
6. Sugimura Y., Miyakoshi N., Miyamoto S., Kasukawa Y., Hongo M., Shimada Y. Prevalence of and factors associated with lumbar spondylolisthesis in patients with rheumatoid arthritis. Mod Rheumatol. 2015:1–5.
7. Sakai T., Tezuka F., Yamashita K. Conservative treatment for bony healing in pediatric lumbar spondylolysis. Spine. 2017;42(12):716–720.
8. Arima H., Suzuki Y., Togawa D., Mihara Y., Murata H., Matsuyama Y. Low-intensity pulsed ultrasound is effective for progressive-stage lumbar spondylolysis with MRI high-signal change. Eur Spine J. 2017:1–7.
9. Busse J.W., Bhandari M., Kulkarni A.V., Tunks E. The effect of low-intensity pulsed ultrasound therapy on time to fracture healing: a meta-analysis. Can Med Assoc J. 2002;166(4):437–441
10. Lee G.W., Lee S.-M., Ahn M.-W., Kim H.-J., Yeom J.S. Comparison of surgical treatment with direct repair versus conservative treatment in young patients with spondylolysis: a prospective, comparative, clinical trial. Spine J. 2015;15(7):1545–1553.
11. Menga E.N., Kebaish K.M., Jain A., Carrino J.A., Sponseller P.D. Clinical results and functional outcomes after direct intralaminar screw repair of spondylolysis. Spine. 2014;39(1):104–110.
12. Ulibarri J.A., Anderson P.A., Escarcega T., Mann D., Noonan K.J. Biomechanical and clinical evaluation of a novel technique for surgical repair of spondylolysis in adolescents. Spine. 2006;31(18):2067–2072.

Print: ISSN 2232-8726
Online: ISSN 2637-3297

13. Violas P., Lucas G. L5S1 spondylolisthesis in children and adolescents. Orthop Traumatol: Surg Res. 2016;102(1):S141–S147
14. Lundine K.M., Lewis S.J., Al-Aubaidi Z., Alman B., Howard A.W. Patient outcomes in the operative and nonoperative management of high-grade spondylolisthesis in children. J Pediatr Orthop. 2014;34(5):483–489.
15. Miletić D, Skeletna radiografija, Glosa, Rijeka, 2008.
16. http://www.poliklinika-lacic.hr/djelatnosti/nuklearna-medicina
17. Dodig D, Usic Z, Ivancevic D (eds). Klinička nuklearna medicina. Medicinska naklada Zagreb, 1999.
18. http://www.kbd.hr/odjeli/centar-za-nuklearnu-medicinu/odsjek-za-dijagnostikuin-vivo/perfuzijska-scintigrafija-miokarda/
19. Janković S, Bešenski N, Klinička neuroradiologija kralježnice i kralježnične moždine, Medicinska naklada, Zagreb, 2013.
20. Gopalakrishnan N, Nadhamuni K, Karthikeyan T. Categorization of Pathology Causing Low Back Pain using Magnetic Resonance Imaging (MRI). JCDR. 2015;9(1):TC17–20.
21. Emch T, Modic M. Imaging of lumbar degenerative disk disease: history and current state. Skeletal Radiol. 2011;40:1175–89.
22. Chen J.C., Chan W.P., Katz J.N., Chang W.P., Christiani D.C. Occupational and personal factors associated with acquired lumbar spondylolisthesis of urban taxi drivers. Occup Environ Med. 2004;61(12):992–998.
23. Kalichman L., Kim D.H., Li L., Guermazi A., Berkin V., Hunter D.J. Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population. Spine (Phila Pa 1976) 2009;34:199–205.
24. Devine J.G., Schenk-Kisser J.M., Skelly A.C. Risk factors for degenerative spondylolisthesis: a systematic review. Evid Based Spine Care J. 2012;3(2):25–34.
25. He L.C., Wang Y.X., Gong J.S., Griffith J.F., Zeng X.J., Kwok A.W. Prevalence and risk factors of lumbar spondylolisthesis in elderly Chinese men and women. Eur Radiol. 2014;24(2):441–448.
26. Wáng Y.X., Deng M., Griffith J.F., Kwok A.W., Leung J.C., Ahuja A.T. Lumbar Spondylolisthesis Progression and De Novo Spondylolisthesis in Elderly Chinese Men and Women: A Year-4 Follow-up Study. Spine (Phila Pa 1976) 2016;41(13):1096–1103.
27. Williams R., Cheung J.P., Goss B., Rajasekaran S., Kawaguchi Y., Acharya S. An International Multicenter Study Assessing the Role of Ethnicity on Variation of Lumbar Facet Joint Orientation and the Occurrence of Degenerative Spondylolisthesis in Asia Pacific: A Study from the AOSpine Asia Pacific Research Collaboration Consortium. Global Spine J. 2016;6(1):35–45.
28. Wang YX. Zoltán Káplár Z. Deng M. Leung JCS. Lumbar degenerative spondylolisthesis epidemiology: A systematic review with a focus on gender-specific and age-specific prevalence. J Orthop Translat. 2017; 11: 39–52.
29. Câmara J.R., Keen J.R., Asgarzadie F. Functional radiography in examination of spondylolisthesis. AJR Am J Roentgenol. 2015;204(4):W461–W469.
30. Aoki, Y., Takahashi, H., Nakajima, A. et al. Prevalence of lumbar spondylolysis and spondylolisthesis in patients with degenerative spinal disease. Sci Rep **10,** 6739 (2020). https://doi.org/10.1038/s41598-020-63784-0
31. Okpala Francis OO. Radiographic lumbar spondylosis: Gender and age group prevalence in Nigeria, TMPH. 2017;10(5): 1199-1204.