ISSN 0974-8237

Journal of Craniovertebral Junction & Spine

www.jcvjs.com

PubMed

January-March 2023 / Volume 14 / Issue 1

Wolters Kluwer

Medknow

Original Article

Prevalence of lumbosacral transitional vertebra among 4816 consecutive patients with low back pain: A computed tomography, magnetic resonance imaging, and plain radiographic study with novel classification schema

ABSTRACT

Study Design: A retrospective single-center study.

Background: The prevalence of the lumbosacral anomalies remains controversial. The existing classification to characterize these anomalies is more complex than necessary for clinical use.

Purpose: To assessment of the prevalence of lumbosacral transitional vertebra (LSTV) in patients with low back pain and the development of clinically relevant classification to describe these anomalies.

Materials and Methods: During the period from 2007 to 2017, all cases of LSTV were preoperatively verified, and classified according to Castellvi, as well as O'Driscoll. We then developed modifications of those classifications that are simpler, easier to remember, and clinically relevant. At the surgical level, this was assessed intervertebral disc and facet joint degeneration.

Results: The prevalence of the LSTV was 8.1% (389/4816). The most common L5 transverse process anomaly type was fused, unilaterally or bilaterally (48%), to the sacrum and were O'Driscoll's III (40.1%) and IV (35.8%). The most common type of S1-2 disc was a lumbarized disc (75.9%), where the disc's anterior-posterior diameter was equal to the L5-S1 disc diameter. In most cases, neurological compression symptoms (85.5%) were verified to be due to spinal stenosis (41.5%) or herniated disc (39.5%). In the majority of patients without neural compression, the clinical symptoms were due to mechanical back pain (58.8%).

Conclusions: LSTV is a fairly common pathology of the lumbosacral junction, occurring in 8.1% of the patients in our series (389 out of 4,816 cases). The most common types were Castellvi's type IIA (30.9%) and IIIA (34.9%) and were O'Driscoll's III (40.1%) and IV (35.8%).

Keywords: Anomalies of the lumbosacral region, degenerative diseases, diagnostics, low back pain, lumbar spine, lumbarization, lumbosacral transitional vertebra, sacralization, treatment

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Submitted: 03-Dec-22 **Accepted:** 15-Jan-23
Published: 13-Mar-23

Access this article online	
	Quick Response Code
Website: www.jcvjs.com	
DOI: 10.4103/jcvjs.jcvjs_149_22	

How to cite this article: Byvaltsev VA, Kalinin AA, Shepelev VV, Pestryakov YY, Aliyev MA, Hozeev DV, *et al.* Prevalence of lumbosacral transitional vertebra among 4816 consecutive patients with low back pain: A computed tomography, magnetic resonance imaging, and plain radiographic study with novel classification schema. J Craniovert Jun Spine 2023;14:35-43.

INTRODUCTION

Anatomically, the lumbar region has 5 vertebrae. However, anomalies where there are 4 or 6 lumbar segments with L5 sacralization or S1 lumbarization, respectively, are common.[1,2] Sacralization of the L5 vertebra is characterized by elongation and expansion of its transverse processes (TPs) to fuse with the sacrum, and S1 lumbarization is characterized by an abnormal lumbosacral articulation, the presence of fully formed facet joints (FJ), and a full-size intervertebral disc (IVD).[3] Such malformations of the spine account for 4%–35% of cases in the population and have the definition of lumbosacral transitional vertebra (LSTV).[4] In the literature, neurological symptomatology in the presence of lumbosacral dysgenesis is called Bertolotti's syndrome; its name comes from the Italian radiologist Mario Bertolotti, who first described the clinical and radiographic findings in such patients.[3]

The etiology of the lumbosacral anomalies is unknown. It is assumed that a possible cause is a defect in the Hox-10 and Hox-11 genes, which are responsible for the axial segmentation of the skeleton.[5] On the other hand, the change in the lumbosacral numbering is compensatory, for example, in the case of underdevelopment of the iliolumbar ligaments.[6]

Castellvi *et al*.[1] described four types of LSTV, depending on the presence of different morphological characteristics on plain radiographs and computed tomography (CT). Mahato,[7] took this further, taking into account the correlation of clinical and biomechanical parameters with the morphological characteristics of the transition region. He identified four main groups and 19 subgroups of lumbosacral dysgenesis, (1) dysplasia of the TP of the L5 vertebra, (2) additional FJ, (3) sacralization, and (4) lumbarization. O'Driscoll *et al*.[8] described four types of S1-2 discs, based on magnetic resonance imaging (MRIs). While they are both well-cited and useful for research, both Castellvi's and O'Driscoll's classifications, like all classifications, suffer from the necessity to memorize what each type is. In addition, both classifications identify types that may be radiographically different but that are not necessarily clinically or practically different. A simpler, more clinically relevant classification is needed. Furthermore, no existing classification has combined the use of plain radiographs, CT, and MRI to analyze and characterize the types of LSTV that exist. As a result, currently, there is no uniform standard for identifying the presence of an LSTV.[9] The heterogeneity of approaches to identifying anomalies in this region includes using standard lumbar radiographs,[10] Ferguson view (beam directed 30° cranially) lumbar radiographs,[11] verification of the attachment site of the lumbar muscle to the lower ribs[12] and identification of the L5 iliolumbar ligaments by MRI.[13]

The purposes of this study are to (1) determine the prevalence of the LSTV in patients with low back pain, (2) characterize their dysgenesis type, (3) describe their clinical and neurological symptoms, and (4) propose a novel classification system for anomalous L5 TPs and a second one for the S1-S2 disc.

MATERIALS AND METHODS

Study design

A total of 4,816 lumbar surgical procedures were performed at the centerof neurosurgery Irkutsk Railway Clinical Hospital from 2007 to 2017. This study was approved by the ethics committee of Irkutsk State Medical University (Protocol No. 3 dated September 02, 2017). Voluntary consent was obtained. Each patient gave voluntary consent to be included in the study. Of these, LSTV was present in 389 cases (8.1%).

Patient inclusion/exclusion

All of these patients had at least a 4-week history of low back pain, lumbar radiculopathy, or both. Figure 1 shows a flow chart describing the design of the study. For 352 of these patients, advanced imaging studies were available, and these subjects were therefore included in the present study.

Patients were excluded if there was a history of spinal trauma, infection, or previous lumbar spine surgery.

Outcomes study

To assess the type of lumbosacral junction anomaly in all 352 patients, we performed a detailed examination of their lumbar radiographs, MRI, and CT scans. The number of vertebrae based on radiographic data was counted starting from the craniocervical junction. Patients' data were de-identified and the radiographic evaluations were performed by two independent experts (neurosurgeon and radiologist). The LSTV was classified according to Castellvi *et al*.[1] and the morphology of the IVD at S1-S2 was classified according to O'Driscoll *et al*.[8] The statistical evaluation of expert agreement on each question was carried out using Kappa statistics (Graph Pad Software, Inc., USA).

Table 1 presents variants of anomalies of the lumbosacral junction of the spine according to the Castelvi classification. Further, their classification differentiates types that may be radiographically different but clinically makes minimal to no difference in treating the patient. We modified the Castellvi's classification to create a novel classification system using descriptive terms. We believe that a novel classification

Table 1: Distribution of patients, depending on the type of anomaly of the lumbosacral junction according to the Castellvi's classification, as well as our novel classification system that uses a simplified modification of the Castellvi system using descriptive terms

Castellvi L5 TP type	Number of patients, *n* (%)	Novel descriptive classification for L5 TP	Number of patients, *n* (%)
IA [Figure 2] Enlarged unilateral (height ≥19 mm)	22 (6.3)	Enlarged (height ≥19 mm)	53 (15.0)
IB [Figure 3] Enlarged Bilateral (height ≥19 mm)	31 (8.8)		
IIA [Figure 4] Pseudarthrosis, unilateral (Bertolotti's)	109 (30.9)	Pseudarthrosis	130 (36.9)
IIB [Figure 5] Pseudarthrosis, bilateral (Bertolotti's)	21 (5.9)		
IIIA [Figure 6] Fused unilateral	123 (34.9)	Fused	169 (48.0)
IIIB [Figure 7] Fused, bilateral	32 (9.3)		
IV [Figure 8] Mixed	14 (3.9)		

TP – Transverse process

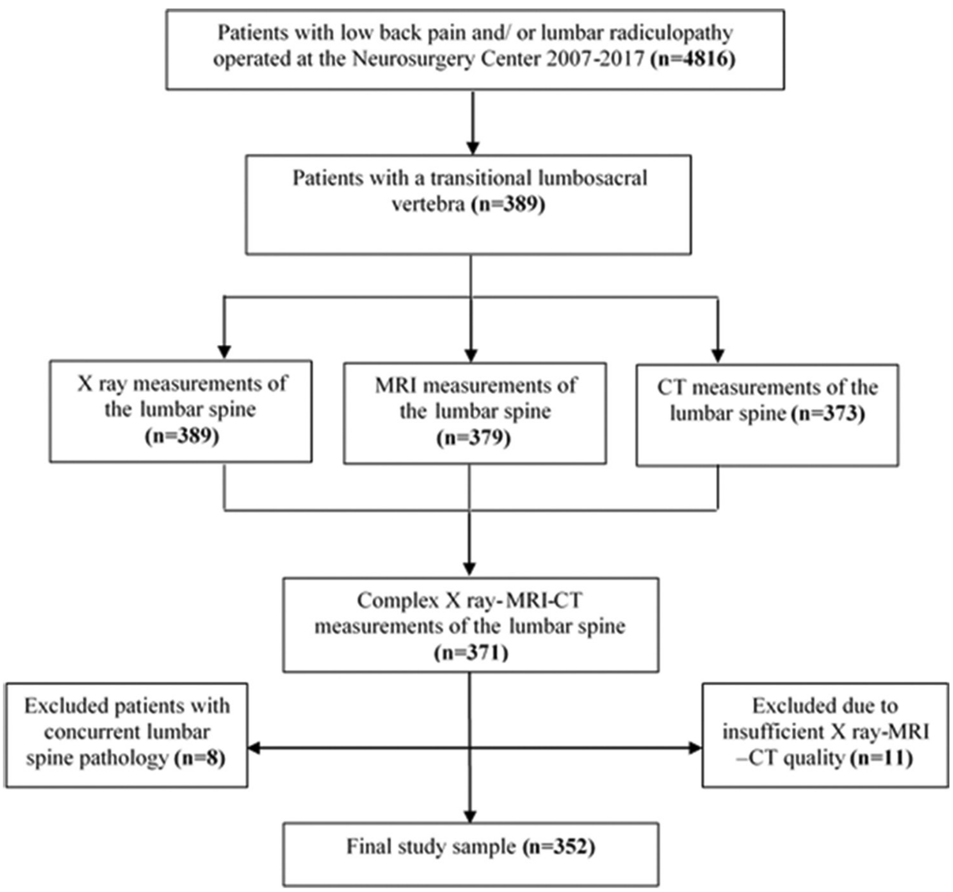

Figure 1: Flow diagram for the study sample selection

schema of the lumbosacral pathology is simpler and more clinically relevant. Castellvi's Type I A and B (unilateral and bilateral, respectively) are TPs that have a height ≥19 mm. We lumped these two into one category: Enlarged TP. An enlarged TP might make it easier to achieve an L5-S1 TP fusion, so is clinically relevant. We felt that for all of these categories, the surgeon's description of the anomaly being unilateral or bilateral is clearer and easier than affixing an "A" or "B" to the category. Castellvi's Type II A and B (unilateral and bilateral, respectively) are TPs that are nearly fused to the sacrum but

Figure 2: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IA. CT – Computer tomography; 3D – Three-dimensional

Figure 3: Three-dimensional CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IB. CT – Computer tomography; 3D – Three-dimensional

Figure 4: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IIA. CT – Computer tomography; 3D – Three-dimensional

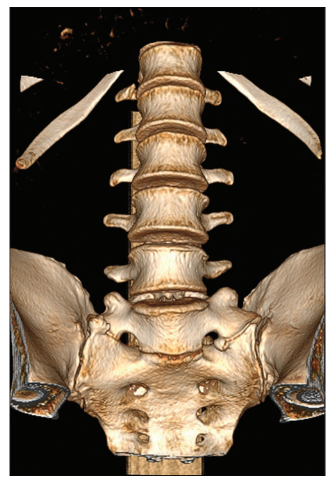

Figure 5: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IIB. CT – Computer tomography; 3D – Three-dimensional

still have a pseudarthrosis with the sacrum. We lumped these two into one category: pseudarthrosis. This is the type that Bertolotti described and reported that some will develop a painful syndrome from the pseudarthrosis. Castellvi's Type III A and B (unilateral and bilateral, respectively) are TPs that are fused to the sacrum and Type IV is a mixed, with one side fused. We lumped all of these into one category: fused, since, if one side is fused, that segment does not move so it makes no difference what the other side looks like. This new classification is presented on the right side of Table 1.

We also modified the O'Driscoll's classification for the S1-2 disc based on MRI findings [Table 2]. O'Driscoll subdivided S1-S2 discs into four types. Type I: No disc material between S1 and S2 and on MRI was seen as a thin, hypointense line. Type II: Small disc between S1 and the sacrum, which does not extend across the entire sacral anterior-posterior (AP) diameter. Type III: Well-formed disc between S1 and the sacrum, which extends across the entire sacral AP diameter. Type IV: Well-formed disc between S1 and the sacrum, which extends across the entire sacral AP diameter, with "squaring" of the upper sacral border. As we evaluated these four types, we noted that, clinically, the most important aspect of characterizing the S1-S2 disc is in making sure that the disc space is not mistaken for an L5-S1 disc on the sagittal MRI. Therefore, we lumped O'Driscoll's first two types into one: Sacral morphology, since no one would mistake these for a lumbar disc. We also lumped O'Driscoll's second two types into one: Lumbar morphology, since on a sagittal MRI alone, these discs could easily be mistaken for a lumbar disc. Patients with lumbar morphology S1-S2 discs are obviously at an increased risk of wrong-level surgery, whereas those with a sacral morphology are not.

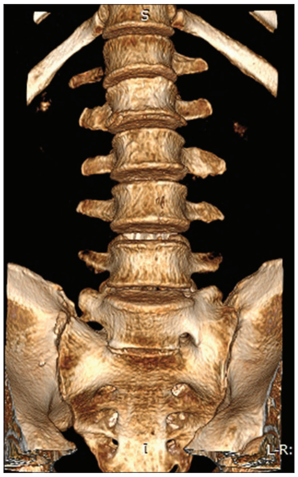

Figure 6: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IIIA. CT – Computer tomography; 3D – Three-dimensional

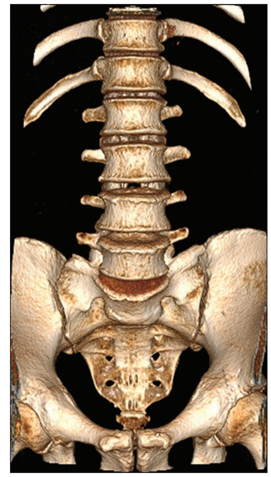

Figure 7: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IIIB. CT – Computer tomography; 3D – Three-dimensional

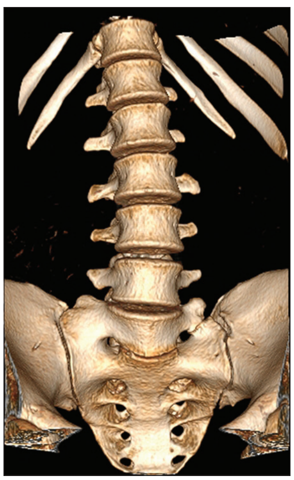

Figure 8: 3D CT representation of anomaly of the lumbosacral junction according to the Castellvi's classification – Type IV. CT – Computer tomography; 3D – Three-dimensional

Figure 9: Examples of morphology of the S1-S2 disc on MRI using the O'Driscoll's classification – Type I. MRI – Magnetic resonance imaging

At the level of the surgical intervention, morphological changes in the IVD were assessed using Pfirrmann *et al*.'s[14] classification and the FJ were assessed using the Fujiwara *et al*.'s[15] classification. The radiographic and clinical indications for surgical intervention were also assessed.

Statistical analysis

Statistical data were obtained using the Statistica-8 database processing program. The distribution pattern was based on the Shapiro–Wilk, Kolmogorov–Smirnov, and Liljefors tests. Taking into an account, the presence of significant differences according to these tests ($P < 0.05$), the distribution was considered to be different from the normal, in connection with which the assessment of the significance of the differences in the sample sets was made according to the criteria of nonparametric statistics. Differences were considered statistically significant at $P < 0.05$. The data were presented as the median, the values of the 1st and 3rd quartiles-Me (Q25; Q75).

RESULTS

Demographic data are presented in Table 3.

Interobserver agreement on the type of lumbosacral anomalies based on Kappa Statistics was excellent for the Castellvi *et al*.'s[1] classification using lumbar X-rays 0.904 ± 0.084 (0.808–1.000, 95% confidence interval [CI]), CT data 0.926 ± 0.051 (0.852–1.000, 95% CI), as well as for the disc morphology at S1-S2 according to the O'Driscoll *et al*.'s[8] classification based on MRIs 0.963 ± 0.037 (0.891–1.000, 95% CI).

The analysis of the type of LSTV according to the Castellvi *et al*.'s[1] classification is presented in Table 1. The prevalence

Table 2: Distribution of patients classified according to the morphology of the S1-S2 disc on magnetic resonance imaging using the O'Driscoll's classification

O'Driscoll S1-S2 type	Number of patients, *n* (%)	Modified classification	Number of patients, *n* (%)
I No disc material between S1 and S2. Thin, hypointense line on sagittal MRI [Figure 9]	21 (5.9)	Sacral morphology (AP disc diameter smaller than L5-S1 disc diameter. Easy to distinguish that this is a sacral disc)	85 (24.1)
II Small disc between S1 and the sacrum, which does not extend across the entire sacral AP diameter [Figure 10]	64 (18.2)		
III Well-formed disc between S1 and the sacrum, which extends across the entire sacral AP diameter [Figure 11]	141 (40.1)	Lumbar morphology (AP disc diameter equal to L5--S1 disc diameter. Easy to mistake this for an L5-S1 disc)	267 (75.9)
IV Well-formed disc between S1 and the sacrum, which extends across the entire sacral AP diameter, with "squaring" of the upper sacral border [Figure 12]	126 (35.8)		

MRI – Magnetic resonance imaging; AP – Anterior-posterior

Table 3: Information about the patients included in the study

Criterion	Study group (*n*=352)
Age (years), median (25-75)	42.3 (24.9-63.7)
Sex, *n* (%)	
Male	211 (59.9)
Female	141 (40.1)
BMI (kg/m^2)	24.2 (22.9-26.4)

BMI – Body mass index

of type IIA (30.9%) and IIIA (34.9%) among the treated patients was noted. On the right side of the table, we describe our novel classification scheme. The fused type was the most prevalent type of anomaly (48%) followed by the pseudarthrosis type (36.9%).

Table 2 demonstrates the types of the S1-S2 morphology on MRI using the O'Driscoll *et al*.'s[8] classification. Based on the analysis, types III (40.1%) and IV (35.8%) were the most prevalent.

Forty-one patients had 6 lumbar vertebrae. Twenty-four of these had 12 ribbed vertebrae and had an S1 that was lumbarized. The remaining 17 had a nonribbed T12.

In our study, we did not reveal L1 thoracization and 13 ribbed vertebrae. We found 7 cervical ribs, but this was not associated with a specific type of lumbosacral junction anomaly.

Clinical and radiographic data of the operative level are shown in Table 4. In most cases, neurological compression symptoms (85.5%) were concordant with the presence of spinal canal stenosis (41.5%), herniated disc (39.5%), Pfirrmann *et al*.[14] Grade III-IV disc degeneration (81.1%), decreased disc height (76,1%) and Fujiwara *et al*.[15] Grade II-III FJ degeneration (70%). In the majority of patients

Figure 10: Examples of morphology of the S1-S2 disc on MRI using the O'Driscoll's classification – Type II. MRI – Magnetic resonance imaging

with noncompressive clinical symptoms, there was mechanical back pain (58.8%), Pfirrmann *et al*.[14] Grade II disc degeneration (70.7%), normal disc height (68.6%), and Fujiwara *et al*.[15] II-III Grade FJ degeneration (80%).

All patients with neurological symptoms were treated with a variety of procedures. In 215 cases (61.1%), posterior decompression and stabilization were performed. For 47 cases (13.3%), a discectomy was performed. In 39 cases (11.1%), a decompression without discectomy was done. In patients with mechanical back pain without neurological symptoms, laser denervation of the FJ and/or laser ablation of the disc was performed.

DISCUSSION

The presence of anatomical anomalies in the lumbosacral junction increases the risk of incorrect preoperative diagnosis, as well as wrong-level surgery.[3] Despite these

Table 4: Clinical and radiographic data in the study group

Criterion	Study group (*n*=352)	
	Compressive symptoms (*n*=301), *n* (%)	Noncompressive symptoms (*n*=51), *n* (%)
Pathological substrate	Spinal stenosis - 125 (41.5)	Discogenic - 7 (13.7)
	IVD hernia - 119 (39.5)	Arthrogenic - 30 (58.8)
	Degenerative spondylolisthesis - 38 (12.6)	Combined - 14 (27.5)
	Spondylolysis - 19 (6.4)	
IVD changes according to Pfirrmann		
I	13 (4.3)	-
II	35 (11.6)	36 (70.7)
III	168 (55.8)	9 (17.6)
IV	76 (25.3)	4 (7.8)
V	9 (3.0)	2 (3.9)
Disc height		
Normal	61 (20.3)	35 (68.6)
Decreased	229 (76.1)	13 (25.5)
Collapsed disc space	11 (3.6)	3 (5.9)
FJ changes according to Fujiwara		
Right facet		
I	23 (7.6)	3 (5.9)
II	98 (32.6)	21 (41.2)
III	124 (41.2)	25 (49)
IV	56 (18.6)	2 (3.9)
Left facet		
I	19 (6.3)	4 (7.8)
II	113 (37.5)	27 (53)
III	120 (39.9)	15 (29.4)
IV	49 (16.3)	5 (9.8)

IVD – Intervertebral disc; FJ – Facet joint

Figure 11: Examples of morphology of the S1-S2 disc on MRI using the O'Driscoll's classification – Type III. MRI – Magnetic resonance imaging

Figure 12: Examples of morphology of the S1-S2 disc on MRI using the O'Driscoll's classification – Type IV. MRI – Magnetic resonance imaging

important concerns, there is a paucity of information on the prevalence of LSTV in patients with back pain. And although the two most commonly used classifications describing the anomalies of this area, Castellvi's *et al*.'s classification[1] for the L5 TP and O'Driscoll *et al*.[8] for the S1-S2 disc, are radio graphically easily discernable and sensible, neither categorize the anomalies into clinically useful groups. We, therefore, undertook this study to describe the prevalence and morphology of the different types of LSTV. Further, we came up with new classification schema that we believe are easier to remember, more practical and clinically useful that the currently existing ones.

Lumbosacral junctional anomalies are common, with reported prevalence rates of 4%–35%, with Castellvi types II and III being the most common.[4,16] The prevalence of such developmental defects is higher in men compared to women – 28.1% and 11.1%, respectively.[14] Moreover, sacralization is more often recorded in men, while lumbarization in women.[17]

Our study, based on a comprehensive of lumbosacral dysgenesis among 4816 patients, is, to our knowledge, the second largest series in modern literature. French *et al*.[10] studied 5941 radiographs and found LSTV in 9.9% of cases; Hanhivaara *et al*.[18] studied 3855 abdominal CT scans and found an anomaly in 28.6% of cases; Nardo *et al*.[19] evaluated 4636 radiographs and found an anomaly in 18.1% of cases; Tini *et al*.[20] analyzed 4000 radiographs and found an anomaly in 6.7% of cases. These numbers are roughly comparable to our finding of LSTV in 8.1% of cases. Only Hanhivaara's finding of anomalies in 28.6% of cases is substantially different. While we have no explanation for why this might be the case, we conjecture that different populations may have differences in congenital morphologies.

Biomechanically, the greatest axial load develops in the transition regions, including in the lumbosacral junction.[2,21] This is felt to be one of the reasons that degenerative pathology is so prevalent in the lumbosacral region.[22,23] Lumbosacral dysgenesis disrupts the natural kinematics of the spine due to the fact that the sacrum, with an altered size, shape, and area provides a nonphysiological distribution of the upper body weight on the sacroiliac joint.[24,25] Anatomical changes which are characteristic of the LSTV include changes in the height and size of the pedicles, as well as their inclination; asymmetry of FJ and increased coronal orientation; the presence of concomitant anomalies in the development of neural structures; a decrease in the disc height compared to the adjacent one; and weakness of the ilio-transverse ligaments with impaired segmental stability.[6,26,27] Clinical manifestations of the degenerative disease in the presence of an LSTV are usually caused by accelerated degeneration of the overlying segment due to its hypermobility.[28,29]

In our series, we had 41 patients with 6 lumbar vertebrae. Twenty-four of these had 12 ribbed vertebrae and had an S1 that was lumbarized. The remaining 17 had a nonribbed T12. We did not reveal L1 thoracization and 13 ribbed vertebrae. We found 7 cervical ribs, but this was not associated with a specific type of lumbosacral junction anomaly.

The presence of an anomaly in the development of the lumbosacral junction of the spine can result in a discrepancy between clinical symptoms and radiographic data.[25,30] This increases the risk of miscounting the number of lumbar segments, which in turn increases the risk of a wrong-level operation.[10] We recommend getting full-spine radiographs and/or CT on all such patients and counting down from the first ribbed vertebra to avoid mislabeling a level based only on MRI images. Such a situation might occur in a patient with a lumbarized S1. With the benefit of both X-rays and MRI, one can discern that the most caudal mobile segment is S1-S2. However, a neuroradiologist interpreting the MRI without radiographs may assume that the most caudal mobile segment is L5-S1. In addition to miscounting the vertebral level, another form of "wrong-level" surgery could happen in correctly counted cases where the dermatomes and myotomes are anomalous. For example, in a patient with 6 lumbar vertebrae with several disc herniations, which one corresponds to the typical L5 distribution?

Due to the relatively low incidence of verified anomalies of the lumbosacral junction as well as definitive papers on the topic, there may be a lack of awareness among spinal surgeons about this pathology, as well as with ineffective preoperative identification of such patients.

Limitations of the study

Limitations of the study include the following: (1) the absence of asymptomatic subjects, which may affect the true prevalence of the lumbosacral junctional vertebra in the population; (2) the retrospective nature of the study; (3) the study population is from one country and the results may not be representative of a multiracial global population.

Strengths of the study

The main strength of this study includes the following: (1) the large number of analyzed cases; (2) the detailed preoperative radiographic analysis using plain radiographs, CT, and MRI of 352 lumbar spines to verify the exact type of LSTV; (3) independent assessment by two experienced specialists (neurosurgeon and radiologist); (4) three-dimensional (3D) CT images demonstrating the pathology; and (5) utilization of two existing classifications and modifying them to simpler and, we believe, more clinically relevant ones.

CONCLUSIONS

The prevalence of LSTV in this study sample was 8.1%. LSTVs are a common finding among patients with low back pain, which is important for spine surgery and requires careful preoperative planning to prevent wrong-level surgery, which is one of the leading complications of lumbar surgery. Surgeons can use the 3D CT images in this paper as a reference to visualize and understand the various kinds of anomalies that exist at the lumbosacral junction.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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