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Case Report

Is There A Need for Servicothoracic Survey Images for Vertebral Enumeration in LSTV; MRI Study

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Abstract

Objectives: In this study we aimed to evaluate any reliable marker on MRI studies for vertebral enumeration without any need to whole spine imaging.

Background: Lumbosacral transitional vertebra (LSTV) is an anatomical variation that is mostly incidentally detected in routine spinal magnetic resonance imaging (MRI) studies. Its detection and awareness have great importance especially for planning of an interventional procedure.

Methods: We retrospectively evaluated 899 lumbar MRI examinations. Vertebral levels of aortic bifurcation (AB), celiac trunk (CT), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), inferior vena cava (IVC) confluence), 12th costovertebral junction and the origin level of psoas muscle were evaluated.

Results: The incidence of LSTV was 10.3%. The visibility of these anatomical structures were AB; 100%, CT; 96.8%, SMA; 96.8%, LRA; 96.8%, RRA; 95.7%, IVC confluence; 77.4%, ILL; 30.1%, 12. costovertebral junction; 11.8%, PO; 97.8%.

Conclusion: Vascular landmarks were detected to be more proximally located in LSTV group. As a result there was not any reliable anatomical landmark to predict the correct enumeration of the vertebrae.

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Introduction

Lumbosacral transitional vertebrae (LSTV) is an anatomic variation involving the lumbarization of the first sacral vertebra (S1) and the sacralization of the fifth lumbar vertebra (L5) [1-3]. Castellvi et al. defined four different subtypes [4]. Although the presence of LSTV can be recognized by x-ray, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI), multiplanar imaging with CT can demonstrate the LSTV anatomy with higher reliability due to its higher spatial resolution and multiplanar slicing ability.

However, LSTV is usually an incidental finding in spinal imaging and identifying LSTV has great importance in the planning of surgery at the right level, especially in patients who are candidates for lumbar spinal surgery for various reasons such as trauma, tumor and disc disease [5]. MRI is a frequently used imaging modality in the diagnosis of low back pain and degenerative disc diseases and before spinal surgery. It is possible to determine the exact level of the surgical intervention when the whole spine survey images are included to the MRI studies. However, the detection of the correct level in MRI examinations, especially when only the lumbar region is displayed is a controversial issue. Several studies have been conducted on this case, but no standard has been established yet [6-8]. In this study, we aimed to determine whether various anatomical and vascular structures that are easily visible in MRI examinations can be used as a marker for vertebrae numbering by evaluating and comparing the patients with normal lumbosacral junction anatomy.

Materials and Methods

MRI examinations of 1332 adult patients who underwent lumbar spinal MRI between October 2018 and January 2019 with the preliminary diagnosis of lumbar radiculopathy and low back pain in our clinic were evaluated retrospectively. Ethics Committee Approval was received for the study. Three hundred seventy-four patients with a history of spinal trauma, surgery, infection, and spondylolisthesis were excluded; hence, these pathologies could lead to a change in the lumbosacral junction anatomy.

Also, patients who had advanced abdominal aortic tortuosity (n=23), abdominal aortic aneurysm (n=27), nephrectomy history (n=3), ectopic kidney (n=4) and horseshoe kidney (n=2) were also excluded because the patients could mislead the determination of vascular landmarks. As a result, 899 patients were evaluated for the presence of LSTV in the study.

All patients underwent standard lumbar spinal MRI protocol using a spinal coil with 1.5 Tesla MRI (Philips Achieva, Best, and Netherlands). Examination protocol: Axial T2-weighted fast spin echo; TR: 3800 ms, TE: 100 ms, Sagittal T1-weighted spin echo; TR: 500ms, TE: 10ms, Sagittal T2-weighted fast spin echo; TR: 2500ms, TE: 100 ms. FOV: 28 cm (sagittal images) and 22 cm (axial images), matrix: 256×192, slice thickness: 4 mm, interslice gap: 0, 4 mm. The average number of slices for axial T2-weighted images were 26 and it was 14 for sagittal T1-weighted and T2-weighted images.

All the examinations were performed on the picturing archiving and communications system (Infinitt Healthcare, South Korea) Workstation. Two radiologists with seven years and five years of experience in the field of spinal imaging have evaluated all the images independently, and a consensus was established for each patient.

The cervicothoracic survey images were used for the numbering of the vertebrae. C2 vertebra was set as the initiation point and counting performed in the craniocaudal direction starting from C2, and the counting was correlated with the sagittal lumbar MRI. By using the location marker feature of the Workstation, the vertebrae were numbered until the sacrum (Figure 1).

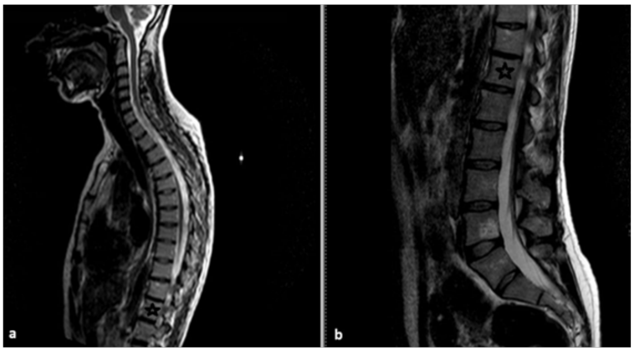

Figure 1: Cervicothoracic survey image (a). Starting to enumerate from C2 craniocaudally T12 (star) vertebra is detected (a) and which is correlated with sagittal T2-weighted image (b).

Iliolumbar ligaments, vascular structures (aortic bifurcation (AB), celiac trunk (CT), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), inferior vena cava (IVC) confluence), 12th costovertebral junction and the origin level of psoas muscle were determined as the anatomical landmarks. Their visibility and levels were evaluated.

The visual acuity of the iliolumbar ligaments was evaluated in axial T2W images. Iliolumbar ligaments were accepted as structures in the form of hypointense linear bands extending from transverse process to the posteromedial of the iliac crest (Figure 2). The origin vertebra of this structure was correlated with sagittal T2W images using the location marker feature in the axial T2W section.

The level of aortic bifurcation from the vascular landmarks was determined on axial T2W images and correlated with the corresponding level in the sagittal T2W images (Figure 3). The origin of the celiac trunk and superior mesenteric artery were determined in the sagittal T2W images (Figure 4).

Renal artery origin was primarily evaluated in axial T2W images. When the axial images could not be seen, rounded structures showing a signal void in sagittal paramedian sections were identified and correlated with the corresponding level in midsagittal sections. IVC confluence visibility and level were evaluated on axial T2W sections, and the corresponding level was determined in sagittal T2W sections. To be able to clarify the costa - transverse process in sagittal T1W sections was considered as criteria for visibility of 12th costovertebral junction. The visual acuity and level of the Psoas muscles visibility and level were determined according to the visibility of their origin in transverse processes in axial and consecutive sagittal sections.

Figure 2: Axial T2-weighted MR image showing iliolumbal ligament on the left as a hypointense linear bands extending from transverse process to the posteromedial of the iliac crest.

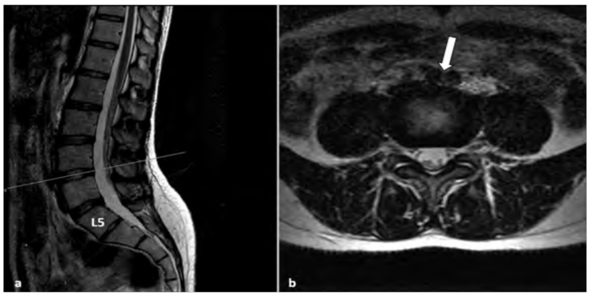

Figure 3: Sagittal T2-weighted MR image (a) of a LSTV patient, and corresponding axial T2-weighted MR image (b) passing through the L3-L4 intervertebral disc level at which the aortic bifurcation (arrow) is seen.

Figure 4: Sagittal T2-weighted MR image of a LSTV patient. Origins of celiac truncus (thin arrow) and superior mesenteric artery (thick arrow) are seen with the corresponding vertebral levels T12 proximal half and L1 proximal half respectively.

In this study, 124 patients with preserved intervertebral joint distances, normal lumbar lordosis, lumber MRI examinations reported as "lumber MR imaging within normal limits", and having normal lumbosacral junction anatomy were included as control group.

Statistical analysis of the data was analyzed using the Statistical Package for Social Sciences version 15.0 (SPSS, Chicago, USA). Data of continuous variables were expressed as mean, standard deviation, median, minimum, maximum, and categorical variables with frequency and percentage. In the comparison of the groups, Chi-square test and Fisher exact test for categorical variables, Mann-Whitney U test for continuous variables and Spearman test for correlations were used. The results were evaluated with a 95% confidence interval and a significance level of $p < 0.05$ (*p<0.05, **p<0.01, ***p<0.001).

Results

LSTV was present in 10.3% (n = 93) of 899 patients included in the study. The mean age of the LSTV group was 37.03±11.44, and the mean age of the control group was 30.30±9.28 (p<0.0001). The viewability ranking of the anatomical landmark is shown in Table 1.

In the control group, the rate of visualization of the psoas origin was higher compared to the LSTV group. Although the rate of visualization of the right renal artery and the celiac trunk was lower, there was no statistically significant difference (p>0.05) (Table 2).

The distribution of levels in which the vascular landmark is visualized in the LSTV and control groups are shown in Table 2. (AB: aortic bifurcation, CT: coeliac truncus, SMA: superior mesenteric artery, RRA: right renal artery, LLA: left renal artery, IVC: inferior vena cava, PO: psoas origin)

Discussion

In this study, we aimed to determine whether paraspinal anatomical structures and intraabdominal vascular structures can be used as a marker for vertebra numbering in people with LSTV anatomy.

Hughes and Saifuddin showed that ILL took origin from the L5 vertebrae transverse processes and this vertebra can be accepted as L5 in the presence of ILL [6]. Also, studies are showing that ILL takes origin from different levels other than L5 vertebra [7,9,10]. However, in our study, the visibility of ILL, one of the paraspinal anatomical structures, in patients with LSTV anatomy in MR Imaging was found significantly lower than those in the control group. This situation shows that, although it is seen as an essential criteria in vertebra numbering in its existence, it is not a usable landmark since its detectability rate is low.

Vascular structures of AB, SMA, and RRA have been the subject of various studies. For AB L4 vertebral corpus [5,11]and L3-L4 levels [12], for SMA L1 vertebrae corpus [5]and T12 vertebrae corpus [12], and RRA L1 vertebrae corpus [5,12] and L1-L2 distance were most commonly shown as origin points. In Lee et al.'s [11] study of 210 people, they concluded that AB and RRA could be reliable anatomical markers. In our study, we found similar rates in people with normal lumbosacral junction anatomy, but it was different in LSTV cases. AB and RRA were more proximal in LSTV cases. In our study, the results we obtained for AB, SMA, and RRA were similar to those of other studies. In similar studies in the literature, LRA was not included in the studies because it was less visible in sagittal sections since it has a shorter course compared to the right. In our study, LRA was evaluated among the possible markers, and it was seen that it was mostly originated from the L1 vertebral corpus, L1 vertebra proximal (54,8%) and L1 vertebra distal (29%), in LSTV cases. In the control group, it was found to be more inferior.

A remarkable point in our study in vascular markers is that compared with those with standard lumbosacral junction anatomy AB, SMA, RRA, and LRA are more proximal in people with LSTV anatomy. CT was most commonly originated from T12 vertebra corpus in patients with LSTV. In the control group, in addition to the T12 vertebrae corpus, it was also originated from the T12-L1 with a similar frequency. However, in the cases with LSTV, it was rarely originated from this level. In the anatomy study, Lee et al. evaluated the paraspinal structures in the MRI and showed that the AB was located in the distal L4, CT was originated from T12-L1, and RRA was originated from L1-L2. Besides, Josiah et al. also found that some anatomic structures such as iliac crest, iliac vein, iliac bifurcation were more proximal than the control group [13]. In our study, the results were L4 proximal for AB level, T12 proximal and L1 distal respectively for CT and RRA origin levels. This difference may be due to the lower number of the control group with normal lumbosacral junction anatomy in our study.

LSTV			Controls			
	n	%		n	%	P
ILL	28	30.1	ILL	101	81.5	**0.0001** ***
AB	93	100	AB	124	100	-
CT	90	96.8	CT	115	92.7	0.137
SMA	90	96.8	SMA	120	96.8	0.999
RRA	89	95.7	RRA	114	91.9	0.364
LRA	90	96.8	LRA	115	92.7	0.198
IVC confluence	72	77.4	IVC confluence	112	90.3	**0.009** **
12.costovertebral junction	11	11.8	12.costovertebral junction	43	34.7	**0.0001** ***
PO	91	97.8	PO	124	100	0.183

Table 1: The view ability ranking of anatomical landmark.

	LSTV		Controls	
	n	%	n	%
AB				
L3 proximal	16	17.2	2	1.6
L3 distal	22	23.7	5	4
L3-L4	33	35.5	21	16.9
L4 proximal	21	22.6	73	58.9
L4 distal	1	1.1	18	14.5
L4-L5	0	0	2	1.6
L5 proximal	0	0	3	2.4
CT				
Not visualized	3	3.2	10	8.1
T12 proximal	46	49.5	37	29.8
T12 distal	36	38.7	33	26.6
T12-L1	6	6.5	32	25.8
L1 proximal	2	2.2	10	8.1
L1 distal	0	0	2	1.6
SMA				
Not visualized	3	3.2	4	3.2
T12 proximal	7	7.5	5	4
T12 distal	36	38.7	32	25.8
T12-L1	34	36.6	29	23.4
L1 proximal	11	11.8	41	33.1
L1 distal	2	2.2	9	7.3
L2 proximal	0	0	4	3.2
RRA				
Not visualized	4	4.3	9	7.3
T12-L1	13	14	0	0
L1 proximal	52	55.9	17	13.7
L1 distal	20	21.5	52	41.9
L1-L2	3	3.2	32	25.8
L2 proximal	1	1.1	6	4.8
L2 distal	0	0	7	5.6
L3 distal	0	0	1	0.8
LRA				
Not visualized	3	3.2	9	7.3
T12-L1	9	9.7	0	0
L1 proximal	51	54.8	18	14.5
L1 distal	27	29	52	41.9
L1-L2	2	2.2	32	25.8
L2 proximal	1	1.1	6	4.8
L2 distal	0	0	7	5.6
IVC confluence				
Not visualized	21	22.6	12	9.7
T12-L1	7	7.5	1	0.8
L1 proximal	15	16.1	18	14.5
L1 distal	33	35.5	44	35.5
L1-L2	14	15.1	32	25.8
L2 proximal	3	3.2	9	7.3
L2 distal	0	0	6	4.8
L3 proximal	0	0	2	1.6
PO				
Not visualized	2	2.2	0	0
T12	17	18.3	26	21
L1	74	79.6	98	79

Table 2: The distribution of levels in which the vascular landmark is visualized in the LSTV and control groups.

In our study, since it did not frequently enter the cross-sectional area in sagittal sections, and did not coincide in axial cross-sections because of the slice gap, IVC confluence was only visualized in 77.4% of the cases. Between visualized, similarly to the control group, it was observed distal to L1 level. This vascular marker has not been a parameter that has been evaluated in every study and differs with others in our study [1].

Psoas muscle origin is best visualized in coronal sections. However, in many centers, only the axial and sagittal sections are present in the routine lumbar MRI protocol. It may not be possible to see the origin of the psoas muscle, which is seen as hypointense structures beside the vertebrae in axial sections. In our study, all of the control group could be visualized, and 2 of the patients with LSTV could not be evaluated. In both groups, it was observed that it originated from T12 and L1 levels with similar rates, frequently at L1 levels. In the study of François et al. MRI of 477 patients, 81.4% of 43 patients with LSTV anatomy, psoas origin was detected in L1 vertebrae [14]. This ratio is 79.6% in our study with 93 LSTV cases, and it is similar to the control group.

Considering all findings, vascular landmarks compared to patients with normal lumbosacral junction anatomy, AB was in a more proximal position, and the abdominal aortic branches originate from a more proximal position in the patients with LSTV. In addition, when level detection is performed with only lumbar MR images, it can result in some surgical errors. Also, some morphological parameters, such as the vertebral corpus shape, S1-S1 disc morphology, or lumbosacral angle, may also cause a false level detection [5]. Hahn et al. [15] and Peh et al. [16], respectively, stated the importance of cervicothoracic sagittal and coronal localizer images in level detection in LSTV cases. Similarly, Tokgöz et al. also found a mistake in 14.1% of the lumbar MR images obtained without whole spine localizer images.

As a result, LSTV is an anatomical variation and in such cases various vascular landmarks are more located more proximally. Also, there is no anatomic structure, from vascular structures and other anatomical structures such as ILL and PO that can be used as a landmark in vertebra numbering in patients with LSTV. In conclusion it is the best thing to include servicothoracic survey images to standard lumbar MRI protocols in order to avoid important diagnostic and interventional mistakes.

Limitation

In our study, LSTV was discussed in general, no the distinction of sacralization and lumbarization was made, and it was not evaluated whether there was a difference between the two groups regarding anatomical landmark.

There were no coronal sections in our standard MRI protocol; therefore evaluation in three plans was not made. In addition, since the field of view did not extend to the distal part of the coccyx, it was assumed that all cases had a normal vertebral count.

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