

Detection of Numeric and Morphological Variation at Lumbosacral Junction: Role of Whole Spine Magnetic Resonance Imaging

Radha Sarawagi, Srilatha Kankanala, Sanjeev Kumar Gupta

Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Puducherry, India

Correspondence: Dr. Radha Sarawagi, Department of Radiodiagnosis, Peoples College of Medical Sciences and Research Centre, Bhopal, Madhya Pradesh, India. E-mail: radhasanjeevgupta@gmail.com

ABSTRACT

Introduction: Numeric variation in presacral vertebral segments and lumbosacral transitions has been reported in different studies with wide range of prevalence (4–36%). There is no standard method for numbering of lumbar vertebrae. In typical regional sequences for lumbar spine magnetic resonance imaging (MRI), vertebral and disc morphology, intervertebral angle, and various local anatomical structures are used as landmarks for numbering. **Aim:** (a) To document the prevalence in variation of presacral mobile vertebral count and lumbosacral vertebral transition using whole spine MRI. (b) To evaluate the accuracy in the location of the proximal right renal artery (RRA), aortic bifurcation, and conus termination as a landmark for vertebral numbering. **Materials and Methods:** This prospective observational study includes 317 patients, referred for MRI of the lumbosacral spine. Vertebrae were counted manually using sagittal whole spine localizer images (Mobi View). Short tau inversion recovery (STIR) coronal images were included for classification of lumbosacral transitional vertebrae (LSTV). Prevalence and types of LSTV and level of proximal RRA, aortic bifurcation, and conus termination were documented. **Results:** About 25.5% of patients showed LSTV and 7.8% of patients showed variation in presacral vertebral count without LSTV. Castellvi Type IIb LSTV was most prevalent followed by Type IIb. There was significant variation in the level of aortic bifurcation, RRA, and conus termination in patients with normal count and with LSTV. **Conclusions:** Spinal and paraspinal structures, such as aortic bifurcation, RRA, and conus termination, cannot be considered as landmark for numbering of vertebrae. Counting of vertebrae manually from C2 is recommended for confident documentation of numerical variation in vertebrae. The inclusion of STIR coronal image helps in better identification and characterization of the LSTV.

Key words: Aortic bifurcation; conus termination; lumbar spine; magnetic resonance imaging; right renal artery; transitional vertebra

Introduction

The classical number of vertebrae in humans is considered to be seven cervical, 12 thoracic, five lumbar (i.e., 24 presacral mobile vertebrae), a sacrum of five fused segments, and a coccyx of four fused segments; however, this anatomy is seen only in 20% of the population. Sacral groups including sacrococcygeal segments are most variable.^[1,2] Presacral vertebral group can show anatomical variation within groups without numerical

variation in total presacral segments. When there is numeric variation in presacral segment, it could be at occipitocervical, cervicothoracic, thoracolumbar and lumbosacral levels. There can be either cranial shift with 23 mobile presacral vertebrae or caudal shift with 25 presacral vertebrae. Various clinical and anthropologic studies have shown that numeric variation in the presacral segments occurs in 2–23% of the population.

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Sarawagi R, Kankanala S, Gupta SK. Detection of numeric and morphological variation at lumbosacral junction: Role of whole spine magnetic resonance imaging. West Afr J Radiol 2016;23:95-100.

Access this article online

Quick Response Code:



Website:

www.wajradiology.org

DOI:

10.4103/1115-3474.179254

[3-5] Transitional vertebra is defined as vertebra showing morphological characteristics of two different types of vertebrae. Lumbosacral transitional vertebra (LSTV) is the most common with incidence ranging from 4% to 36%. [6-8] Various morphologic characteristics of vertebral bodies and intervertebral discs are used to define the lumbosacral transition. [9-12] The numbering techniques used in identification of lumbar vertebrae always remained controversial. Various proposed theories include adjacent anatomical structures as landmarks such as the aortic bifurcation, the right renal artery (RRA) origin, conus termination and iliolumbar ligament, morphology of vertebra, intervertebral disc, and intervertebral angle for identification of type of vertebra. [4,13,14] However, studies have shown that position of these structures are variable and cannot be used as a reliable marker. [2,15,16] To improve accuracy and standardize spine labeling, several techniques such as cervicothoracic localizer and automated spine survey are used to image entire spine and counting was done from C2. However, these techniques are not fully accurate in identifying all the variations. [1,5,17] The purpose of the study is to count the number of vertebrae manually cephalad to caudad from C2, using total spine magnetic resonance imaging (MRI) (in sagittal Mobi View) and finding the prevalence of numerical variation of vertebral count, and lumbosacral transition in all the patients referred for MRI of the lumbosacral spine. We also aim to evaluate the accuracy in location distribution of proximal RRA, aortic bifurcation, termination of conus medullaris in all patients with or without lumbosacral transition.

Materials and Methods

This prospective observational study was conducted in a Tertiary Care Hospital in South India. Our study was approved by the Institutional Review Board; a written informed consent was taken from all the patients before imaging. All patients of more than 18 years of age who were referred for MRI of the lumbosacral spine from April 2011 to December 2011 were reviewed. Cases with inadequate imaging and patients with spinal deformity, spinal trauma, aneurysmal dilatation of the abdominal aorta, extremely tortuous aorta, multiple right renal arteries, malignant vertebral lesions, and severe infections with collapse were excluded from our study. A total of 317 patients (160 males and 157 females) were finally included in our study. Their age ranged between 18 and 88 years with mean age of 43 years.

MRIs were obtained with a 1.5-Tesla scanner (Achieva SE, Philips Healthcare). Imaging was performed with all the patients lying in a supine position using a sense spine coil. Each examination included a coronal or three-plane localizer series with following sequences.

Sagittal whole spine images were acquired using T2-weighted fast gradient-recalled echo sequence (TR/TE-3007/120; FOV: 270 mm × 251 mm × 89 mm; Flip angle - 90°; Matrix - 216 × 40; Slice thickness - 5 mm; and Slice gap - 0.5 mm). For

each study lumbosacral, thoracic, and cervical stack images were acquired and fused into a single image using the Philips Mobi View software. Time taken for this sequence is about 2 min 24 s.

Coronal short tau inversion recovery (STIR) images (TR/TE-4000/80, TI-100, FOV: 220 × 332 × 75, Slice thickness - 5 mm), sagittal T1-weighted spin-echo images (TR/TE-400/80; FOV: 300 × 66 × 329; Slice gap - 0.4; Slice thickness - 4 mm; Matrix - 332 × 262; Flip angle - 90°), sagittal T2-weighted images (TR/TE-3000/80; FOV: 331 mm × 66 mm × 285 mm; Slice thickness - 4 mm; Slice gap - 0.4 mm; Flip angle - 90°; Matrix - 440 × 57), axial T1-weighted spin-echo images (TR/TE-3500/90; FOV: 30 mm × 30 mm × 170 mm, AP-170; Slice thickness - 4 mm; Slice gap - 0.4 mm; Flip angle - 90°; Matrix - 240 × 166), and axial T2-weighted spin-echo images (TR/TE-550/84; FOV: 30 × 170 × 170; Slice thickness - 4 mm; Slice gap - 0.4 mm; Flip angle - 90°; Matrix - 292 × 199) were acquired.

All patients were reviewed in chronological order. Study parameters included were (1) total number of mobile presacral vertebrae, (2) the presence or absence of LSTV and its type, (3) level of proximal RRA, (4) termination of conus medullaris, and (5) level of bifurcation of aorta.

On sagittal whole spine image, manual counting of vertebrae was performed in a cranial-to-caudal approach counting from C2 to sacral segments. In our study, we grouped vertebral column into presacral and sacral segments, and total numbers of mobile presacral vertebrae were counted in each patient. Last mobile presacral vertebra was defined as the one with lumbar type morphology, forming a sharp angulation with sacrum and the presence of a well-formed disc between the vertebra and the sacrum. The presence of LSTV was identified separately irrespective of the total count, based on morphological criteria in sagittal view. Cross localization of sagittal whole spine image with STIR coronal image was done using Picture Archiving and Communication System Workstation (Novarad, American Fork, UT), and subtype of LSTV is documented based on Castellvi classification. [12,18] Type I LSTV includes dysplastic transverse process measuring at least 19 mm in craniocaudal dimension (unilateral Ia; bilateral Ib) [Figure 1]. Type II includes incomplete unilateral (IIa) or bilateral (IIb) lumbarization/sacralization showing enlarged transverse process with pseudarthrosis with adjacent sacral ala [Figure 2]. Type III LSTV includes unilateral (IIIa) or bilateral (IIIb) lumbarization/sacralization showing enlarged transverse processes fused with adjacent sacral ala [Figure 3]. Type IV includes a unilateral Type II transition in one side and a Type III on other side [Figure 4]. The cephalad shift at this level is grouped under lumbarization, and caudad shift under sacralization assuming seven cervical, 12 thoracic vertebrae as constant segments.

Axial T2-weighted fast spin-echo imaging was used to evaluate the aortic bifurcation. The longest horizontal position before the aorta was bifurcated into both common iliac arteries was selected as the point of aortic bifurcation [Figure 5]. Sagittal T2-weighted spin-echo is used in the study of the RRA. The proximal portion of the RRA was defined as a small round signal void at the right parasagittal images [Figure 6]. For conus medullaris,

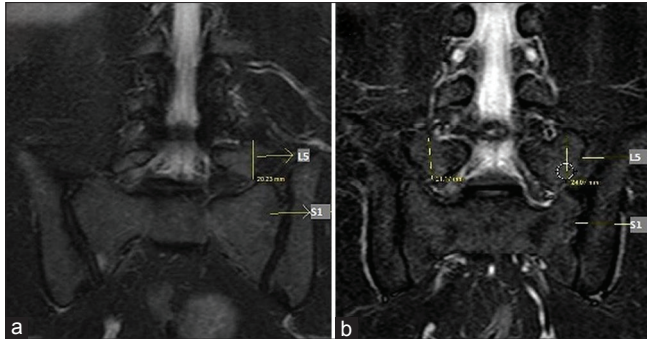


Figure 1: Coronal short tau inversion recovery images. (a) Type Ia lumbosacral transitional vertebrae with enlarged left transverse process of an L5 vertebra. (b) Type Ib lumbosacral transitional vertebrae with enlarged transverse processes of L5 vertebra bilaterally

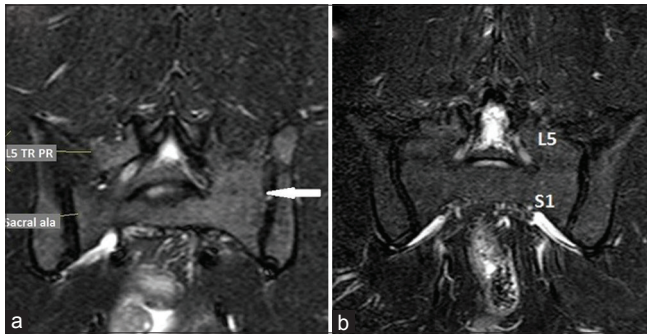


Figure 3: Coronal short tau inversion recovery images (a) Type IIIa lumbosacral transitional vertebrae with enlarged left transverse process of L5 vertebra fused with sacral ala (arrow). (b) Type IIIb lumbosacral transitional vertebrae with enlarged transverse processes of L5 vertebra fused with sacral ala bilaterally



Figure 5: Axial T2-weighted magnetic resonance imaging showing aortic bifurcation

the tip of the conus was defined as the most distal point of the cord on the T1- and T2-weighted sagittal sequences [Figure 7].

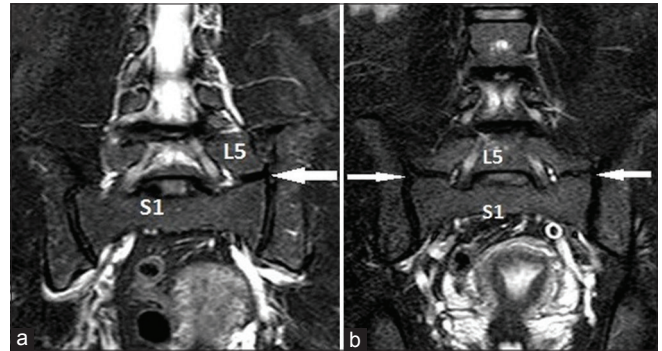


Figure 2: Coronal short tau inversion recovery images. (a) Type IIa lumbosacral transitional vertebrae with enlarged left transverse process of L5 vertebra forming pseudoarthrosis with sacral ala (arrow). (b) Type IIb lumbosacral transitional vertebrae with enlarged transverse processes of L5 vertebra forming pseudoarthrosis with sacral ala bilaterally (arrows)

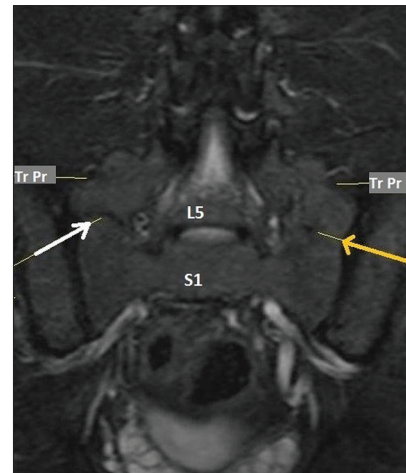


Figure 4: Coronal short tau inversion recovery images showing Type IV lumbosacral transitional vertebrae with right sided Type II pattern (white arrow) and left sided Type III pattern (yellow arrow)



Figure 6: Right parasagittal T2-weighted magnetic resonance imaging of lumbar spine showing origin of right renal artery as a round signal void (arrow)

Statistical analysis

All data were analyzed using statistical software program (Statistical Package for the Social Science for Windows, Version 16.0, SPSS Inc., Chicago, IL, USA). Descriptive and inferential statistical analysis has been carried out in the present study, and results on categorical measurements are presented in number (%).

Results

Among total 317 patients, 211 patients (66.5%) had 24 presacral mobile vertebrae (PSMV) without evidence of lumbosacral vertebral transition [Figure 8a]. In 23 patients (6.9%), there was evidence of 23 PSMV without transitional vertebra at the lumbosacral junction [Figure 8b]. Three patients (0.9%) had 25 PSMV without any LSTV [Figure 8c]. Evidence of lumbosacral vertebral transition was noted in 81 patients (25.5%) with sacralization in 68 (21.4%) and lumbarization in 13 (4.1%) cases [Figure 8d].

Table 1 shows distribution of different types of LSTV according to Castellvi classification. Type IIIb (33.3%) was most prevalent followed by Type IIb (30.8%).

Tables 2-4 show location distribution of level of aortic bifurcation, level of RRA, and level of conus termination in patients with normal count, variations in count, and transitional vertebrae.

The aortic bifurcation was seen at the level of L4 vertebra in 49% of patients with normal 24 PSMV. In remaining patients, it was seen at the level of L3 body or L3-4 disc. The aortic bifurcation was noted at L3 body level in two-third of patients with sacralization and those with 23 PSMV. In patients with lumbarization, it was seen at L4 level in 62% of patients.

In patient with normal 24 presacral mobile vertebrae, the level of renal artery was seen most commonly at the level

of L1 vertebra and L1-2 disc level (82%). In patients with sacralization, the RRA was seen at the level of L1 vertebra and L1-2 disc level in 69% of cases. In 28% of patients with sacralization, the renal artery was seen at T12 body and

Table 1: Distribution of LSTV according to Castellvi classification

Castellvi type	n (%)
Type Ia	3 (3.7)
Type Ib	9 (11.1)
Type IIa	11 (13.5)
Type IIb	25 (30.8)
Type IIIa	4 (4.9)
Type IIIb	27 (33.3)
Type IV	2 (2.4)
Total	81 (100)

LSTV – Lumbosacral transitional vertebrae

Table 2: Location distribution of aortic bifurcation in different group of patients

Level	24 PSMV* (n=211) (%)	23 PSMV* (n=22) (%)	Sacralisation (n=68) (%)	Lumbarisation and 25 PSMV (n=16) (%)
L2-3	0	2 (9.09)	2 (2.94)	0
L3	69 (32.7)	14 (63.63)	40 (58.82)	4 (25)
L3-4	38 (18)	4 (18.18)	13 (19.11)	0
L4	103 (48.81)	2 (9.09)	13 (19.11)	10 (62.5)
L4-5	1 (0.47)	0	0	1 (6.25)
L5	0	0	0	1 (6.25)
Total	211 (100)	22 (100)	68 (100)	16 (100)

*PSMV – Presacral mobile vertebra



Figure 7: Sagittal T2-weighted magnetic resonance imaging showing tip of conus medullaris (arrow)

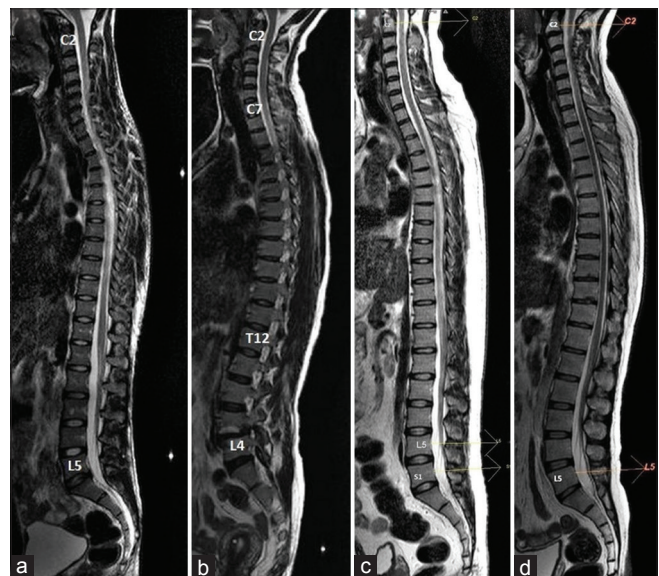


Figure 8: Sagittal whole spine magnetic resonance imaging (Mobi View). (a) 24 presacral mobile vertebra. (b) 23 presacral mobile vertebra without evidence of lumbosacral transitional vertebrae. (c) 25 presacral mobile vertebra without evidence of lumbosacral transitional vertebrae. (d) Sacralization of L5 vertebra with rhomboid shape of vertebra and smaller size of L5-S1 disc

Table 3: Location distribution of proximal right renal artery in different group of patients

Level	24 PSMV* (n=211) (%)	23 PSMV (n=22) (%)	Sacralization (n=68) (%)	Lumbarization and 25 PSMV (n=15)* (%)
T12	3 (1.42)	2 (9.09)	9 (13.23)	0
T12-L1	8 (3.79)	8 (36.36)	10 (14.7)	0
L1	131 (62.08)	11 (50)	42 (61.76)	10 (66.66)
L1-2	43 (20.37)	1 (4.54)	5 (7.35)	3 (20)
L2	26 (12.32)	0	2 (2.94)	2 (13.33)
Total	211 (100)	22 (100)	68 (100)	15 (100)

*PSMV – Presacral mobile vertebra; *Not measured in 1 case due to ectopic kidney

Table 4: Location distribution of conus termination in different group of patients

Level	24 PSMV* (n=211) (%)	23 PSMV* (n=22) (%)	Sacralization (n=68) (%)	Lumbarization and 25 PSMV (n=16) (%)
T11	0	0	1 (1.47)	0
T11-12	1 (0.47)	0	0	0
T12	13 (6.16)	7 (31.81)	2 (2.94)	0
T12-L1	14 (6.63)	5 (22.72)	15 (22.05)	0
L1	119 (56.39)	10 (45.45)	40 (58.82)	10 (62.5)
L1-2	32 (15.16)	0	8 (11.76)	4 (25)
L2	32 (15.16)	0	2 (2.94)	2 (12.5)
Total	211 (100)	22 (100)	68 (100)	16 (100)

*PSMV – Presacral mobile vertebra

T12-L1 disc level. In 86% of patient with lumbarization, the RRA was seen at the level of L1 vertebra and L1–2 disc level.

The conus medullaris was variably located between T11 and T12 intervertebral disc to L2 body. It is most commonly seen at the level of L1 body in all groups (45–62%).

There was significant difference between the location distribution of aortic bifurcation, RRA, and conus termination in patients with LSTV and without LSTV. The location of conus medullaris termination was most variable. We also found that these structures were seen at relatively higher level in sacralization and at lower level in lumbarization.

Discussion

There is wide variation in the reported prevalence of LSTV in different studies and it ranges from 4% to 36%. This has possibly occurred due to difference in the population being studied, different imaging technique used, and different diagnostic criteria.^[19] The prevalence was higher in studies which included patients with low back pain as compared to community-based studies.^[8,20] Our study includes patients with low back pain which possibly explains higher prevalence of LSTV in our study. About 7.8% of our patient also showed variation in count of PSMV without evidence of LSTV. Given the relatively high prevalence of numeric and morphologic

variation at the lumbosacral junction, finding the variation in presacral mobile vertebrae with documentation of type of variation and accurate vertebral numbering is critical to avoid numbering discordance. In general, localization of the vertebral segment in the lumbar spine MRI is determined by examining the morphology of L5 and S1 vertebrae and L5–S1 disc as subjective observation on sagittal image.^[10,18] In our study, we included STIR coronal sequence for better classification of type of LSTV. Castellvi Type I and Type IIa, contributing to 28.2% of prevalence, can be commonly missed on subjective observation on sagittal images, unless cross localization with coronal sequence or plain radiograph was performed, due to their subtle morphological changes that need more keen observation.

The level of aortic bifurcation generally lies at the level of L4 according to Grey's anatomy.^[21] Different studies have shown the level of aortic bifurcation was found at L4 level in 67–83% of patients.^[15,16,22] Prakash *et al.* and Appaji *et al.*^[23,24] in their study on cadavers have revealed that aortic bifurcation was seen at the level of L4 vertebra in 54% and 53% respectively. Our study has also showed similar result. Previous studies^[16,22] have reported that aortic bifurcation was noted most commonly at L3 vertebral level in patients with sacralization. We have also seen a cranial shift in level of aortic bifurcation in patients with sacralization.

Lee *et al.*^[15] had found that in the normal group, the ostia of RRA was situated between the lower half of L1 and the upper half of L2 body in 92% of the patients when focusing on the L1–2 disc and recommended as a useful anatomic marker for numbering vertebral levels. In another study,^[25] the RRA was near L1–2 discs only in 73.5% of cases. In 82% of our cases with normal vertebral count, the RRA was at the level of L1 vertebra or L1–2 disc. Its location ranges from T12 to L2 vertebra. A significant number of patients with sacralization and with 23 PSMV showed level of proximal RRA at T12 vertebra and T12–L1 disc.

Previous studies have revealed that level of conus medullaris termination ranges from the lower part of T11 to upper part of L3 vertebrae with most prevalent at L1 vertebral level.^[15,16,25,26] In our study, the conus termination was located between T11 and 12 disc level to L2 vertebral levels. Most common site of conus termination was posterior to L1 vertebral body in all the groups. Conus termination was most variable in normal groups and those with LSTV in our study as reported in previous studies.^[15,16]

The results of our study also found that aortic bifurcation, RRA, and conus termination were at higher level in sacralization and lower level in lumbarization. Similar findings were noted in other studies.^[15,16] Although different literature have proposed that use of the paraspinal structures such as aortic bifurcation and RRA can be used as

landmark for vertebral labelling and to predict transitional vertebra,^[13,15,22] other studies have questioned their reliability due to significant variability in location.^[2,22,25] Our study also shows significant variability in these structures; hence, these cannot be used as reliable landmark for vertebral labelling and prediction of LSTV.

Limitations: Association of numeric variations with cervicodorsal and dorsolumbar transition was not studied. Correlation with radiographs of those regions will more specifically help in excluding the transition at cervicodorsal, and dorsolumbar region and further evaluation of transitional vertebra.

Conclusions

There is significant variation noted in the spinal and paraspinal structures such as aortic bifurcation, RRA, and conus termination, both in patients with normal count and with variations; hence, these cannot be considered as landmark for numbering of vertebrae. Counting of vertebrae manually from C2 or C1 craniocaudally in total spine localizer is recommended for confident documentation of numerical variation in vertebrae. It is also important to convey the method of numbering of vertebra while reporting the lumbar spine MRI to avoid confusion. Inclusion of coronal MRI sequence helps to improve identification and classification of LSTV. Documenting type of variation avoids wrong site surgery, postoperative bias and has forensic implication.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- Weiss KL, Storrs JM, Banto RB. Automated spine survey iterative scan technique. *Radiology* 2006;239:255-62.
- Carrino JA, Campbell PD Jr, Lin DC, Morrison WB, Schweitzer ME, Flanders AE, *et al.* Effect of spinal segment variants on numbering vertebral levels at lumbar MR imaging. *Radiology* 2011;259:196-202.
- Bailey W, Carter RA. Anomalies of the spine: A correlation of anatomical, roentgenological, and clinical findings. *Cal West Med* 1938;49:46-52.
- Hahn PY, Strobel JJ, Hahn FJ. Verification of lumbosacral segments on MR images: Identification of transitional vertebrae. *Radiology* 1992;182:580-1.
- Akbar JJ, Weiss KL, Saafir MA, Weiss JL. Rapid MRI detection of vertebral numeric variation. *AJR Am J Roentgenol* 2010;195:465-6.
- Uçar D, Uçar BY, Cosar Y, Emrem K, Gümüşsuyu G, Mutlu S, *et al.* Retrospective cohort study of the prevalence of lumbosacral transitional vertebra in a wide and well-represented population. *Arthritis* 2013;2013:461425.
- Apazidis A, Ricart PA, Diefenbach CM, Spivak JM. The prevalence of transitional vertebrae in the lumbar spine. *Spine J* 2011;11:858-62.
- Sekharappa V, Amritanand R, Krishnan V, David KS. Lumbosacral transition vertebra: Prevalence and its significance. *Asian Spine J* 2014;8:51-8.
- Wigh RE, Anthony HF Jr. Transitional lumbosacral discs. Probability of herniation. *Spine (Phila Pa 1976)* 1981;6:168-71.
- Nicholson AA, Roberts GM, Williams LA. The measured height of the lumbosacral disc in patients with and without transitional vertebrae. *Br J Radiol* 1988;61:454-5.
- O'Driscoll CM, Irwin A, Saifuddin A. Variations in morphology of the lumbosacral junction on sagittal MRI: Correlation with plain radiography. *Skeletal Radiol* 1996;25:225-30.
- Castellvi AE, Goldstein LA, Chan DP. Lumbosacral transitional vertebrae and their relationship with lumbar extradural defects. *Spine (Phila Pa 1976)* 1984;9:493-5.
- Lee CH, Park CM, Kim KA, Hong SJ, Seol HY, Kim BH, *et al.* Identification and prediction of transitional vertebrae on imaging studies: Anatomical significance of paraspinal structures. *Clin Anat* 2007;20:905-14.
- Hughes RJ, Saifuddin A. Numbering of lumbosacral transitional vertebrae on MRI: Role of the iliolumbar ligaments. *AJR Am J Roentgenol* 2006;187:W59-65.
- Lee CH, Seo BK, Choi YC, Shin HJ, Park JH, Jeon HJ, *et al.* Using MRI to evaluate anatomic significance of aortic bifurcation, right renal artery, and conus medullaris when locating lumbar vertebral segments. *AJR Am J Roentgenol* 2004;182:1295-300.
- Tokgoz N, Ucar M, Erdogan AB, Kilic K, Ozcan C. Are spinal or paraspinal anatomic markers helpful for vertebral numbering and diagnosing lumbosacral transitional vertebrae? *Korean J Radiol* 2014;15:258-66.
- Peh WC, Siu TH, Chan JH. Determining the lumbar vertebral segments on magnetic resonance imaging. *Spine (Phila Pa 1976)* 1999;24:1852-5.
- Konin GP, Walz DM. Lumbosacral transitional vertebrae: Classification, imaging findings, and clinical relevance. *AJNR Am J Neuroradiol* 2010;31:1778-86.
- French HD, Somasundaram AJ, Schaefer NR, Laherty RW. Lumbosacral transitional vertebrae and its prevalence in the Australian population. *Global Spine J* 2014;4:229-32.
- Nardo L, Alizai H, Virayavanich W, Liu F, Hernandez A, Lynch JA, *et al.* Lumbosacral transitional vertebrae: Association with low back pain. *Radiology* 2012;265:497-503.
- Healy JC, Borley NR, Mundy AR, Collins P, Wigley C. True pelvis, pelvic floor and perineum. In: Standring S, editor. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 39th ed. New York: Elsevier Churchill Livingstone; 2005. p. 1360.
- Chithraki M, Jaibaji M, Steele RD. The anatomical relationship of the aortic bifurcation to the lumbar vertebrae: A MRI study. *Surg Radiol Anat* 2002;24:308-12.
- Appaji AC, Kulkarni R, Pai B. Level of bifurcation of aorta and ilioacaval confluence and its clinical relevance. *IOSR J Dent Med Sci* 2014;13:56-60.
- Prakash, Mokhasi V, Rajini T, Shashirekha M. The abdominal aorta and its branches: Anatomical variations and clinical implications. *Folia Morphol (Warsz)* 2011;70:282-6.
- Saifuddin A, Burnett SJ, White J. The variation of position of the conus medullaris in an adult population. A magnetic resonance imaging study. *Spine (Phila Pa 1976)* 1998;23:1452-6.
- Soleiman J, Demaerel P, Rocher S, Maes F, Marchal G. Magnetic resonance imaging study of the level of termination of the conus medullaris and the thecal sac: Influence of age and gender. *Spine (Phila Pa 1976)* 2005;30:1875-80.