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Comparison of lumbar CT and routine lumbar MRI sequences in detecting lumbosacral transitional vertebrae in patients with low back pain and the value of coronal STIR sequence on MRI

Bel ağrısı hastalarında lumbosakral transisyonel vertebra saptanmasında lomber BT ve rutin lomber MRG sekanslarının karşılaştırılması ve MRG incelemelerinde koronal STIR sekansının değeri

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Abstract

Purpose: This study aims to compare the detection rates of LSTV (lumbosacral transitional vertebrae) and its subtypes in routine lumbar MRI performed without a coronal sequence with those of lumbar spine CT, which is the gold-standard method in this regard.

Materials and methods: This retrospective study evaluated 1,560 patients who presented with "back pain" between February 2016 and April 2024 and had both lumbar MRI and CT images recorded. A total of 105 patients with LSTV on CT were identified, and two observers independently reviewed the MRI images of these patients for LSTV detection, Castellvi subtype classification, extraforaminal stenosis, and detection of edema at the pseudoarticular level.

Results: LSTV was identified in 9.16% of the 1.446 patients. The mean age of the patients was 60, and 72.4% were female. The MRI evaluation revealed LSTV in 64 patients (61%). A high level of agreement was observed between the observers for LSTV detection (κ=0.795, *p*<0.001); however, a significant discrepancy appeared in subtype classification (κ=0.0, *p*=0.755). When comparing CT and MRI results, the accuracy of MRI in classifying LSTV types remained low (κ=0.192, *p*<0.001). Both observers similarly detected edema at the pseudoarticulation level (κ=0.9576, *p*<0.001). Extraforaminal stenosis was identified in 20 patients on CT and 16 patients on MRI, with a high degree of agreement between the observers (κ=0.926, *p*<0.001).

Conclusion: LSTV is often overlooked in routine MRI protocols because the focus is on disc pathology. A coronal STIR sequence is essential for detecting LSTV and identifying inflammation and stenosis at this level.

Keywords: Lumbosacral transitional vertebra, magnetic resonance imaging, STIR, pseudoarticulation, back pain.

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Öz

Amaç: Bu çalışmanın amacı, koronal sekans kullanılmadan yapılan rutin lomber MRG incelemelerinde LSTV (lumbosakral transisyonel vertebra) ve alt tiplerinin saptanma oranlarını, bu konuda altın standart yöntem olan lomber BT ile karşılaştırmaktır.

Gereç ve yöntem: Bu retrospektif çalışmada, Şubat 2016 ile Nisan 2024 arasında kliniğe "bel ağrısı" nedeniyle başvuran ve hem lomber MRG hem de BT görüntüleri bulunan 1.560 hasta değerlendirildi. BT'de LSTV varyasyonu olan toplam 105 hasta belirlendi ve bu hastaların MRG görüntüleri, LSTV'nin tespiti, Castellvi sınıflamasına göre alt tip belirlenmesi, foraminal stenoz değerlendirilmesi ve varsa psödoartikülasyon düzeyindeki ödem tespiti için iki gözlemci tarafından bağımsız olarak incelendi.

Bulgular: 1,446 hastanın %9,16'sında LSTV saptanmıştır. Hastaların yaş ortalaması 60 olup, %72,4'ü kadın hastadır. MRG değerlendirmesinde 64 hastada (%61) LSTV saptandı. İki gözlemci arasında LSTV tespiti konusunda yüksek düzeyde uyum gözlenmiştir (κ=0,795, *p*<0,001); ancak alt tip sınıflandırmasında anlamlı uyumsuzluk bulunmuştur (κ=0,0, *p*=0,755). BT ve MRI sonuçları karşılaştırıldığında, MRG'nin LSTV tiplerini sınıflandırmadaki doğruluğu oldukça düşük kalmıştır (κ=0,192, *p*<0,001). Psödoartikulasyon seviyesinde ödem, her iki gözlemci tarafından benzer şekilde tespit edilmiştir (κ=0.9576, *p*<0,001). BT'de 20 hastada, MRG'de ise 16 hastada foraminal stenoz saptanmış olup gözlemciler arasında yüksek düzeyde uyum gözlenmiştir (κ=0,926, *p*<0,001).

Sonuç: Rutin MRG protokollerinde disk patolojilerine odaklanılması nedeniyle LSTV sıkça gözden kaçmaktadır. Koronal planda STIR sekansının eklenmesi, LSTV'nin saptanması ve bu düzeydeki inflamasyon ve stenozun erken dönemde fark edilmesi açısından önemlidir.

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Anahtar kelimeler: Lumbosakral transisyonel vertebra, manyetik rezonans görüntüleme, STIR, psödoartikülasyon, bel ağrısı.

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Introduction

Lumbosacral transitional vertebra (LSTV) is defined as the unilateral or bilateral articulation of the transverse process of the last lumbar vertebra with the sacrum at varying degrees [1]. LSTV is a commonly observed variation, with its prevalence reported to range between 4% and 35.5% in various studies [2].

LSTV may be associated with findings accompanied by clinical symptoms, primarily low back pain. Bertolotti was the first to associate this condition with low back pain and functional impairments [3].

The modern classification of LSTVs was introduced by Castellvi et al. in 1984 [4], dividing them into four main types. This classification is further categorized into "a" and "b" subtypes based on whether the anomaly is unilateral or bilateral. Accordingly;

- Type I refers to the unilateral (Ia) or bilateral (Ib) enlargement of the transverse process of the L5 vertebra, with a width greater than 19 mm.

- Type II is characterized by incomplete sacralization of L5 or incomplete lumbarization of S1. In this type, the transverse process forms a pseudoarticulation (false joint) with the sacral ala.

- Type III describes the complete fusion of the transverse process with the sacral ala.

- Type IV refers to the presence of a Type IIa anomaly on one side and a Type IIIa anomaly on the opposite side.

This classification is widely used for defining the anatomical variations of LSTVs and serves as a guide in clinical evaluation processes. Reliable imaging techniques play a critical role in the accurate diagnosis and effective management of Bertolotti Syndrome [5].

Specialized Ferguson radiographs can detect LSTV; however, they are not routinely used [6]. Standard AP radiographs are insufficient for detecting or accurately classifying LSTV, and they can correctly identify the Castellvi type only 53%-59% of the time [7].

Compared to conventional radiographic methods, CT (Computed Tomography) and MRI (Magnetic Resonance Imaging) techniques offer higher accuracy in detecting and classifying LSTVs. These advanced imaging modalities also allow for a more detailed assessment of accompanying pathologies, such as nerve root compression and disc degeneration in adjacent segments. Although there are more studies on MRI in the scientific literature, CT is the best imaging technique and gold standard modality for characterizing LSTVs because LSTVs primarily involve anatomical variations in bony structures, and CT provides detailed anatomical data through reconstructed images in desired planes [7-9].

Coronal CT images offer more precise osseous information in the Castellvi classification [10]. However, due to radiation exposure, CT is generally not the first choice for non-traumatic patients and is not used specifically for LSTV detection [8].

Farshad Amacker et al. [6] reported that coronal MRI is superior to standard AP lumbar spine radiographs in detecting and classifying LSTVs. Similarly, Hashimoto et al. [11] demonstrated that the affected nerve roots are compressed between the transverse segment of the transitional vertebra and the sacral ala. This condition was best observed on coronal MRI images, whereas detection rates in axial and sagittal images remained significantly lower. Additionally, MRI is beneficial in revealing bone edema around inflamed pseudoarthrosis [12]. However, MRI is insufficient in detailing bony structures compared to CT. Moreover, coronal plane MRI sequences are not routinely used in clinical practice [10].

In light of this information, in this study, we aimed to compare MRI and CT in terms of their ability to detect and classify LSTVs in patients who did not undergo standard coronal MRI sequences. Additionally, we sought to compare the detection rates of foraminal and extraforaminal stenosis in axial and sagittal sections, as well as the identification of edema at the pseudoarthrosis level in sagittal STIR sequences, and to assess interobserver reliability.

Materials and methods

Study design and patient population

This study was approved by the Pamukkale University Non-Interventional Clinical Research Ethics Committee (approval date: 30.04.2024, approval number: E-60116787-020-521271).

In the study, 1,560 patients who presented to our center with complaints of “low back pain” between February 2016 and April 2024 and had lumbar MRI images in our hospital’s Picture Archiving and Communication System (PACS), along with lumbar.

CT images taken within less than six months of the MRI were retrospectively evaluated. In MRI, 9 patients who did not meet optimal imaging conditions, 51 patients with malignant diseases involving lumbar vertebral involvement at the time of imaging, 43 patients with previously diagnosed benign rheumatologic diseases (17 ankylosing spondylitis, 7 rheumatoid arthritis, 19 other), and 11 patients with acute or chronic vertebral fractures or a history of surgery were excluded from the evaluation. The relevant flowchart is provided below (Table 1).

Table 1. Classification of LSTVs on CT

Types	1A	1B	2A	2B	3A	3B	4	Total
L frequency	9		13		3			
R frequency	7		9		2			
Total Frequency	16	39	22	9	5	10	4	105
%	15.2	37.1	21.0	8.6	4.8	9.5	3.8	100.0

L=Left, R=Right

In the remaining patients, various degrees of LSTV variations were observed in 105 cases on CT imaging. The MRI images of these 105 patients were independently evaluated by two observers: an experienced radiologist with 29 years of expertise in neuroradiology and musculoskeletal radiology and a fourth-year radiology resident who had completed their relevant rotations.

The observers individually recorded their detection rates of LSTV, the subtypes identified according to the Castellvi classification, the presence of foraminal stenosis (if any), and the detection of edema at the pseudoarticulation level on STIR sequence. Observer comparisons were then assessed.

Image acquisition and MRI protocol

All MRI scans were conducted using a 1.5-T scanner (Ingenia; Philips Healthcare) equipped with a dStream Posterior coil. The scanner had a gradient power of 45 mT/m on each axis and a maximum slew rate of 200 mT/m/sec. All MRI scans comprised the following pulse sequences: T1-weighted sagittal fast spin-echo (FSE) without fat suppression, T2-weighted sagittal FSE without fat suppression, T2-weighted axial FSE without fat suppression parallel to the disc, and sagittal short tau inversion recovery (STIR).

Image acquisition and CT protocol

CT image acquisition of the lumbosacral region was performed using a multidetector CT scanner (Philips Ingenuity 128, Philips Healthcare, Cleveland INC, United States). The following parameters were utilized for the axial lumbosacral CT acquisition: a collimation width of 64 × 0.625 mm, a slice thickness of 1.5 mm, a matrix size of 512 × 512, a rotation time of 0.4 s, a tube voltage of 120 kV, and a tube current of 140 mA. The CT images were reconstructed in both the sagittal and coronal planes.

Imaging analysis

Conventional spinal MRI is insufficient for visualizing degenerative changes at the pseudoarticulation level and in the paraspinal area, as well as the accompanying inflammation [13]. According to Lakadamyali et al. [14], the STIR sequence, with the aid of fat suppression techniques, allows for a much clearer visualization of edema compared to conventional MR images, thereby enabling a more precise depiction of degenerative changes. For this reason, in our study, we evaluated the signal increase in the joint space or bone surfaces at the level of pseudoarthrosis using the STIR sequence.

Foraminal or extraforaminal stenosis was assessed based on the displacement of the nerve root or a reduction or loss in the size of epidural fat compared to its symmetrical counterpart [15].

Statistical analysis

The analyses were conducted using IBM SPSS Statistics (version 29). For continuous variables (e.g., “age”), distributions were summarized by calculating the mean, standard deviation, minimum, and maximum values. Categorical variables were summarized using frequency and percentage distributions.

To assess the agreement between CT and MRI imaging results, as well as the consistency between independent radiologists’ MRI interpretations, Cohen’s kappa coefficient (κ) was calculated to quantitatively express the level of agreement. This coefficient was used to determine the degree of consistency between CT and MRI findings and between the two radiologists. Kappa values were interpreted as follows: $\kappa<0$ = no agreement; 0.01-0.20 = very weak agreement; 0.21-0.40 = weak agreement; 0.41-0.60 = moderate agreement; 0.61-0.80 = strong agreement; 0.81-1.00 = very strong agreement. The threshold for statistical significance was set at $p<0.05$.

Results

Among the 1,446 evaluated patients, LSTV was detected in 105 cases (9.16%), which was consistent with the values reported in the literature [2]. Of these patients, 76 (72.4%) were female, and 29 (27.6%) were male. The age range varied between 16 and 84 (mean 60) years.

The classification of subtypes on CT is presented in Figure 1.

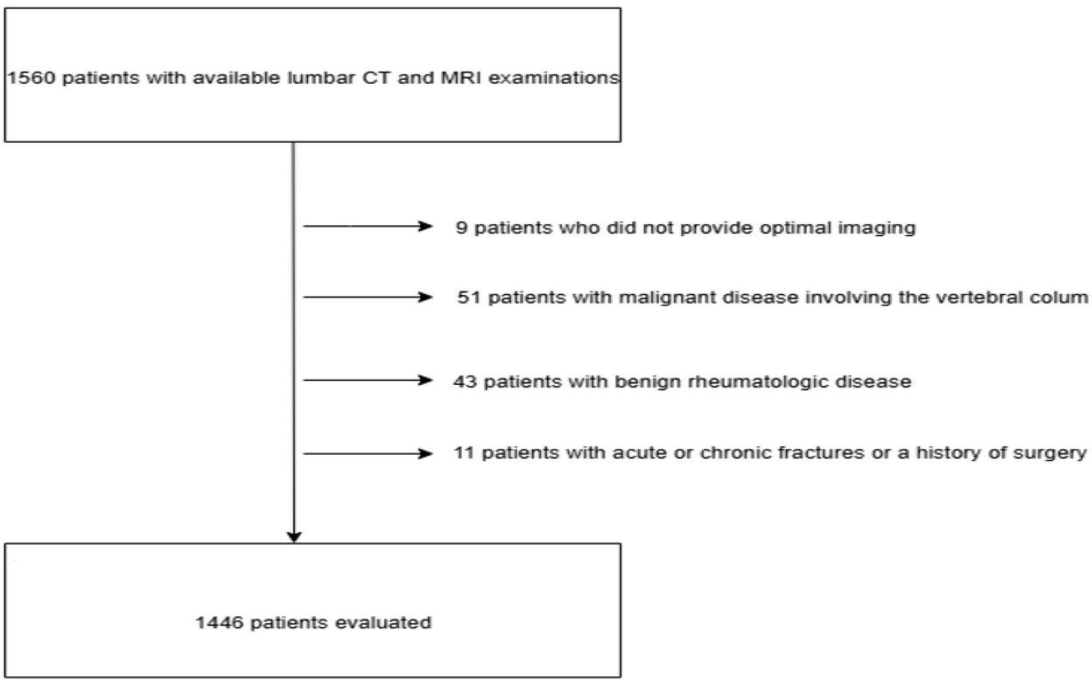

Figure 1. Flowchart of participant inclusion

Upon evaluating the axial and sagittal planes of the MRI examination, observer 1 identified LSTV variation in 64 patients (61%), while observer 2 reported the presence of LSTV in 70 patients (66.7%). The LSVT was missed on the MRI examination in 41 patients (39%) of observer 1 and 35 patients (33.3%) of observer 2. Among the 62 patients classified as having LSTV by observer 1, observer 2 made the same assessment, with discrepancies observed in only 2 cases. However, the interobserver agreement was found to be statistically significant (κ=0.795, *p*<0.001) (Figure 2) (Table 2).

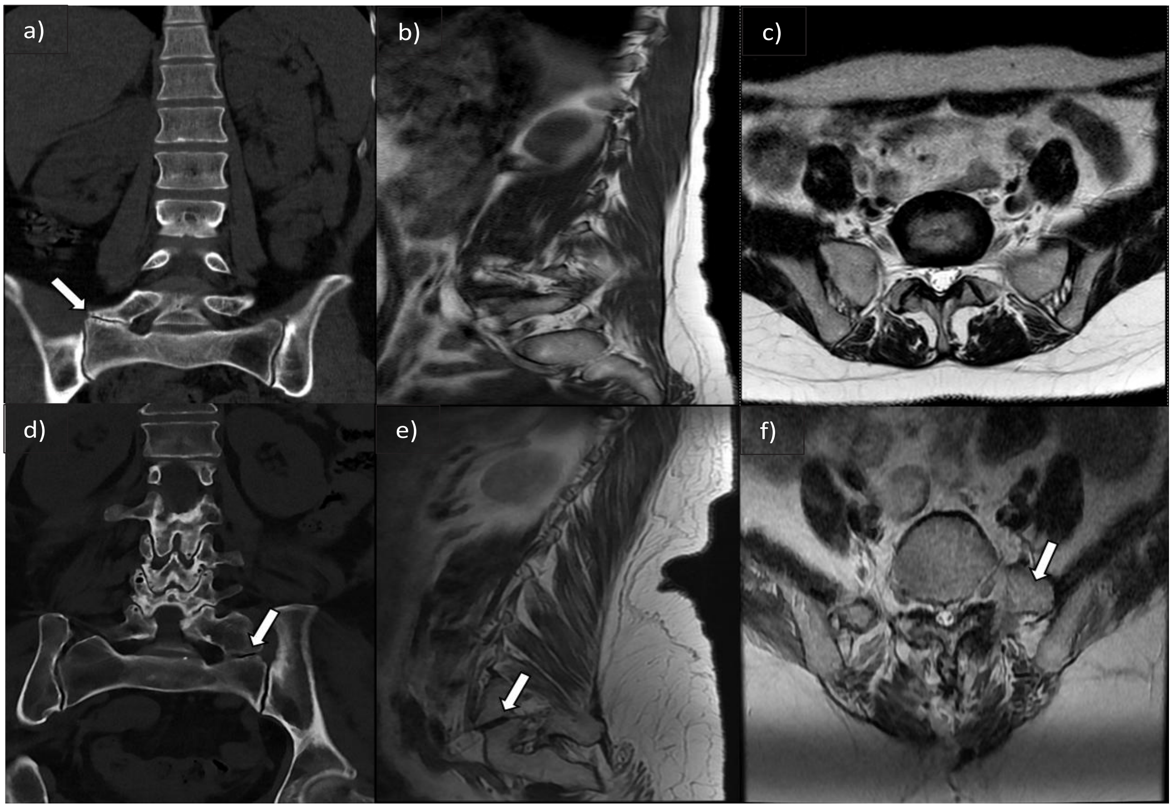

Figure 2. Pseudoarticulation is clearly visible (arrowheads) on coronal reformatted CT (a) in a patient with type IIA LSTV, but not on sagittal (b) and axial (c) T2-weighted MR images. Another patient's LSTV Type IIA variation is seen on both coronal reformatted CT (d) and sagittal (e) and axial (f) T2-weighted MR images (arrowheads)

Table 2. Interobserver agreement results

Evaluated Feature	Observer 1 (n) (%)	Observer 2 (n) (%)	Matching Evaluated (n) (%)	Kappa	*p* value
LSTV Presence	64 (60.5%)	70 (66.67%)	62 (59.05%)	0.795	<0.001
LSTV Subtypes					
Type 1	19 (18.10%)	27 (25.71%)			
Type 2	37 (35.24%)	35 (33.33%)			
Type 3	8 (7.62%)	8 (7.62%)			
Pseudoarticulation Edema	13 (12.38%)	14 (13.33%)	13 (12.38%)	0.958	<0.001
Foraminal Stenosis (CT)	20 (19.05%)	20 (19.05%)		-	-
Foraminal Stenosis (MRI)	16 (15.24%)	16 (15.24%)	15 (14.29%)	0.926	<0.001

A *p* value <0.05 was considered statistically significant

In the comparison of LSTV types in CT and MRI examinations, it was found that, although significant agreement was observed between the examinations, the performance of the MRI examination was quite weak (κ=0.192, *p*<0.001).

Observer 1 detected LSTV in 33 patients on the sagittal plane, in 11 patients on the axial plane, and in 19 patients on both planes, whereas Observer 2 evaluated 36 patients as having LSTV on the sagittal plane, 14 patients on the axial plane, and 20 patients on both planes.

In subtype classification with MRI examination, observer 1 categorized 19 patients as type 1, 37 patients as type 2, and 8 patients as type 3. In contrast, observer 2 classified 27 patients as type 1, 35 patients as type 2, and 8 patients as type 3. A marked disagreement between observers was noted in subtype classification (κ=0.0, *p*=0.755).

Regarding edema at the pseudoarticulation level, observer 1 detected edema in 13 patients, while observer 2 reported edema in 14 patients. A statistically excellent agreement was observed among the 13 patients identified by both observers (κ=0.9576, *p*<0.001).

For extraforaminal stenosis, CT findings indicated stenosis in 20 patients. In MRI evaluations, both observers reported stenosis in 16 patients. In 15 of these 16 cases, the observers agreed, demonstrating a high level of interobserver agreement (κ=0.926, *p*<0.001).

Discussion

LSTV variation is frequently overlooked in MR imaging performed for low back pain. One of the main reasons for this is the absence of the coronal plane in routine sequences of cases referred for low back pain. As a result, pain or sciatica due to LSTV may be overlooked in some patients, and in some cases, revision surgeries may be required due to undetected pathologies.

In our study, we found that LSTVs observed on CT scans were largely overlooked (39%) in MR imaging of the same patients. Additionally, we observed that MR imaging had a low success rate in determining LSTV types. Furthermore, stenosis due to pseudoarticulation hypertrophy at the LSTV level, which was detected on CT, was missed in 20% of cases on MR imaging. On the other hand, edematous signal changes at the LSTV pseudoarticulation level, which could only be detected on the sagittal STIR sequence, were observed in 13 patients (12%).

In many centers, MR imaging is primarily performed to detect disc pathologies, with only sagittal and axial slices parallel to the disc space being obtained. Therefore, coronal sequences are not included in routine examinations [16-21]. MR imaging is inferior to CT in the evaluation of bony structures. However, MR imaging, particularly with the STIR sequence, better demonstrates inflammatory edema at the pseudoarticulation level [21]. Due to these factors, identifying and distinguishing LSTV types using only sagittal and axial slices is quite challenging. Our study also found that LSTV variations were largely overlooked with routine MR sequences. Since axial slices are mostly taken for the disc space and sagittal slices focus on discopathy without including the paravertebral areas, sections from the LSTV levels may not be obtained, leading to missed diagnoses. For similar reasons, the success rate of LSTV classification using routine MR imaging was found to be quite low.

In the literature, it is recommended to add the coronal plane to lumbar MR imaging, especially in young adults, as the likelihood of Bertolotti syndrome is high in cases of chronic low back pain [3, 6, 9, 12, 21, 22]. Based on the findings of our study, we recommend adding the coronal plane to routine sequences or, if not possible, obtaining a lumbosacral radiograph, even though it may not be sufficiently sensitive.

In our study, we also evaluated inflammatory edema at the pseudoarticulation level of LSTV in both the joint and bone marrow using the sagittal STIR sequence included in routine imaging. Accordingly, pseudoarticulation-level edema was detected in 13 patients (12%). Considering that in many cases, the LSTV level was not included in the sagittal section, this rate was expected to be even higher. Therefore, to detect potential pain causes originating from the LSTV level, adding a STIR sequence in the coronal plane would be more beneficial. The literature contains numerous studies and recommendations on this subject [22-25]. However, Nevalainen et al. [26] found that LSTV-level edema was not associated with pain in their study. However, their study focused on the hip-pubic region due to pain in that area, included only a single additional sequence for the lumbar region, and was retrospective, which may limit its reliability.

When evaluating our study regarding extra-foraminal stenosis, we found that four out of 20 patients (20%) who were diagnosed with stenosis on CT were overlooked in routine MR imaging, which is a high rate. The literature includes studies emphasizing the importance of extra-foraminal stenosis in MR imaging [11, 15, 27, 28]. If the coronal sequence is not obtained, this finding may often be overlooked, and particular attention should be paid to patients with L5 nerve root compression. In such cases, if coronal sections cannot be obtained, at the very least, care should be taken to ensure that axial sections pass through this level, and when necessary, further evaluation with CT should be performed. Bezuidenhout and Lotz [29] recommend obtaining a T1-weighted coronal section for this purpose. However, we believe that an STIR sequence would be more beneficial in detecting inflammatory edema at the pseudoarticulation level.

Our study has some limitations. Firstly, it was a single-center retrospective study, which makes it susceptible to selection bias. Another limitation was that the included patients were not asymptomatic, so a control group could not be established. Nevertheless, our study included a large and homogeneous patient population.

The strengths of our study include being, to our knowledge, the first study to compare both CT and MR imaging in the same patient with a large sample size, which increases its reliability. Additionally, an interobserver evaluation was performed, and despite differences in experience among observers, high agreement was found.

In conclusion, LSTV is frequently overlooked in many centers due to routine MR protocols being focused on discopathy and the absence of coronal sequences. Therefore, including a STIR sequence in the coronal plane in MR imaging for low back pain and sciatica would help reveal the presence of LSTV, detect possible inflammatory edema at the pseudoarticulation level, and prevent missing extra-foraminal stenosis.

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Conflict of interest: No conflict of interest was declared by the authors.

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