Original research article

A study to evaluate the accuracy of using the site of the superior mesenteric artery origin in predicting the level of lumbar vertebrae on Lumbosacral MRI

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Abstract
According to the cadaveric studies, it's shown that in subjects with sacralization, the height of the sacrum measured excluding the transition vertebrae is smaller than normal. This suggests that during rudimentary developmental stage based on the weight bearing capacity of normal sacrum from S1-S5, either addition or diminution of segments to form LSTV. 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. In the normal segmentation group majority i.e. 29.1% had SMA at the level of Upper L1 and Mid L1. In Sacralized subjects majority i.e. 50% had SMA at the level of T12–L1.In Lumbarized subjects there was equal distribution at the levels of T12-L1, L1 upper, L1 lower, L1-L2 and Mid L2.
Keywords: Superior mesenteric artery, lumbar vertebrae, lumbosacral MRI

Introduction
The normal segmentation of vertebral column into different segments is regulated by HOX genes. The sacrum which forms the base of vertebral column helps in optimization of dissipation of weight from the upper vertebral column towards the Sacroiliac joint by forming a mass of bony elements [1]. In spite of segmentation is regulated by HOX genes, it's also influenced by amount of load to be transferred to Sacroiliac junction. According to the cadaveric studies, it's shown that in subjects with sacralization, the height of the sacrum measured excluding the transition vertebrae is smaller than normal [2]. This suggests that during rudimentary developmental stage based on the weight bearing capacity of normal sacrum from S1-S5, either addition or diminution of segments to form LSTV. So subjects with inherent small sacrum & inadequate SI joint weight bearing surface area may fuse with L5 and form sacralization. In subjects with large inherent weight bearing surface area may release S1 to form lumbarization.
Superior mesenteric artery is one of the branch of abdominal aorta arises at the level of L1 vertebral body, approximately 1 cm above the Celiac trunk. It arises above the renal artery (L1-L2 level). It supplies to the midgut. SMA initially courses forwards and downwards and posterior to the neck of pancreas and splenic vein [3, 4].

Methodology
The study design and protocol was reviewed and approved by Institutional Review Board.

Study design: Prospective observational study.
Study area: Lumbosacral spine MRI.

Study population
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.

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

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.

Reference standard

Whole spine screening and counting of vertebral body levels from C2 downwards.

List of tool for data collection

1. 1.5 T Siemens Avanto machine.
2. PACS (Picture Archiving and Communication Systems) from MEDIFF technologies (INSTA Rad and INSTA Pusher) lossless transmission.
3. Workstation with BARCO Coronis 5MP diagnostic gray scale display system for reviewing images.

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 1A: Association between LSTV and Level of SMA

		Segmentation					
		Normal		Sacralization		Lumbarization	
		Count	%	Count	%	Count	%
SMA	T12	21	12.2%	6	33.3%	0	0.0%
	T12-L1	44	25.6%	9	50.0%	1	00.0%
	L1	106	61.6%	3	16.7%	2	40.0%
	L1-L2	0	0.0%	0	0.0%	1	40.0%
	L2	0	0.0%	0	0.0%	1	20.0%
	L3	1	0.6%	0	0.0%	0	0.0%

$\chi^2 = 91.75$, df = 10, $p < 0.001$*

In the normal segmentation group majority i.e. 61.6% had SMA origin at the level of L1. In Sacralized subjects majority i.e. 50% had SMA at the level of T12-L1. In Lumbarized subject's majority had SMA at the level of L1.

Table 1B: Association between LSTV and Level of SMA origin

SMA Origin		Segmentation					
		Normal		Sacralisation		Lumbarization	
		Count	%	Count	%	Count	%
Level of SMA	T12 upper	1	0.6%	0	0.0%	0	0.0%
	T12 mid	8	4.7%	2	11.1%	0	0.0%
	T12 lower	12	7.0%	4	22.2%	0	0.0%
	T12-L1	44	25.6%	9	50.0%	1	0.0%
	L1 upper	50	29.1%	3	16.7%	1	20.0%
	L1 mid	50	29.1%	0	0.0%	0	0.0%
	L1 lower	6	3.5%	0	0.0%	1	20.0%
	L1-L2	0	0.0%	0	0.0%	1	40.0%

	L2 mid	0	0.0%	0	0.0%	1	20.0%
	L3 mid	1	0.6%	0	0.0%	0	0.0%

$\chi 2 = 98.61$, df = 18, p <0.001*

In the normal segmentation group majority i.e. 29.1% had SMA at the level of Upper L1 and Mid L1. In Sacralized subjects majority i.e. 50% had SMA at the level of T12-L1. In Lumbarized subjects there was equal distribution at the levels of T12-L1, L1 upper, L1 lower, L1-L2 and Mid L2.

Discussion

Accuracy of Superior mesenteric artery (SMA) in forecasting vertebral level: Following identification of vertebral body level using whole spine localizer (WSL), the level of superior mesenteric artery origin was identified in sagittal and axial MR T2 weighted images.

Superior mesenteric artery (SMA) origin is at L1 body level in normal segmentation subjects; shifted cranially or caudally in subjects with sacralization or lumbarization respectively.

Normal segmentation: SMA origin at L1 (62%), -specifically, at upper/mid L1 (58%).

Our study, in normal segmentation subjects SMA origin most frequently found at L1 body (61.6%), followed by T12-L1 disc (25.6%) & T12 body (12.2%) levels. When specifying upper/mid/lower vertebral level, SMA origin most frequently found at upper/mid L1 body (58%), followed by T12-L1 disc (26%), lower T12 body (7%) and mid T1-T2 body (5%) levels.

Nil Tokgoz *et al*. [5] studied 1049 cases; in normal segmentation subjects SMA origin most frequently found at L1 body (55.10%), followed by T12-L1 disc (31.6%) levels. Chang Hee Lee *et al*. [6] studied 210 cases; in normal segmentation subjects SMA origin most frequently found between T12-L1 to upper half of L1 body (73.8%) levels.

Comparison of our study with literature results: In normal segmentation subjects SMA origin level in our study correlates well with results reported by other authors.

Overall, SMA origin was most frequently found at L1 body (62%) with most cases are at upper and mid L1 body levels (58%).

Sacralisation: SMA origin shifted cranially: 83% above L1, 100% above mid L1.

Our study, in sacralization subjects SMA origin most frequently found at T12-L1 disc (50.0%), followed by T12 body (33.3%) & L1 (16.7%) levels. In this 83% of cases SMA origin was above the level of L1 body. When specifying upper/mid/lower vertebral levels, we found SMA origin most frequently at T12-L1 disc (50%), lower T12 (22%), upper L1 (17%) and mid T12 (11%) levels. In 100 % of cases SMA origin was found above mid L1 body level.

Nil Tokgoz *et al*. [5] studied 1049 cases, in sacralization subjects SMA origin most frequently found at T12 body (42.9%) and followed by T12-L1 disc (35.2%), L1 body (20.0%) levels.

Chang Hee Lee *et al*. [6] studied 210 cases, in sacralization subjects SMA origin most frequently found between T12-L1 discs to upper half of L1 body (87.8%).

Comparison of our study with literature results: In sacralization subject's level of SMA origin in our study correlates well with the results reported by other authors. When specifying upper/mid/lower vertebral level, we found that 100% were above mid L1 body level. This upper/mid/lower specification has not been addressed by other authors.

Overall, 83% cases with SMA origin were above L1 body level and 100% cases SMA origin is above the level of mid L1 body. This suggests the cranial shift of SMA origin in subjects with sacralization.

Lumbarization: SMA origin shifted caudally: 80% below mid L1.

Our study, in lumbarization SMA origin was most frequently found at L1 (40.0%) & L1-L2 (40%), followed by L2 (20%) level. The most common location is L1 which is similar to the SMA origin level of normal segmentation population. When specifying upper/mid/lower vertebral level, we found SMA origin most frequently at L1-L2 disc (40%), followed by lower L1 body (20%), mid L2 body (20%) and upper L1 (20%) levels. In 80% of subjects SMA origin was found below the level of mid L1.

Nil Tokgoz *et al*. [5] studied 1049 cases, in lumbarization subjects SMA origin most frequently found at L4 body (42.5%) followed by L4-L5 (32.5%) and L5 body (20%) levels.

Chithriki *et al*. [7] studied 441 cases, in lumbarization subjects they found SMA origin most frequently at L1 body (59%), followed by L1-L2 disc (29%) levels.

Comparison of our study with literature results: In our study when we studied SMA origin in relation to entire vertebral body, SMA origin was most frequently found at the same level as in normal segmentation. In fact, other authors with larger series of lumbarization (53 subjects in Chang et al study and 80 subjects in Nil et al study) have reported a predominantly caudal shift with 30-70% of subjects showing the SMA origin to be located below L1.When specifying upper/mid/lower vertebral level, we

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

found SMA origin located below the level of Mid L1 in 80% of subjects. This infers the caudal shift in SMA origin level in subjects with lumbarization. This correlates well with other studies [8].

Conclusion

Superior mesenteric artery (SMA) origin:
Normal: L1.

Sacralization: Cranial shift.

Lumbarization: Caudal shift.

Normal segmentation: SMA origin at L1 (62%), -specifically, at upper/mid L1 (58%) in subjects with normal segmentation SMA origin was found at L1 body (62% with upper: 29%, mid: 29%, lower: 4%) followed by T12-L1 (26%), T12 (12%) levels.

Sacralization: SMA origin shifted cranially: 83% above L1, 100% above mid L1.
In subjects with sacralization, SMA origin was found at a higher level at the T12-L1 disc (50%) followed by lower T12 (22%), upper L1 (17%) and Mid T12 (11%).

Lumbarization: SMA origin shifted caudally: 80% below mid L1.
When viewing the vertebral body as a whole, SMA origin was found most frequently at L1 (40%) followed by L1-L2 disc (40%) and L2 body (20%). However, when the vertebral level is specified as upper/mid/lower, SMA origin was located below mid L1 in 80%, indicating a caudal shift.

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