Original research article

Accuracy of using the site of the iliolumbar ligament and shape of L5 and S1 in predicting the level of lumbar vertebrae: Lumbosacral MRI

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Abstract
Accurate numbering is more important than just identification of LSTV. It's very much essential for surgery because inaccurate numbering can led to wrong unintended level of surgery/interventional procedure. The accurate method available is conventional radiograph of whole spine. Conventional whole spine radiographs not only helps in counting of vertebral bodies from C2 downwards and also helps in differentiating the hypoplastic lower ribs from transverse process and in turn helps in identification of actual L1 and segmentation anomalies at thoraco-lumbar junction. Totally 224 Indian subjects who underwent lumbar spine MRI with whole spine screening in Radiology department were studied. Most of these subjects were referred for evaluation of backache and radiculopathy. After reviewing 21 patients with prior spine surgery, severe alterations in spine curvature, extremely tortuous aorta and spine deformities were excluded. In subjects with normal segmentation majority i.e. 98.8% had Iliolumbar ligament at the level of L5, among Sacralized subjects majority i.e. 94.4% had Iliolumbar ligament at the level of L4 and in Lumbarized subjects majority i.e. 80% had Iliolumbar ligament at the level of S1.
Keywords: Iliolumbar ligament, lumbar vertebrae, lumbosacral MRI

Introduction

Classical method of identification of LSTV is by using lateral and Ferguson radiograph. Ferguson radiograph is an AP radiograph with 30 degree cranial angulation. However, CT is considered as the best imaging technique to characterize because of its spatial resolution, but not used frequently because of radiation concern and it's not useful is evaluation of non-traumatic backache which is the most common indication for lumbar spine imaging [1]. Castellvi *et al*. described 4 types of LSTV using radiographs on the basis of morphological characteristics. Type I includes unilateral (Ia) or bilateral (Ib) dysplastic transverse processes, measuring at least 19 mm in width (craniocaudal dimension). Type II exhibits incomplete unilateral (IIa) or bilateral (IIb) lumbarization/sacralization with an enlarged transverse process that has a diarthrodial joint between itself and the sacrum. Type III LSTV describes unilateral (IIIa) or bilateral (IIIb) lumbarization/sacralization with complete osseous fusion of the transverse process (es) to the sacrum [2]. Type IV involves a unilateral type II transition with a type III on the contralateral side.

This classification provides information on relationship between transitional segment and the level above/ below. But doesnot provide information related to the accurate number of involved segment.

Accurate numbering is more important than just identification of LSTV. It's very much essential for surgery because inaccurate numbering can led to wrong unintended level of surgery/interventional procedure [3]. The accurate method available is conventional radiograph of whole spine. Conventional whole spine radiographs not only helps in counting of vertebral bodies from C2 downwards and also helps in differentiating the hypoplastic lower ribs from transverse process and in turn helps in identification of actual L1 and segmentation anomalies at thoraco-lumbar junction. But it's not routinely done and not available at the time of imaging and mostly lumbar spine radiographs alone available. In case of availability of only lumbar spine radiographs, the numbering can be done but false results are possible because it does not differentiate between hypoplastic lower ribs from transverse process (thoracolumbar junction segmentation anomalies) [4].

Iliolumbar ligament has got anterior & posterior band. Anterior band is broad and flat originates from the anterior-inferior-lateral part of the L5 transverse process and expands as wide fan before inserting on the anterior part of the iliac tuberosity below the posterior band. The posterior band is thinned than anterior band and originates from the apex of L5 transverse process and inserts on the iliac crest [5, 6].

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

Methodology

Totally 224 Indian subjects who underwent lumbar spine MRI with whole spine screening in Radiology department were studied. Most of these subjects were referred for evaluation of backache and radiculopathy. After reviewing 21 patients with prior spine surgery, severe alterations in spine curvature, extremely tortuous aorta and spine deformities were excluded. The 8 subjects with age less than 20 years were also excluded, so final study group includes 195 subjects.

Inclusion criteria

All Indian subjects referred to Radiology department for MRI Lumbosacral spine.

Exclusion criteria

1. Age group <20 years.
2. Subjects who have had metallic devices placed in their body like pacemaker, eye implant, aneurysmal clip and pedicle screws.
3. Subjects refusing consent for the study.
4. Subjects who are not of ethnic Indian origin.
5. Subjects with history of extremely tortuous aorta, aortic aneurysm history of spinal deformities, trauma, infection, tumor and previous spinal surgery.

MRI Lumbar spine procedure

- Informed written consent is taken from the subject after briefing them about the procedure.
- If contra-indications to MRI exist, the procedure is not done and the subject is excluded from the study.
- Standard Lumbosacral MRI will be performed as given below

MRI Imaging protocol

All scans were performed on a 1.5 T Siemens Avanto machine.

- **T2W:** Sagittal plane whole spine; 3 mm sections, TR: 3400ms, TE: 105ms, FOV: 300mm.
- **T2W:** Axial plane lumbar spine; 4mm sections, TR: 4500ms, TE: 105ms, FOV: 180mm.
- **T2W:** STIR coronal plane dorsolumbar spine; 4mm sections, TR: 4000ms, TE: 45ms, FOV: 300 mm.

Image Post-processing/analysis: The raw imaging data obtained from: SIEMENS 1.5T MRI will be sent to PACS (picture archiving and communication system) workstations and viewed on BARCO 5 mega pixel image viewer.

Results

Table 1: Association between LSTV and Level of Iliolumbar Ligament

Iliolumbar ligament	Segmentation					
	Normal		Sacralization		Lumbarization	
	Count	%	Count	%	Count	%
L4	1	0.6%	17	94.4%	0	0.0%
L5	170	98.8%	1	5.6%	1	20.0%
S1	1	0.6%	0	0.0%	4	80.0%

$\chi^2 = 275.59$, df = 4, p <0.001*

In subjects with normal segmentation majority i.e. 98.8% had Iliolumbar ligament at the level of L5, among Sacralized subjects majority i.e. 94.4% had Iliolumbar ligament at the level of L4 and in Lumbarized subjects majority i.e. 80% had Iliolumbar ligament at the level of S1.

Table 2: L5 vertebral body Shape in study population

L5 Shape	Segmentation					
	Normal		Sacralisation		Lumbarization	
	Count	%	Count	%	Count	%
Square	172	100%	1	5.5%	5	100.0%
Rhomboid	0	0.0%	17	94.5%	0	0.0%

$\chi^2 = 173.94$, df = 4, p <0.001*

All the normal segmentation & lumbarization subjects had square shaped L5. In sacralisation subject's majority, 15 subjects (83.3%) had rhomboid shaped L5 and rest of the 3 subjects (16.7%) had square shaped L5.

Table 3: S1 vertebral body Shape in study population

S1 Shape	Segmentation					
	Normal		Sacralization		Lumbarization	
	Count	%	Count	%	Count	%
Square	0	0.0%	0	0.0%	5	100.0%
Rhomboid	172	100.0%	18	100.0%	0	0.0%

χ^2 = 163.01, df = 4, p <0.001*

In Normal group 0.6% had Square S1 and in Sacralized group none had Rhomboid S1 and Square S1. In Lumbarized group 20% had Rhomboid and 80% had Square S1. This difference in shape of S1 vertebrae between three groups was statistically significant.

Table 4: S1-S2 disc morphology in study population

Disc Morphology (O Driscoll type)	Segmentation					
	Normal		Sacralization		Lumbarization	
	Count	%	Count	%	Count	%
1.	1	0.6%	1	5.6%	0	0.0%
2.	168	97.7%	17	94.4%	0	0.0%
3.	2	1.2%	0	0.0%	1	20.0%
4.	1	0.6%	0	0.0%	4	80.0%

χ^2 = 94.76, df = 6, p <0.001*

In the Normal segmentation group majority i.e. 94.8% had type 2 disc morphology, in Sacralized group 94.4% had type 2 disc morphology and in Lumbarized subjects majority i.e. 60% had a type 4 disc morphology.

Discussion

Accuracy of using Iliolumbar ligament (ILL) in forecasting vertebral level: Following identification of vertebral body level using whole spine localizer (WSL), the level of iliolumbar ligament (ILL) origin was identified in axial MR T2 weighted images.
Iliolumbar ligament (ILL) arises from L5 transverse process in normal segmentation subjects; shifted cranially or caudally in subjects with sacralization or lumbarization respectively.

Normal segmentation: ILL origin at L5 (99%).
Our study, in normal segmentation subjects ILL was most frequently found at L5 transverse process (98.8%), followed by L4 and S1 levels (0.6% each).
Hughes *et al*. [7] studied 500 cases; in normal segmentation subjects ILL was found at L5 transverse process in all cases. Chang Hee Lee *et al*. [8] studied 514 subjects; in normal segmentation subjects ILL was frequently found at L5 transverse process (97.3%).

Comparison of our study with literature results: In normal segmentation subject’s level of ILL in our study correlates well with results reported by other authors.

Sacralization: ILL origin shifted cranially: at L4 (94%).

Our study: In sacralization subjects ILL was most frequently found at L4 transverse process (94.4%), followed by L5 (5.6%) levels.
Chang *et al*. [8] studied 514 cases; in sacralization ILL was most frequently found at L5 (67.6%), followed by L4 (18.9%) and at both L4-L5 (13.5%) levels. Hughes *et al*. [7] studied 500 cases; in sacralization ILL was most frequently found at L5 transverse process in all cases.

Comparison of our study with literature results
In our study similar to vascular landmarks, ILL origin level also shifted cranially in sacralization i.e. L5 level in normal segmentation and L4 level in sacralization. Chang *et al*. found ILL origin level distributed at both L4, L5 levels. This difference could be due to different ethnicity of the study groups (our study done in Indian population and Chang *et al*. study done on South Korean population). Hughes *et al*. found ILL origin at L5 level in all cases with sacralization. This difference is likely due to methodology of study; because they have considered LSTV cases with identifiable ILL as lumbarized and unidentifiable ILL cases as sacralized. They found small ligament at L5 in sacralized subjects.
Lumbarization
ILL origin shifted caudally: at S1 (80%).
Higher percentage of caudal shift in Indian population (80%) compared to South Korean (64%).

Our study: In lumbarization subjects ILL was most frequently found at S1 transverse process (80%), followed by L5 (20%) levels.

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

Chang *et al*. [8] studied 514 cases; in lumbarization ILL was most frequently found at S1 (64%), followed by L5 (10%) and at both L5-S1 (26%) levels. Hughes *et al*. [7] studied 500 cases; in lumbarization ILL was most frequently found at L5 transverse process in all cases.

Comparison of our study with literature results
In our study similar to vascular landmarks, ILL origin level also shifted caudally in lumbarization i.e. L5 level in normal segmentation and S1 level in lumbarization. Chang *et al*. found ILL origin level distributed at both L5, S1 levels. This difference could be due to different ethnicity of the study groups (our study done in Indian population and Chang *et al*. study done on South Korean population). Hughes *et al*. found ILL origin at L5 level in all cases with lumbarization. This difference is likely due to methodology of study; because they have considered LSTV cases with identifiable ILL as lumbarized and unidentifiable ILL cases as sacralized.

1. Accuracy of using shape of L5 & S1 vertebral bodies in forecasting vertebral level
In normal segmentation subjects L5 is square shaped and S1 is rhomboid in shape. In sacralization subjects both L5 and S1 were rhomboid in shape; in lumbarization subjects both L5 and S1 were square in shape.

Normal segmentation: L5 square/ S1 rhomboid (100%).
Our study; L5 was square shape and S1 was rhomboid in shape in all subjects (100%).
Both Nil *et al*. [9] and Chang *et al*. [8] studies; in normal segmentation subjects L5 square shape and S1 rhomboid shape in all cases (100%).

Comparison of our study with literature results: In subjects with normal segmentation Shape of L5 and S1 in our study correlate well with the results reported by other authors.

Sacralization: S1 rhomboid (100%)/ L5 rhomboid (95%).
Our study; S1 was rhomboid shape in all subjects (100%) and L5 was rhomboid shape in 17 (95%) and square shape in 1 (5%) subjects.
Both Nil *et al*. [9] and Chang *et al*. [8] studies; in sacralization subjects L5 &S1 were rhomboid shape in all cases (100%).

Comparison of our study with literature results: In sacralization subjects Shape of L5 and S1 in our study correlates well with the results reported by other authors.

Lumbarization: S1 square (100%)/L5 square (100%).

Our study: S1 was square shape in all cases (100%) and L5 was also square shape in all cases (100%).
Both Nil *et al*. [9] and Chang *et al*. [8] studies; in lumbarization subjects L5 and S1 were square shape in all cases (100%).

Comparison of our study with literature results: In lumbarization subjects Shape of L5 and S1 in our study correlated well with results reported by other authors [10].

Conclusion
Iliolumbar ligament (ILL):

Normal: L5.

Sacralization: Cranial shift.

Lumbarization: Caudal shift.

Normal segmentation: ILL origin at L5 (99%).
In subjects with normal segmentation ILL origin was found at L5 body (98.8%) followed by L4 and S1 body (0.6% each).

Sacralization: ILL origin shifted cranially: at L4 (94%).
In subjects with sacralization ILL origin was found at L4 (94%) followed by L5 transverse process (6%).In Chang *et al*. study (L5:68%, L4:19%, both L4&L5:13%) ILL origin distributed at both L4 & L5 levels.

Lumbarization

ISSN:0975 -3583,0976-2833 VOL14, ISSUE 08, 2023

ILL origin shifted caudally: at S1 (80%)
Higher percentage of caudal shift in Indian population (80%) compared to South Korean (64%).

Shape of L5, S1 vertebral bodies:
Normal: L5 square/S1 rhomboid.

Sacralization: L5 rhomboid/S1 rhomboid.

Lumbarization: L5 square/S1 square.

Normal segmentation: L5 square/S1 rhomboid (100%).
In subjects with normal segmentation, an L5 square and S1 rhomboid shape was found in all cases (100%).

Sacralization: S1 rhomboid (100%)/ L5 rhomboid (95%)
In subjects with sacralization, an L5 rhomboid shape was found in 95% and an L5 square shape in 5%.

Lumbarization: S1 square (100%)/ L5 square (100%)
In subjects with lumbarization, an S1 square shape was found in 100% of cases.

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