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ORIGINAL ARTICLE

Evaluation of the Role of Anatomical Landmarks in Lumbosacral Transitional Anomalies Identification on Magnetic Resonance Imaging of Spine

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Abstract

Background: Labeling a transitional vertebra (lumbarization or sacralization) as "LSTV" helps in simplifying the reporting process but leads to misnumbering and must be avoided, as reliable identification of vertebral levels is essential for surgical interventions and inter- and intra-disciplinary communications. Many landmarks such as the iliolumbar ligament [ILL], costal facets [CF], aortic bifurcation [AB], psoas muscle [PM] origin and conus level [CL] have all been suggested to identify the level of the last lumbar vertebral body in LSTV. However, there are contradictory results in literature regarding their usefulness. Hence we conducted this study to assess usefulness of different anatomical structures (ILL, CF, AB, PM and CL), that can help in counting and identifying last lumbar vertebrae in cases of a LSTV.

Methods: 260 patients with confirmed L5 level (identified on 1.5T MR screening of whole spine) were included in the study. The level(s) of ILL, CF, AB, PM and CL were documented in all of them, and analysis was done.

Results: All patients with normal lumbosacral junction had ILL arising from L5. In the cases of unilateral sacralization and lumbarization, level of origin of ILL was different on right and left side of vertebral column. In these patients ILL was noted to be arising from last lumbar like transverse process on either side. When we used lumbar spine MRI alone for identifying transitional vertebrae the sensitivity of ILL, CF, AB, PM and CL were 85%, 78%, 65.8%, 51.2%, 58.5% respectively and specificity were 100%, 97.3%, 82.2%, 58.0%, 68.0% respectively.

Conclusion: ILL, CF, AB, PM and CL had variable origin with caudal and cranial shifts in lumbarization and sacral-ization respectively and these are not reliable identifier of the L5 vertebra in the setting of LSTV anomalies.

Keywords: Iliolumbar ligament, Lumbosacral transitional vertebrae, Lumbarization, Sacralization

Introduction

"Lumbosacral transitional vertebra (LSTV)" is the term used for congenital anomalies defined as either sacralization of the lowest lumbar vertebrae or lumbarization of the first sacral vertebrae because it is not always possible to differentiate between these two without imaging of the entire spine [1].

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Labeling a transitional vertebra as "LSTV" in lumbosacral spine imaging is helpful in simplifying the reporting process but this may lead to misnumbering and must be avoided [1].

Reliable identification of lumbar vertebral levels is essential for surgical interventions, image-guided injections and inter- and intra-disciplinary communications [2,3]. Transitional vertebrae can also be a source of back pain, especially seen in cases of Bertolotti's syndrome [4,5]. Whole spine images obtained using high-field magnetic resonance imaging (MRI) are helpful in counting vertebrae and identifying transitional vertebrae [6].

Many landmarks such as the iliolumbar ligament, level of costal facets, level of the aortic bifurcation, the origin of psoas muscle and level of conus medullaris have all been suggested to identify the level of last lumbar vertebral body in LSTV. However, there are contradictory results in literature regarding their usefulness [7,8].

In our study, we sought to assess usefulness & reliability of different anatomical structures (iliolumbar ligament [ILL], costal facets [CF], aortic bifurcation [AB], psoas muscle [PM] origin, conus level [CL],) that can help in counting and identifying last lumbar vertebrae as there is no standardized method to identify LSTV unequivocally [7-9].

Methods

This prospective, cross-sectional study was conducted in our institution over a period of one year. MRI lumbosacral spine with whole spine MRI screening of 260 patients were included in this study after excluding those with fractures, infection, vertebral metastasis or gross vertebral destruction or previous lumbar spine surgery, disabling proper evaluation and vertebral counting.

All MR images were acquired using 1.5T Siemens MR scanner. MRI spine sequences included sagittal & axial, T1-weighted (T1W) & T2-weighted (T2W); sagittal & coronal short-tau inversion recovery (STIR); coronal T2W and whole spine screening using sagittal T2W sequence. Whole spine MRI sagittal T2W images were used to accurately number the vertebrae. The L5 vertebra was identified by counting down from C2 vertebra in midsagittal T2W images of whole spine.

The patients were divided into three main groups:

Group-1: Patients with typical normal lumbosacral junction

Group-2: Patients with sacralization type lumbosacral junction

Group-3: Patients with lumbarization type lumbosacral junction

The patients with sacralization type LSTV (Group-2) were further classified into four types according to Castellvi et al [10] (Table 1).

The patients with Lumbarization type LSTV (Group-3) were also further divided as partial (incomplete separation of S1–S2 bodies and their neural arches) or complete (complete separation of S1–S2 bodies and their neural arches) according to Mahato NK [11]. Partial lumbarization was further subdivided into unilateral partial (incomplete separation of S1–S2 bodies and their neural arches on one side and complete separation of S1–S2 bodies and their neural arches on other side) and bilateral partial (incomplete separation of S1–S2 bodies and their neural arches on both the sides).

Two radiologists studied the lo-cation of the anatomical structures ILL, CF, AB, PM and CL of all patients. ILL was assessed on axial and coronal T2-weighted images. Origin of the ILL was documented separately on both right and left sides with respect to the vertebral level. CF was assessed on sagittal and coronal T2- weighted images and level of last costal facet is noted. AB and CL were assessed on sagittal and axial T2-weighted images. Coronal and axial T2-weighted images were used for assessing the PM origin. AB, CL and PM origin level were noted. Intervertebral disc level was counted with its inferior vertebral level for statistical purpose.

Results

Two hundred and sixty patients including in our study group comprised of 126 males and 134 females with age-range of 11-81 years and mean age of 42.97 years. Most common age group in our study was 31-40 years.

Out of 260 patients, 219 (84.3%) had normal lumbosacral segmentation while 41 (15.7%) had transitional lumbosacral junctions. 35 out of 41 patients (13.4% of total) revealed sacralization of L5 while rest 6 (2.3% of total) revealed lumbarization of S1 vertebra.

ILL was found bilaterally in all patients. All patients from group-1 (219 patients) had ILL arising from L5 vertebra bilaterally. In group-2 (35 patients), 25 patients had ILL

Table 1: Castellvi et al. classification.

Types	Characteristics	Subtype (if any)	
Type-I	dysplastic transverse processes, measuring at least 19 mm in width (craniocaudal dimension)	Ia	Unilateral
		Ib	Bilateral
Type-II	sacralization with an enlarged transverse process that has a diarthrodial joint between itself and the sacrum	IIa	Unilateral
		IIb	Bilateral
Type III	sacralization with complete osseous fusion of the transverse process (es) to the sacrum	IIIa	Unilateral
		IIIb	Bilateral
Type IV	a unilateral type II transition with a type III on the contralateral side	-----	

arisen from the L4 vertebra bilaterally, 2 patients had ILL arisen from L5 vertebra bilaterally and 8 patients had ILL arising from the L4 vertebra on one side and from L5 vertebra on other side. In group-3 (6 patients), 3 patients had ILL arisen from the S1 vertebra bilaterally, 1 patient had ILL arising from the L5 vertebra bilaterally and 2 patients had ILL arising from the L5 vertebra on one side and from S1 vertebra on other side.

Among the cases of sa-cralization (35 patients), Castellvi types IIb, IIIb and IV consti-tuted 25 cases and had ILL arising from the L4 vertebra bilaterally. Castellvi types IIa and IIIa consti-tuted 10 cases. Of those 8 patients had ILL arising from the L4 vertebra on sacralized side and from L5 vertebra on contralateral side and 2 patients had ILL arising from the L5 vertebra bilaterally.

Among the cases of lumbarization (6 patients), 3 patients had complete lumbarization and had ILL arisen from S1 vertebra bilaterally, 1 patient had bilateral partial lumbarization and had ILL arisen from L5 vertebra bilaterally and 2 patients had unilateral partial lumbarization and had ILL arisen from S1 vertebra on lumbarized side and from L5 vertebra on contralateral side (Table 2, Figure 1 and 2).

Of the 260 patients, 245 (94.3%) patients had the last CF at D12. Eleven of the 260 patients (4.2%) had the last CF at D11, with 6 of them in the sacralization group and 5 in the normal group. Only four patients (1.5%) had their last CF at L1, with three of them in the lumbarization group and one in the normal group. The last CF at D12 was identified in 97.2%, 82.9%, and 50% in the normal, sacralization, and lumbarization groups, respectively (Table 3, Figure 3).

AB was observed at L2–L3 to L5 levels. Over-all, L4 was the commonest site of AB in 165 of 260 pa-tients, contributing to the incidence of 63.4%, followed by L3–L4 (42/260), which contributed to 16.1%. L4 (143/219) and L3–L4 (37/219) were the commonest sites of AB in the

Table 2: Location of Iliolumbar ligament.
L - Lumbar vertebrae, S - Sacral vertebrae, r - Right side, l - Left side, b - Both sides.

Iliolumbar ligament	Grade	bL4	bL5	rL4-IL5	rL5-IL4	rL5-IS1	rS1-IL5	bS1	Total
Sacralization	2a	-	1	4	3	-	-	-	8
	2b	5	-	-	-	-	-	-	5
	3a	-	1	-	1	-	-	-	2
	3b	19	-	-	-	-	-	-	19
	4	1	-	-	-	-	-	-	1
Normal		-	219	-	-	-	-	-	219
Lumbarization	Unilateral Partial	-	-	-	-	1	1	-	2
	Bilateral Partial	-	1	-	-	-	-	-	1
	Complete	-	-	-	-	-	-	3	3
Total		25	222	4	4	1	1	3	**260**

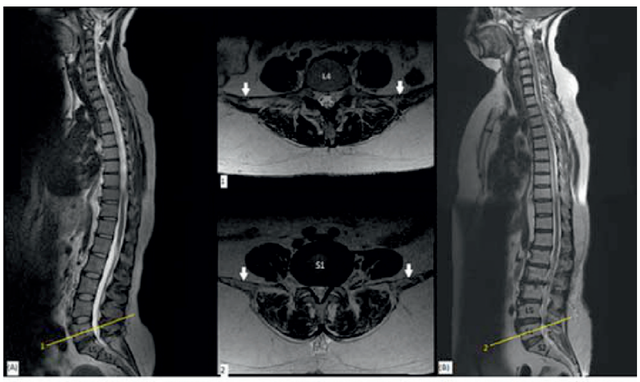

Figure 1 : Clockwise - MRI images of (A) T2W mid sagittal section of LSTV spine with sacralization of L5 (Castellvi 3b); (1) T2W axial section of spine shown in (A) at L4 showing bilateral ILL arising from L4; (B) T2W mid sagittal section of LSTV spine with complete lumberization of S1; and (2) T2W axial section of spine shown in (B) at S1showing bilateral ILL arising from S1.

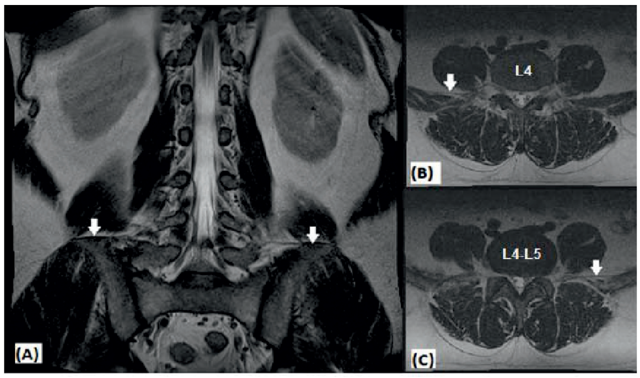

Figure 2 : Clockwise - MRI images of (A) T2W coronal section of LSTV spine with sacralization (Castellvi type 2a); (B) T2W axial section of spine shown in (A) at L4 showing right ILL arising from L4; and (c) T2W axial section of spine shown in (a) at L4-L5 showing left ILL arising from L5.

Table 3: Location of inferior most costal facet

Costal Facet	Group			Total
	Normal	Sacralization	Lumbarization	
D11				
Count	5	6	0	11
% within group	2.3	17.1	0	4.2
% of total	1.9	2.4	0	4.2
D12				
Count	213	29	3	245
% within group	97.2	82.9	50	94.3
% of total	81.9	11.1	1.15	94.3
L1				
Count	1	0	3	4
% within group	0.5	0	50	1.5
% of total	0.4	0	1.15	1.5
Total Count	219	35	6	260
% of total	84.2	13.5	2.3	100.0

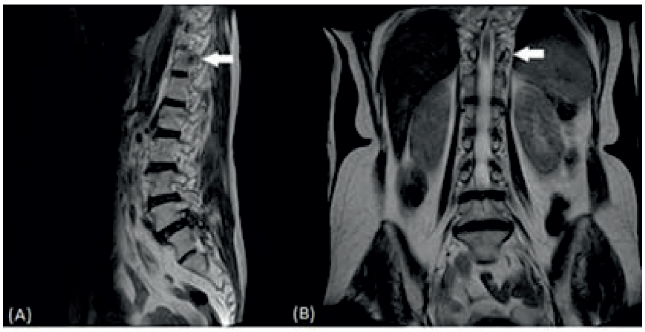

Figure 3 : MRI images of :(A) T2W parasagittal section of spine with typical normal lumbosarcral junction showing costal facet at D12; (B) T2W coronal section of spine shown in (A) showing costal facet at D12.

normal group, contributing to 65.3% and 16.9%, respectively. In the sacralization group, L4 (18/35) and L3 (9/35) were the commonest sites of AB in patients contributing to 51.4% and 25.7%, respectively. L4 (4/6) and L4–L5 (1/6) was the commonest sites of AB in patients in the lumbarization group, contributing to 66.6% and 16.7%. Low bifurcation at L5 was observed in two patients (0.9%) in the normal group. High bifurcation at or above L3 was observed only in 17 patients (7.76%) in the normal group and 9 (25.7%) in the sacralization group and none in lumbarization group (Table 4, figure 4).

Psoas muscle origin (superior most fibers) was observed from D11-D12 to L1-L2 levels. In the normal group, PM were observed originating more commonly at D12-L1 in 102/219 patients (46.6%) and at D12 in 89/219 patients (40.6%). The remain-ing cases in the normal group had PM origin from L1 (25/219 [11.4%]), L1–L2 (2/219 [0.9%]), and D11–D12 (1/219 [0.5%]). In the sacralization group, the PM ori-gin was observed at D12 in 16/35 patients (45.7%), D12–L1 in 16/35 (45.7%) patients and at L1 in 2/35(5.7%) patients. Only in 1 case (2.9%), it was observed at D11–D12. In the lumbarization group, the PM origin was at L1 in 3 (50%) patients, at L1–L2 in 2 (33.3%) patients and at D12 in 1 (16.7%) patient (Table 5, figure 5).

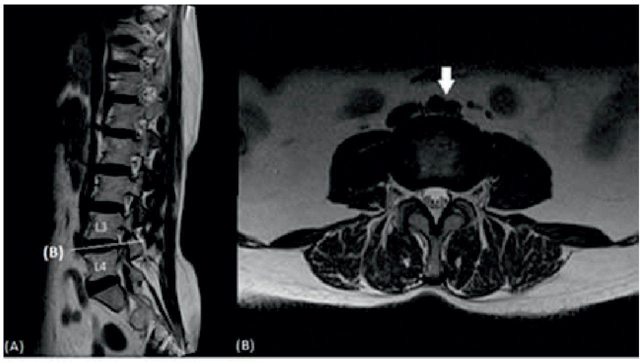

Figure 4: MRI images of :(A) T2W parasagittal section of spine with typical normal lumbosarcral junction (B) T2W axial section of spine shown in (A) at L3-L4 showing aortic bifurcation.

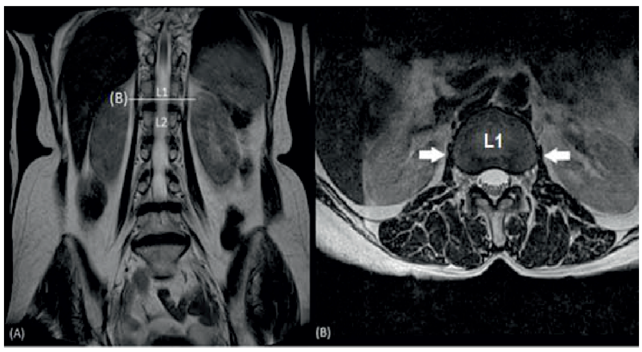

Figure 5: MRI images of :(A) T2W coronal section of spine with typical normal lumbosarcral junction; (B) T2W axial section of spine shown in (A) at L1 showing of superior-most fibres of bilaeral psoas muscles.

CL was observed at D11-D12 to L2-L3 levels. Over-all, L1 was the commonest site of CL in 124 of 260 pa-tients, contributing to the incidence of 47.7%, followed by D12-L1 (49/260), which contributed to 18.9%. L1 (111/219) and L1–L2 (42/219) were the commonest sites of CL in

Table 4: Level of aortic bifurcation

Aortic bifurcation	Groups			Total
	Normal	Sacralization	Lumbarization	
L2-L3				
Count	1	0	0	1
% within group	0.5	0	0	0.4
% of total	0.4	0	0	0.4
L3				
Count	16	9	0	25
% within group	7.3	25.7	0	9.6
% of total	6.2	3.5	0	9.6
L3-L4				
Count	37	5	0	42
% within group	16.9	14.3	0	16.1
% of total	14.2	1.92	0	16.1
L4				
Count	143	18	4	165
% within group	65.3	51.4	66.6	63.4
% of total	55	6.92	1.5	63.4
L4-L5				
Count	20	3	1	24
% within group	9.1	8.6	16.7	9.2
% of total	7.7	1.16	0.4	9.2
L5				
Count	2	0	1	3
% within group	0.9	0	16.7	1.1
% of total	0.7	0	0.4	1.1
Total				
Count	219	35	6	260
% of total	84.2	13.5	2.3	100.0

Table 5: Origin of superior most fibers of psoas muscle

Psoas Muscle Origin	Groups			Total
	Normal	Sacralization	Lumbarization	
D11-D12				
Count	1	1	0	2
% within group	0.5	2.9	0	0.8
% of total	0.4	0.4	0	0.8
D12				
Count	89	16	1	106
% within group	40.6	45.7	16.7	40.8
% of total	34.3	6.2	0.4	40.8
D12-L1				
Count	102	16	0	118
% within group	46.6	45.7	0	45.4
% of total	39.2	6.2	0	45.4
L1				
Count	25	2	3	30
% within group	11.4	5.7	50	11.5
% of total	9.6	0.7	1.2	11.5
L1-L2				
Count	2	0	2	4
% within group	0.9	0	33.3	1.5
% of total	0.7	0	0.7	1.5
Total				
Count	219	35	6	260
% of total	84.2	13.5	2.3	100.0

the normal group, contributing to 50.7% and 19.2%, respectively. In the sacralization group, L1 (12/35) and D12-L1 (10/35) were the commonest sites of CL in patients contributing to 34.3% and 28.6%, respectively. L1-L2 (2/6) was the commonest site of CL in pa-tients in the lumbarization group, contributing to 33.3%. Low position at L2-L3 was observed in two patients (0.9%) in the normal group. High position at or above D12 was observed only in 24 patients (11%) in the normal group and 10 patients (28.5%) in the sacralization group and none in lumbarization group (Table 6).

Discussion

LSTV is an anatomical variant which includes both lumbarization of the S1 vertebra and sacralization of the L5 vertebra [3]. Correct identification of an LSTV on imaging studies is essential because of potential clinical implications [6]. Inaccurate identification may lead to surgical and procedural errors and poor correlation with clinical symptoms and moreover legal implications [2,3,6]. Moreover, there is increased prevalence of disc protrusion or extrusion in the disc above LSTV [2,12,13].

We feel that the most reliable way to number the vertebra is by counting down from C2 vertebrae as proven from previous published literature [6]. Therefore, our study included only those subjects in whom accurate numbering of the last lumbar vertebra or LSTV was possible on whole spine sagittal T2W MRI pasted images. Radiographs of the entire spine may allow the radiologist not only to count from C2 vertebrae inferiorly but also to differentiate hypoplastic ribs from lumbar transverse processes; however, there are very few cases nowadays in which plain films of the entire spine of a given patient are available [14-17]. Moreover, in cases of MRI lumbar spine, whole spine screening is not done routinely in most of the centers. Therefore many parameters have been described in literature like iliolumbar ligament [ILL], level of the aortic bifurcation, the origin of psoas muscle, level of costal facet, level of conus medullaris, the origin of iliac arteries and the renal arteries as means for numbering and determination of the last lumbar vertebral body [8,9,18,19]. However, there are contradictory results in literature regarding their

Table 6. Level of conus medullaris

Conus Level	Groups			Total
	Normal	Sacralization	Lumbarization	
D11-D12				
Count	1	2	0	3
% within group	0.5	5.7	0	1.15
% of total	0.4	0.7	0	1.15
D12				
Count	23	8	0	31
% within group	10.5	22.8	0	11.9
% of total	8.8	3	0	11.9
D12-L1				
Count	38	10	1	49
% within group	17.3	28.6	16.7	18.9
% of total	14.6	3.8	0.4	18.9
L1				
Count	111	12	1	124
% within group	50.7	34.3	16.7	47.7
% of total	42.7	4.6	0.4	47.7
L1-L2				
Count	42	2	2	46
% within group	19.2	5.7	33.3	17.7
% of total	16.1	0.7	0.7	17.7
L2				
Count	2	0	1	3
% within group	0.9	0	16.7	1.15
% of total	0.7	0	0.4	1.15
L2-L3				
Count	2	1	1	4
% within group	0.9	2.9	16.7	1.5
% of total	0.7	0.4	0.4	1.5
Total				
Count	219	35	6	260
% of total	84.2	13.5	2.3	100.0

usefulness.

In our study, ILL emerged bilaterally from the last lumbar vertebra L5 in 85% of the patients. Rest of the patients had origin of ILL from L4 or S1 vertebrae bilaterally or at least on one side from L4 or S1 vertebrae. In our study all patients (100%) with typical normal lumbosacral junction had ILL arising from L5 vertebra bilaterally.

Among the cases of bilateral sacralization in our study, ILL was seen arising from the L4 vertebra bilaterally. In unilateral sacralization, ILL was arising from the L4 vertebra on the sacralized side and from L5 vertebra on other side or L5 vertebra bilaterally. As L5 vertebrae had sacrum like morphology in these cases, ILL like ligament at L5 level could be sacral ligaments seen normally at S1 level and non-recognition of ILL at L4 level in these patients could be due to limitation of non-continuous sections.

In patients with lumbarization type lumbosacral junction (6 patients), 3 patients with complete lumbarization had ILL arising from the S1 vertebra, 1 patient with bilateral partial lumbarization had ILL arising from L5 vertebra and 2 patients with unilateral partial lumbarization had ILL arising from S1 vertebra on lumbarized side and from L5 vertebrae on other side. We further observed that in the cases of unilateral sacralization and lumbarization, level of origin of ILL was different on right and left side of vertebral column.

Carrino et. al. [20] in their study also found that ILL did not always denote the level of L5 and suggested that ILL could be used to identify the lum-bosacral junction rather than L5. Bressler also reiter-ated the same point [21].

The last CF at D12 was identified in 97.2%, 82.9% and 50% in the normal, sacralization, and lumbarization groups, respectively. When we used lumbar spine MRI alone for identifying transitional vertebrae using the last CF at D12, the sensi-tivity was 78% and specificity was 97.3%. The reason for the reduced sensitivity is that 6 cases (17%) of sacralization had the last CF at D11. Differentiation of the rudimentary CF from a rudimentary posteri-or element was difficult in some cases. CFs were superior and anterior to the posterior margin of the vertebral body, whereas the rudimentary posterior element was superior and posterior to the posterior margin of the vertebral body [22].

The Aortic bifurcation at L4 [including L3-L4] was identified in 82.2%, 65.7% and 66.6% in the normal, sacralization, and lumbarization groups, respectively. When we used lumbar spine MRI alone for identifying transitional vertebrae using the aortic bifurcation at L4 (including L3-L4), the sensi-tivity was 65.8% and specificity was 82.2%.

The Psoas muscle origin at L1 [including D12-L1] was identified in 58.0%, 51.4%, and 50% in the normal, sacralization and lumbarization groups, respectively. When we used lumbar spine MRI alone for identifying transitional vertebrae using the psoas muscle origin at L1 (including D12-L1), the sensi-tivity was 51.2% and specificity was 58.0%.

The conus level at L1 [including D12-L1] was identified in 68.0%, 62.9% and 33% in the normal, sacralization, and lumbarization groups, respectively. When we used lumbar spine MRI alone for identifying transitional vertebrae using the conus level at L1 (including D12-L1), the sensi-tivity was 58.5% and specificity was 68%.

Lee et al. in their study involving 534 patients to assess the location of paraspinal structures on MRI, found that the paraspinal structures of S1 lumbarization were positioned more caudally, whereas the paraspinal struc-tures of L5 sacralization were positioned more cephalad [7,21].

Based on above findings, we recommend that if additional imaging is not possible then one should make an explicit statement in lumbar spine MR imaging report regarding how the lumbosacral junction was determined (e.g., "this report assumes that there are five lumbar-type vertebrae, with the lowest lumbar vertebra identified by the ILL"). If an LSTV is present, this should be stated along with its characterization, including where the lowest well-formed intervertebral disk is. This landmark can be identified at fluoroscopy during surgical or percutaneous procedures. Our study supports the use of this type of corroborative imaging during procedures because of the association of LSTVs with anomalous numbers of vertebrae [20].

Limitations of the Study

- Selection bias in the study population.
- Absence of correlation with radiography.
- Non-identification of numerical variants of the spine as a separate en-tity from transitional lumbosacral vertebrae.
- Lack of availability of contiguous axial images from L4 to S1 levels.

Conclusion

In patients with LSTV, AB, CL, CF and PM have variable origin with caudal and cranial shifts in lumbarization and sacral-ization, respectively. Among these CF shows highest sensitivity and specificity. ILL is not a reliable identifier of L5 vertebra in the setting of an LSTV, but simply identifies the lowest lumbar-type vertebral segment. In our opinion, the most ideal scenario would be to acquire whole spine T2-weighted images in every case to avoid any potential pitfall in vertebral count-ing and identification.

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Ethics:	There is no ethical violation as it is based on voluntary anonymous interviews
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