Medico Research Chronicles

ISSN No. 2394-3971

Original Research Article

INCIDENCE OF LUMBOSACRAL TRANSITIONALVERTEBRAE (LSTV) AMONGEST THE POPULATION OF UP—A MORPHOLOGICAL STUDY ON BONES

Dr. Nisha Kaul

Professor & HOD of Anatomy, Santosh Medical College, Ghaziabad, Uttar Pradesh, India

Submitted on: July 2018
Accepted on: August 2018
For Correspondence
Email ID:
nishakaul.nk@gmail.com

Abstract

Introduction: The human vertebral column is divided into five regions viz cervical, thoracic, lumbar, sacral and coccygeal regions. The lumbar region is designed mainly to facilitate movements of the back and support the body weight. Abnormal fusion between L5 & S1 vertebrae results in Sacralisation. Lumbarization occurs when the first segment of the sacrum is not fused with rest of sacrum & remains free to move. Both these conditions are discussed under one common heading"Lumbosacral transitional vertebrae" (LSTV). The prevalence is 1-30 %. Various researchers have identified the role of LSTV in low back pain. Sacralized segment can impinge on spinal nerve roots or the cauda equina structures producing various symptoms & signs.

Aim: Knowledge of LSTV is helpful 1 to diagnose and treat patients with low back pain 2. Awareness of such congenital anomaly of the vertebral column is important before undertaking any spinal surgery.

Material & Methods: 100 dry adult sacra belonging to the dept. of anatomy SMC, Ghaziabad (UP) were used for the study. Every specimen was studied for features of: 1. Sacralization 2.Lumbarization.

Observation: LSTV was seen in 27%; four specimens showing lumbarization & 23 showing sacralization of grade IIIb (of Castellvi).

Discussion: The association between LSTV and back pain was first described in 1917 by Bertolotti. Mutations of HOX10/ HOX11 genes may play a role in the formation of LSTV. A knowledge of LSTV helps in treating low backache & diagnosis of various associated pathologies of the vertebral column.

Keywords: Vertebrae; Sacrum; Sacralisation; Lumbarisation; Transitional vertebrae, HOX gene.

Introduction

The vertebral column is a part of the axial skeleton of a man, which encloses and protects the spinal cord in the spinal canal. The human vertebral column consists of thirty-three vertebrae which are enumerated as seven cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae, five sacral vertebrae and four coccygeal vertebrae. The five sacral vertebrae are fused with one another in adults, to form a one-piece sacrum and lower four coccygeal vertebrae are fused to form one coccyx. The number of vertebrae in a region can vary but the number in the cervical region is rarely changed. [(1)]

The lumbar region of the vertebral column is designed mainly to facilitate movements of the back and support the body weight. The fifth lumbar vertebra has a peculiar shape and characteristics to suit its normal location and functions. Sometimes due to the abnormal fusion of the lumbar vertebra with the sacrum, the lumbar movements can get affected and conditions like lumbar scoliosis can develop**.** [(2)]

Anatomy of the Adult Lumbar vertebra

The lumbar vertebra is irregular in shape, having a large body, stout pedicles and thick lamina. It shows slender transverse processes & a short, thick, square spinous process. Biomechanics and functions of a lumbar vertebra are such so as to support the upper body, transfer weight from axial to appendicular skeleton, and to provide mobility in the lower back. Lumbar vertebrae are strong enough to support the upper body and yet flexible enough to allow the needed mobility; but at the same time, if any of the above mechanisms is subjected to failure, it may result in low back pain.[(3)]

Anatomy of the Adult sacrum

Grossly the sacrum appears as a triangular bone with a concave ventral surface (facies pelvina), a convex dorsal surface (facies dorsalis), and an apex (apex osseous sacri) that projects downwards & posteriorly to increase the forward angulation formed between the lumbar spine and sacrum. This is known as the sacral promontory or sacrovertebral angle & appears as a distinct ridge. This angle is initially approximately 20° at birth and increases progressively during growth to approximately 70° in adulthood. Often, this distinct ridge can be used as a landmark in anterior lumbosacral approaches. [(4)]

In man anatomically, the strongest intervertebral disc is between the 5th lumbar and 1st sacral vertebra. [(5)]

Its functions are:

1. To reduce the depreciation impact on the spine when walking.
2. To maintain a desired value of the field in the intervertebral segment of L5-SI, through which important nerve trunks of the spinal cord , come out for their distribution to the gluteal region and lower limb.
3. To protect nerves of the cauda equina (accumulation of nerve fibers in the lower part of the spine).

Owing to these special properties of the segment L5-SI, any damage including sacralization increases the load on the upper lumbar segment (L1-L4). This function is usually coped by the spinal column until a person starts heavy lifting daily i.e. bending and unbending, as a result of the professional activity. In such a situation at a certain point, the intervertebral discs from L1-L4 cannot cope with the assigned load, thus resulting in lower back pain due to nerve compression syndrome (nerve root entrapment). [(5)]

Two important congenital entities produced by the abnormal fusion of vertebrae are Sacralisation of L5 and Lumbarisation of S1. There can be a varying degree of transition from partial to complete fusion. [(6)]

A sacralized vertebra is a type of fusion between L5 & S1 either completely or partially and has more in common with sacrum than its lumbar ones. In some cases, an additional transitional vertebra can also exist, (named L6) and this can also be sacralized rarely. In extreme cases, 2 vertebrae may be sacralized, usually L5 and L4. **(7)**

A sacral segment is said to be summarised when the uppermost segment of the sacrum is not fused with rest & remains free to move. **(8)**

Details of Sacralization

Sacralization is a congenital condition in which the fifth lumbar vertebra mainly its transverse process, gets fused or semi-fused with the sacrum or the ilium or to both. This fusion can occur on one or both sides of the body. When fusion occurs with the body of the sacrum, it is central sacralization and when fusion occurs with the sides of the sacrum, it is transverse sacralization (unilateral for one side and bilateral for both sides). **(2, 9)**

Incomplete sacralization shows a well-defined joint line between the transverse process and the sacrum. (10)

Due to fusion, the intervertebral disc between L5&S1 may be narrow or absent. As a result, the L5vertebra appears and works more like the sacral components and hence it is termed as Sacralized vertebra & is considered as a part of sacrum leaving only four lumbar vertebrae. Hence the condition is also called as 'one less vertebra'. After sacralization, L4 becomes the last lumbar vertebra and it lacks the ability to perform & function like L5. It is difficult for L4 to cope with increased load demand, causing overuse and undue strain to the disc between L4 and L5. This usually leads to pain and discomfort in the region of the lower back. **(2)**

Sacralization can also lead to a narrowing of intervertebral foramina causing compression of the spinal nerve which can cause spinal or radicular pain. **(10)**

Features of Sacralisation of L5

- assimilation of L5 to the sacrum
- presence of four rib-free lumbar-type vertebrae, which may have the following features

a. wedging of the lowest lumbar (transitional) vertebra
b. hypoplastic or absent facet joints or intervertebral disc**(6)**

In **coccygeal sacralization,** coccyx fuses completely or partially with the sacrum. **(9)**

Details of Lumbrization

Lumbarisation is a condition where the uppermost segment of the sacrum is not fused with rest. Rather it is free to move and participates, along with the neighboring lumbar vertebrae in spinal activity. The first sacral segment is said to be summarised. L6 in lumbarization is not 'an extra vertebra'. Rather it is one more mobile lumbar segment due to non-fusion of the first segment of the sacrum. **(8)**

Features of Lumbarisation of S1:

* assimilation of S1 to lumbar spine
* less common than Sacralisation, occurring in ~2% of the population.
* Presence of six rib-free lumbar-type vertebrae, which may have the following features

a. Squaring of highest sacral (transitional) vertebra
b. Presence of facet joints (even rudimentary) and intervertebral disc between S1 and S2.**(6)**

Lumbosacral Transitional Vertebrae (LSTV)

Both lumbarisation and sacralization are now a days discussed under one common heading "Lumbosacral transitional vertebrae" (LSTV). **(10)**

LSTV was observed first time by **Bertolotti in 1917** who stated that these abnormal vertebrae might produce low back pain due to arthritic changes which occured

at the site of false articulation. [11] **Castellvi et al**. classified LSTV into 4 types [3, 12]

The Sacralization of L5 may be of the following forms

1. Full- fully mergence of all the structural elements in between L5 and S1;
2. Partial – vertebrae are fused partially like handles or spikes, which limit their mobility:
3. Deep- this form stands out only by some scientist and involves the deep penetration of L5 in the sacral area without visible signs of fusion between the vertebrae.

Depending on the peculiarities of the anatomical structures, sacralization of L5 is classified into:

a. True: there is true mergence of all the structural elements between L5 and S1
b. False (pseudo-sacralization): When there is calcification (deposition of calcium salts) of the ligaments of the spine between L5 and S1. This situation is often observed in ankylosing spondylitis where there is calcification of almost all ligaments of the vertebral column.

This "**pseudo- sacralization**" appears in old age, when due to aging process, deposition of calcium salt into the ligaments of the lumbar-sacral region of the spine takes place.

The sacralization of the True form can be distinguished from the false one on the basis of x-ray pictures of the lumbo sacral region.

Following are the criteria for true Sacralization:

a. When the intervertebral gap is completely "shaded" by bone tissue:
b. Poorly differentiated (or missing) of the shadow of the spinous processes of the L5 andS1 Vertebrae. (5)

Many intermediate incomplete transitions have also been recognized and classified as LSTV. [12]

For understanding LSTV, we need to know the normal anatomy of the lumbar and sacral vertebrae, development of the human vertebral column and the factors that can lead to developmental variation. [3]

Development of Vertebrae:

Development of vertebrae commences at the 3rd week of intrauterine life. All vertebrae originate from

somites that form along the cranial-caudal axis, on either side of the notochord, from presomitic paraxial mesoderm.

These somites differentiate further into dermomyotome (future inner dermis and muscle) and sclerotome. Each sclerotome consists of loosely packed cells cranially and densely packed cells caudally. Some densely packed cells move cranially opposite the center of myotome where they form an intervertebral disc. The remaining densely packed cells fuse with the loosely arranged cells of immediately caudal sclerotome to form mesenchymal centrum, i.e. the body of the vertebra. The mesenchyamal cells surrounding the neural tube form neural arch. [10]

Ossification of vertebra begins in 8th week & ends by the 25th year. There are two primary centers & five secondary centers present in each vertebra. Secondary centers are one for the tip of the spinous process, one for the tip each transverse process & two each for annular epiphyses. [3]

Formation of the vertebral column from the 44 mesodermal somatomeres occurs in conjunction with primary neurulation down to the 30th somite, which corresponds to the S1-2 junction. The S-2 segment down to the coccyx is derived from somites 31 to 44 and arises from the caudal eminence (tailbud) during secondary neurulation and the retrogressive differentiation that follows. Developmental disorders during this time course are associated with various dysraphisms, such as with caudal or sacral agenesis if a complete developmental failure occurs. [4]

Initially, in the newborn, the five sacral vertebrae resemble their lumbar

counterparts until ossification of the sacral ala begins late in the 1st year of life. Each sacral vertebra has five ossification centers: a primary center, one in each epiphysial plate, and two for the two vertebral arches.The lateral parts of the sacrum ossify from 10 additional ossification centers. The initial six sites derive symmetrically from the first three vertebrae, which represent the coastal elements. An additional four sites are derived from the two epiphysial plates on each lateral surface, along with one for the auricular surface and another for the remaining thin lateral edge of the bone. Fusion of the sacral vertebra starts at puberty, beginning with the coastal elements. The VBs (vertebra bodies) begin fusing when the individual reaches 18 years of age; this continues during the next two decades in a caudal to cranial fashion.

Complete fusion of the sacrum has been reported to occur Between Years 25 and 33 of life and is related to the load-bearing aspects of this region. In support of the Woolf law regarding bone remodeling, children with paraplegia or those who do not bear weight across the sacral region, do not form the singular osseous sacral mass. [4]

Causes of Lumbo-Sacral Fusion

The vast majority of people affected by this spinal abnormality are born with it. Genetics plays an important role in its development. [12], [13]

Cases of families with increased incidence of LSTV suggest a genetic component. HOX10/HOX11 genes influence the axial pattern of lumbar and sacral vertebrae. The somites are segmentally organized in pairs on both sides of the neural tube and are specific for the axial level at which they are positioned. This segmental identity of the somites is determined by different Hox-genes in the presomitic mesoderm. The specific combination of Hox-genes that is expressed at a particular level seems to determine the axial identity of the resulting structures. Mutations in these genes may play a role in the formation of LSTV. [12, 14]

It has been shown that vertebral sacralization can be induced in transgenic mice by Hoxa11 expression. It was found that in the absence of Hox11 function, sacral vertebrae are not formed and instead these vertebrae assume a lumbar identity. In addition, they showed that in the absence of the Hox10 function, no lumbar vertebrae are formed. Thus, these studies show that the normal patterning of lumbar and sacral vertebrae as well as the changes in the axial pattern, such as LSTV, result from mutations in the Hox-10 and Hox-11 paralogous genes. [14, 15]

In addition, a significant association was found to exist between sacralization and cervical rib. The mechanisms responsible for the development of the lumbosacral spine may therefore also influence the development of the cervical spine and vice versa. [14]

It is reported that vertebrae are developmentally derived from the sclerotomes of the somites.

Embryologically, the vertebra during the developmental process receives a contribution from the caudal half of one sclerotome and from the cranial half of succeeding sclerotomes. Lumbarisation and sacralization are caused by the border shifts. Sacralisation of the fifth lumbar vertebra is due to cranial shift and the lumbarisation of the first sacral segment is due to the caudal shift. It was noted that ossification defects could potentially lead to the development of various vertebral defects but it is very difficult to differentiate between ossification defects and developmental defects as both have the same morphological features. [15]

Less common reasons for a fused lumbo-sacral region include traumatic back injury, extreme arthritic changes and of course, purposeful spinal fusion surgery. [13]

Incidence: Different values have been reported by different researchers.

Sacralisation of fifth lumbar vertebrae is most commonly seen when compared to lumbarisation of first sacral vertebrae; Lumbarisation of first sacral vertebrae is a very rare (LSTV). [14, 15]

The prevalence of LSTV ranges from 1-20%; variation of the prevalence of LSTV in the general population throughout the literature is due to differences in definition and diagnostic modalities. [10]

The incidence ranges from 4.0% - 35.9% with a mean of 12.3%. The prevalence of LSTV is higher in men compared to women (28.1% vs. 11.1%). Sacralization is more common in males; meanwhile, accessory L5-S1 articulations and lumbarization of S1 are more common in women. [11, 12]

Apazidis et al. described the prevalence of LSTV to be 35% in the American population. [15, 16] The prevalence of LSTV is said to vary between 7% and 30% in various studies. [16, 17]

The incidence of (LSTV can be seen in the range of ~25% (range 15-35%) of the general population. Lumbarisation of S1 is less common than sacralization, occurring in ~2% of the population. Sacralization of L5 is more common than lumbarisation, occurring in ~17% of the population [6]

The Castellvi's type IIa pattern was found to be the commonest followed by type IIIb. [17]

The prevalence of transverse sacralization of lumbar vertebra turned out to be 25.7% out of which Castellvi type IIb was found to be most common, accounting for 33.3% cases. 5.7% comprised the group of normal variant (Castellvi's type I) and 68.6% were normal. [18]

Classification of Lumbosacral Transitional Vertebrae

A) In 1984, **Castellvi et al** described a radiographic classification system identifying 4 types of LSTVs on the basis of morphologic characteristics.

Type I: Dysplastic transverse process. The large triangular transverse process, at least 19 mm wide(craniocaudal dimension) (a) unilateral or (b) bilateral.

Type II: Incomplete lumbarization / sacralization. Enlarged transverse process with that has a diarthrodial joint between itself and with the adjacent sacral ala(pseudarthrosis) ;(a) unilateral or (b) bilateral.

Type III: Complete lumbarization / sacralization.The enlarged transverse process, with complete osseous fusion with the adjacent sacral ala; (a) unilateral or (b) bilateral.

Type IV: Mixed Type –IIa on one side and type III an on the other. [19]

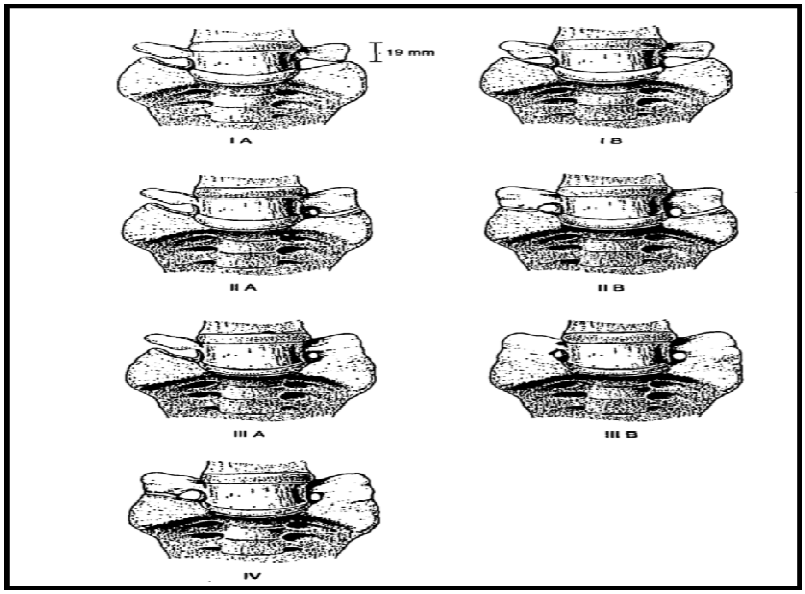

Fig 1 showing grades of LSTV acc. to Castellvi's classification[12]

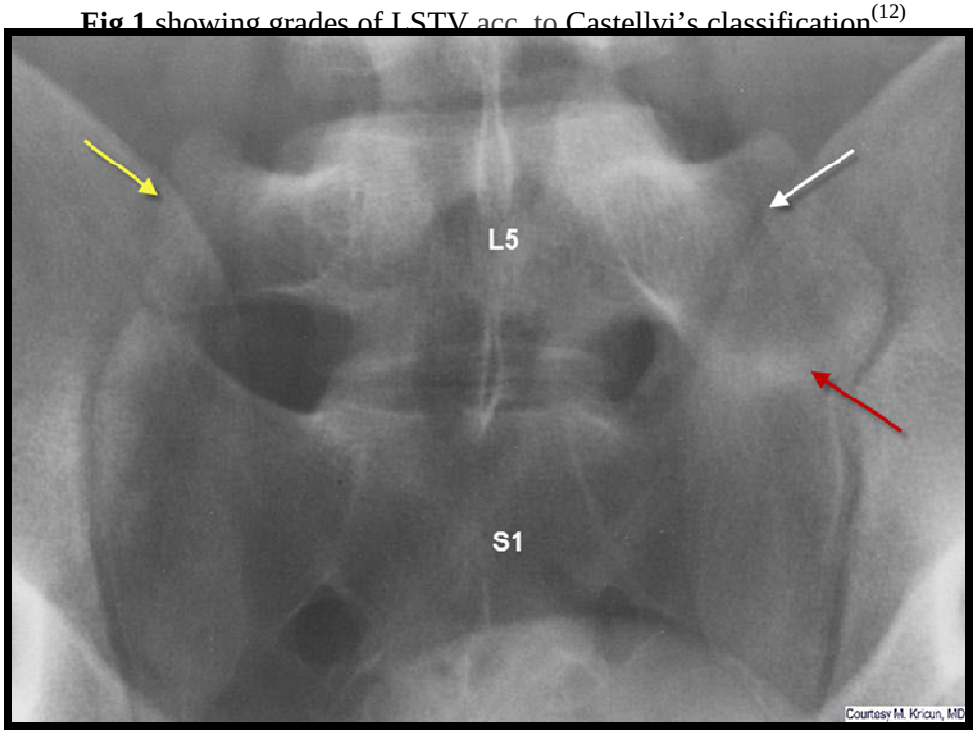

Fig.2 X-Ray of lumbosacral region showingSacralization of L5. A close-up view of the sacrum shows bilaterally enlarged transverse process of L5 (White and yellow arrow,) fused on the left (red arrow) with the sacrum. The fifth lumbar segment is labeled L5 and another first sacral segment is labeled S1. [20]

Disadvantage:

This classification system does not provide information relevant to the accurate enumeration of the involved segment. [21]

B) Classification based on a **scoring system used by Khairnar KB et al (2013)**

A simple score system helpful for clinical purposes and based upon anatomical

changes score system was developed, the six structures assessed were the left and right inferior articular facets, left and right transverse processes, and the left and right sides of the vertebral body. A is score given in such way that 1 point is awarded for:

a) Unilateral fusion of vertebral body (rt. or lt. half)
b) Unilateral fusion of transverse process (rt. or lt. half)
c) Unilateral fusion of inferior artiarticular process (rt. or lt. half)

So ultimately 2 points are awarded for bilateral fusion i.e. rt. half-1 + lt. half-1=2. Here fusion means bone had grown together preventing any motion between segments. [(3)]

Numbering of LSTV

1. Radiographs of the entire spine allow the radiologist not only to count from C2 inferiorly but also to differentiate hypoplastic ribs from lumbar transverse processes, therefore enabling counting of the number of thoracic segments and correct identification of the L1 vertebral body. After this vertebral body is correctly identified, determining the correct numeric assignment of the LSTV is possible.
2. By the use of a sagittal cervicothoracic MR localizer to better evaluate transitional vertebrae. The addition of a coronal MR Cervicothoracic localizer increases the accuracy of enumerating lumbosacral transitional vertebra because it allows better differentiation at the thoracolumbar junction.
3. Another technique used to correctly number an LSTV is locating the iliolumbar ligaments which arise from the L5 transverse processes. It is seen as a low-signal-intensity structure on both axial T1- and T2-weighted MR images as a single or double band extending from the transverse process of L5 to the posteromedial iliac crest. An LSTV is labeled as L5 when no iliolumbar ligament is identified at the level above. When an iliolumbar ligament was seen to rise above the LSTV, then the vertebral body with the iliolumbar ligament was labeled L5 and the LSTV, as S1.
4. By seeing the morphologic characteristics of transitional vertebrae: squaring of the upper sacral segment when it is lumbarized and wedging of the lowest lumbar segment when it is sacralized. These morphologic changes represent cranial and caudal shifts of the spine, respectively, resulting in either a greater or lesser number of motion segments. The "squared" appearance of transitional vertebrae on lateral radiographs is described as the ratio of the AP diameter of the superior vertebral endplate to that of the inferior vertebral endplate as ≤1.37.
5. The use of anatomic markers, including the aortic bifurcation, right renal artery, and conusmedullaris has been reported to be least reliable. [(21)]

LSTV and Back Pain

Some previous workers have suggested the role of LSTV in low back pain whereas others have contradicted the role of LSTV. [(10)]

The association between LSTV and back pain was first described in 1917 by Bertolotti. [11)]

The vast majority of congenital and developmental sacralized conditions is asymptomatic and is not the source of any pain at all. the overwhelming majority of sacralized vertebrae are not painful or problematic, there being great diversity of other possible causes of pain exist in many of these patients, including disc irregularities, spinal curvature concerns, osteoarthritic changes, muscular pain syndromes, and of course, mind-body disorders (the psychogenic variety).

There are a few circumstances where sacralization itself might be part of the pain problem. Usually, these cases revolve

around patients who developed rather sudden organic vertebral fusions following severe traumatic lower back injury. In many of these specific parameter cases, the vertebrae may not have joined at the proper angle to ensure a patent central canal or patent foraminal openings for exiting nerve roots.

In some cases, sacralized segments can impinge on spinal nerve roots or the cauda equina structure, but this is rare. It is always better to achieve an accurate and correct diagnosis before even considering invasive care practices for any suspected source of back pain. [21, 22]

There have been studies reporting no relationship between Lumbar sacralization and back pain and neurological presentations. This relationship is basically associations with "sciatic pain", disc herniation, and nerve root entrapment with radiculopathy etc. [23, 24]

Clinical Presentation:

Patients may present with complaints like back pain, inflammation, swelling, the stiffness of back, difficulty in making certain movements, decreased the range of motion and back muscle spasms. Some may be at an increased risk of nerve injury or inter-vertebral disc problems, especially at the junction of lumbarization. Sometimes, radiculopathy or nerve problems like tingling, burning sensation in the legs can be felt due to sciatic nerve compression in persons experiencing back problems. [22, 23]

Imaging Finding:

Most authors agree LSTV is best seen on anteroposterior (AP) radiographs, although some go further to advocate a **lateral and Ferguson radiographs** (AP radiographs angled cranially at 30° allowing better characterization of the transverse processes of L5°). A newer method for accurate LSTV identification involves using magnetic resonance imaging (MRI) to locate the iliolumbar ligaments that are thought to arise exclusively from the L5 transverse processes, as this identifies the vertebral level consistently. [21,25]

CT can be used for the definitive bony anatomy; they may be more difficult to identify on MRI for a number of reasons. [20]

The aim of Studying LSTV

Knowledge of the presence of such vertebral variation will be helpful for the clinicians to diagnose and treat patients with low back pain. [14]

Awareness of such congenital anomaly is important before any spinal surgery in order to avoid incorrect numbering of vertebrae and consequently prevent wrong level spinal surgery. [19, 21]

Patients with LSTV are often suggested to be prone to various secondary pathologic spinal conditions including intervertebral disc herniation and/or degeneration, facet joint arthrosis and spinal canal or stenosis of foramina. [13, 14]

Material & Methods

The present study was carried out on random 100 dry adult sacra irrespective of gender and age, belonging to the department of anatomy SMC, Ghaziabad (UP), keeping in mind that the bones for study, belonged to those cadavers brought to the anatomy dept from UP belt. The specimens were either separate sacra or articulating with hip bone. Every specimen was studied for

1. A number of vertebrae
2. a. Fusion of bodies if any

b. whether complete or incomplete fusion of vertebral bodies

3. The condition of the transverse process of S1 as follows:

a. enlarged and dysplastic transverse process (at least 19 mm) without fusion- unilateral/bilateral
b. pseudo articulation of the transverse process and sacrum- unilateral/bilateral
c. true fusion of transverse process with the sacrum- unilateral/bilateral

4. The condition of left and right inferior articular facets

Observations:

The observations were as follows:

Total no. of specimens showing LSTV 27%

No of specimens showing Lumbarisation=04

Lumbarisation was identified (Fig-A)

1. by the presence of only 4 sacral segments in individual sacrum of in all four specimens(due to the absence of first sacral segment)
2. Presence of only three sacral foramina.

Fig A. showing features of lumbarization

No. of specimens showing sacralization=23

The observations of Sacralization were further interpreted based upon

1. Castellvi's classification[19]

The observations were arranged according to the following

Table I [20]

Grade			Definition
O			**Normal**
I	**Ia**	**Unilateral**	Dysplastic transverse process. With height 19mm
	Ib	**Bilateral**	
II	**IIa**	**Unilateral**	Incomplete lumbarization/ sacralization Enlarged transverse process with pseudarthrosis with the adjacent sacral ala
	IIb	**Bilateral**	
III	**IIIa**	**Bilateral**	Complete lubrication/ sacralization Enlarged transverse process, which has a complete fusion with the adjacent sacral ala
	IIIb	**Unilateral**	
IV			Mixed

The present observations:

Table II

Refer to the (Figures B, C, D)

Total no of specimens	**100**
No of cases showing LSTV	**27(27%)**
No of cases showing lumbarisation	**04(15.9%)**
No of cases showing sacralization	**23(84.1%)**

Grades of sacralization			
O			Normal
I	Ia	Unilateral	-
	Ib	Bilateral	-
II	IIa	Unilateral	-
	IIb	Bilateral	-
III	IIIa	Unilateral	-
	IIIb	Bilateral (figures B,C,D)	+
IV		Mixed	-

Fig B

Fig C

Fig D

2) Classification based according to the scoring system used by KhairnarKB et al [3]
The observations were arranged according to the following

Table III[3]

Specimen no	Score acc. To Fusion of the vertebral body		Score acc. To Fusion of the Transverse process		Score acc. To Fusion of Inferior articular facet		Total Score
	Rt. side	Lt. side	Rt. side	Lt. side	Rt. side	lt. side	

The present observations:

Table IV

Refer to the (Figures E,F,G,H,I)

Specimen number	Score acc. To Fusion of the vertebral body		Score acc. To Fusion of the Transverse process		Score acc. To Fusion of Inferior articular facet		Total score
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	
Figure E	0	0	1	1	1	1	04
Figure F	1	0	1	1	1	1	05
Figure G	0	1	1	1	1	1	05
Figure H	0	0	1	1	1	1	04
Figure I	1	1	1	1	1	1	06

Fig E

Fig F

Fig G

Fig H

Fig I

Discussion

The Relationship of low back pain and LSTV, termed "Bertolotti Syndrome," has been debated in the literature since its initial description in 1917. Low back pain associated with an LSTV may arise from the level above the transition, the contralateral facet when unilateral, and/or the anomalous articulation when present. Although this association beyond dispute is of importance in identifying LSTV in those patients in whom a surgical or interventional procedure is planned. [(11)]

Williams PC (1965) Reported that anatomical variations occur frequently in the lumbosacral region, making the sacrum the most variable portion of the spine. The variation can be attributed to the dependency of the sacral morphology to the load related fusion of the bone structure as it helps in the transmission of weight to lower extremity. [(26)]

Wigh& Anthony (1981), reported morphologic characteristics of transitional vertebrae to include squaring of the upper sacral segment when it is summarised and wedging of the lowest lumbar segment when it is sacralized. [(27)]

According to Meschan (1985), complete lubrication of the first sacral vertebrae leads to an increase in the number of lumbar vertebrae which are a very rare occurrence as reported in earlier studies. [(28)]

Peh W C et al (1999) reported thatSacralized L5 had a prevalence of 1.7 to 14%, whereas lumbarised S1 had a reported prevalence of 3 to 7%. However, the studies show lumbarization to be more common than sacralization. [(29)]

Eyo MU et al (2001) studied 300 radiographs of patients seen in the Radiology department, complaining of low back pain (LBP) was randomly chosen. Of the total number of patients seen, 143(48%) were males and 157 (52%) were females. The incidence of LSTV was found to be 37% and with a male preponderance. There is a high incidence of lumbosacral transitional vertebrae (LSTV) in (LBP) patients. This cannot be overlooked. This study suggests that there is a strong relationship between the congenital anomaly LSTV and LBP. [(30)]

Cheng & Song (2003) reports lumbarization of first sacral vertebrae is less common compared to the sacralization of fifth lumbar vertebrae the incidence is very low approximately ~2% of the population. [(31)]

Khanna & Chauvan (2003), report the patients who have three dorsal sacral foramina could present with pain in the lower part of the back and legs. If such an anomaly exists then there is all possibility that the fourth sacral nerve roots also passes through the sacral hiatus along with the fifth sacral, coccygeal roots, and the filum terminal exiting through it. In that case, any sacrococcygeal tumor may compress upon fourth sacral roots also, leading to the

neurological involvement of the bladder and rectum also. [32]

Eva GD et all (2006) conducted a review of the plain films of 300 lumbar spine patients presenting for evaluation for axial, referred, and/or radicular pain.Of 300 consecutive lumbar spine patients, 30% had a transitional vertebra.The most frequent type was a complete bilateral (29%). [33]

Acc. to Johannes L et al (2007) several conflicting studies have been published regarding the association of LSTV with other spinal pathology. There seems to be a relation with early disc degeneration above the LSTV in young patients. However, these differences fade with age as they are masked by other degenerative changes of the spine. From a practical viewpoint, failure to recognize and to number LSTV during spinal surgery may have serious consequences. Patients with LSTV are often suggested to be prone to various secondary pathologic spinal conditions including intervertebral disc herniation and/or degeneration, facet joint arthrosis and spinal canal or foraminal stenosis. [14]

Bron JL et al. (2007), reported that wide variations in the prevalence of LSTV reported in the literature, is likely due to differences in individual diagnostic and classification criteria, observer error, imaging techniques, and confounding factors of the population being studied. [34]

Acc. to Konina G.P. et al (2010), a clinician should be able in identifying and correctly numbering LSTVs as well as detecting imaging findings related to the genesis of low back pain. Knowledge of the biomechanical alterations within the spine caused by LSTVs will aid the radiologist in understanding and recognize the imaging findings seen in patients with low back pain and a transitional segment. Additionally, a thorough understanding of the importance for both accurate enumeration of LSTV and communication to the referring clinician will help to avoid such dreaded complications as wrong-level spine surgery. [21]

Nardo L et al (2012) examined 4,636 radiographs and found the prevalence of LSTV in 18.1% (841 of 4636) of participants; out of which 28.1% (539 of 1919) of men and 11.1% (302 of 2717) of women ($P < .001$). No significant difference in the prevalence of LSTV was observed by race. The 841 patients with LSTV were placed into four modified Castellvi classification subgroups; of these, 351 patients (41.7%) had LSTV type I, 349 (41.4%) had LSTV type II, 97 (11.5%) had LSTV type III, and 44 (5.2%) had LSTV type IV. [35]

Deepa TK et al (2014) report that sacrum is clinically important for the caudal epidural block. So incorrect numbering can theoretically lead to problems with the administration of intradural or epidural anesthetics. Surgical treatment of sacral lesions requires an understanding of the underlying anatomy, a task made easier by understanding the developmental aspects and morphological changes that occur with growth.The knowledge of this kind of anomaly is important while reporting the CT, MRI films and X-rays for correct clinical and radiological assessment.Thus clinically the lumbarisation of the 1stsacral vertebra is of paramount importance to surgeons, clinical anatomists, forensic experts, and morphologists. [36]

Gupta R et al (2014) perceived that around 22.2% female had lumbarization in comparisons to males (25%). The incidence of sacralization was also higher in male (i.e. 25%) in comparison to female (i.e. 11.7%).It may be concluded that increase in the incidence of lumbarization and sacralization may lead to increased chances of a low backache and also a higher incidence of lumbarization and sacralization in males perhaps make them more vulnerable to a low backache. Hence a study on LSTV is important because number of vertebrae is

variable and unreliability of anatomical landmark for identification of last lumbar vertebrae. On the other hand, its correlation with a low backache makes it more clinically relevant than anatomically. [37]

French HD et al (2014), performed a retrospective review of 5,941 AP and lateral lumbar X-rays was amongst Australian population. Of the 5,429 lumbar radiographs, 540 were identified as having LSTV, giving a prevalence of 9.9%. Lumbarised S1 and sacralized L5 had a prevalence of 5.8% and 4.1%, respectively. [25]

Adibatti M et al (2015) conducted radiographic study of the entire spine of 100 patients with 50 radiographs of patients with a low backache and 50 radiographs of normal subjects revealed that incidence of sacralization and lumbarization was 5% and of 10% respectively in the study population but this incidence was increased in low backache patients to 8% sacralization and 18% lumbarization. It was also perceived that around 22.2% female had lumbarization in comparisons to males (25%) in 31- 40 years of the age group of low backache patients. The incidence of sacralization was also higher in male (i.e. 25%) in comparison to female (i.e. 11.7%). [15]

Jeffry MJ et al (2015) observed that LSTV is associated with alterations in biomechanics and anatomy of spinal and paraspinal structures, which have important implications for surgical approaches and techniques. LSTV are often inaccurately detected and classified on standard AP radiographs and MRI. The use of whole-spine images as well as geometric relationships between the sacrum and lumbar vertebra increase accuracy. Uncertainty regarding the cause, clinical significance, and treatment of LSTV persist. Some authors suggest an association between LSTV types II and IV and low back pain. Pseudoarticulation between the transverse process and the sacrum creates a "false joint" susceptible to arthritic changes and osteophyte formation potentially leading to nerve root entrapment. [38]

Son KM et al (2016) in a study on the Impact of Lumbosacral Transitional Vertebrae on Therapeutic Outcomes of Transforaminal Epidural Injection in Patients with Lumbar Disc Herniation, observed that out of the 291 patients, 47 (16.2%) had LSTV, including 33 with sacralization and 14 with lumbarization, while 244 (83.8%) did not have LSTV. Patients in both groups improved significantly after transforaminal epidural injection (TFEI)in terms of the visual analog scale (VAS) ($P < 0.001$) and Oswestry Disability Index for functional status(ODI) ($P < 0.001$) scores. However, lumbar disc herniation (LDH) patients with LSTV had a worse clinical outcome after six months of TFEI than did those without LSTV, with a significant difference between groups for both the VAS ($P < 0.01$) and the (ODI) ($P = 0.01$) scores. LDH patients with sacralization had worse post-treatment clinical outcomes than LDH patients with lumbarization ($P < 0.001$) or LDH patients without LSTV ($P < 0.001$). [39]

F de Bruin et al (2017), in a radiological study on Patients suffering from the Spondylo Arthritis, noted that LSTV was found in 68 out of 273 patients (24.9%). Of these, 35 out of 68 (51.5%) were Castellvi type I, 11 out of 68 (16.2%) type II (4 of which were unilateral), 17 out of 68 (25.0%) type III (1 unilateral) and 5 out of 68 (7.4%) type IV. [40]

Gopalan B et al (2018) strongly believe that LSTV is associated with low back pain (LBP). The presence of other spinal disorders (OSD) is associated with LSTV-related LBP, whereas the level of physical activity is not associated with LBP. Furthermore, female sex is independently associated with LBP and OSD, whereas advanced age (>45 years) is associated with

OSD. Our study gives an indication to the dichotomy in the literature regarding the association of LSTV with LBP because proponents may have overlooked the role of age, sex, or OSD, whereas opponents may have negated their confounding role altogether by targeting specific populations. **(41)**

Clinical Significance of LSTV----- Bertolotti's Syndrome

Bertolotti's syndrome is low back pain caused by unilateral partial sacralization where a pseudarthrosis, or developmental joint, forms when a transverse process of L5 nudges permanently up against the bone of the pelvis. The pain of BS is typically one-sided and felt where there is a 'bony hardness' at the top of the back of the pelvis.

Full-fusion unilateral sacralization of the bottom lumbar segment has several knock-on effects. The first is excessive movement strain of the pseudarthrosis on the contralateral side. Unilateralsacralisation also tends to cause problems in the upper lumbar spine on the contralateral side. Typically, there are problems of the L2-3 spinal segment, usually involving the facet joint as well.

Full fusion bilateral sacralization commonly causes degenerative breakdown of the L4 disc above, related to the altered center of gravity of the base of the spine. With the L5 fused to the sacrum, the seat of spinal movement is raised. L4 - the 'new' spinal base - lacks the secure shoring afforded L5 and this can lead overuse syndrome and developmental instability of the L4 segment. **(8)**

Wrong-Level Spine Surgery

The accurate assessment of spinal segmentation is crucial in eliminating surgical and procedural errors because most wrong-level spine surgery occurs in patients with variant spine anatomy, including LSTVs.Often, surgical errors occur when MR imaging of the lumbar spine is reported without accompanying conventional radiographs or cardiothoracic MR localizers. **(21)**

Concluding, our morphological study on 100 dry sacra has also shown a high incidence (27%) of LSTV.LSTVs are common anomalies of the spine necessitating the ability to accurately identify and number the affected segment of the sacrum. A thorough knowledge of the importance of accurate enumeration of LST and its interpretation by clinicians will help to avoid such dreaded complications as wrong-level spine surgery. The study may be helpful to the orthopaedicians, neurosurgeons, physiotherapists to know the correlation between LSTV & low back pain. It is necessary to study more samples to expose the true correlation between LSTV & low back pain to reach at a proper diagnosis of LBA and intervertebral disc degeneration.

References

1) Lumbar vertebrae – Wikipedia ttps://en.wikipedia.org/wiki/Lumbar_vertebrae
2) What is Sacralization and how is it Treated? – ePain Assist https://www.epainassist.com Back Pain Low Back Pain
3) Dr. Karan BhagwanKhairnar, Dr. ManishaBhausahebRajale "SACRALIZATION OF LUMBAR VERTEBRA" Indian Journal of Basic & Applied Medical Research; March 2013: Issue-6, Vol.-2, P. 510-514
4) Joseph S. Cheng, MD; John K. Song, MD Anatomy of the SacrumNeurosurg. Focus. 2003; 15(2)
5) Sacralization of l5 vertebrae: what it is, treatment, symptoms, typesback.vsebolezni.com/deformacii.../lechenie-sakralizacii-pozvonka-l5.htm...
6) A. Prof Frank Gaillard et al.Lumbosacral transitional vertebraLumbosacral transitional vertebra |Radiology Reference

Article.https://radiopaedia.org/articles/lumbosacral-transitional-vertebra
7) Sacralized Vertebra - Back Painwww.cure-back-pain.org/sacralized-vertebra.html
8) Lumbarisation and Sacralisation - impleBackPain.comwww.simplebackpain.com
9) Dr. Shobhakumari, Dr. Rita kumari1, Dr. Padamjeet PanchalMrs. Atulyaprasad, N.J.BrittoStudy of Sacralization of Fifth Lumber Vertebra IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 11 Ver. I (November. 2016), PP 58-6
10) SangeetaWazir. Sacralisation of lumbar vertebrae Int J Anat Res 2014, Vol 2(2):386-89.
11) Bertolotti M. Contribute all a conoscenza deivizi di different zazionedelrachide con special areguardo all assimilazi on esacraledella v lombare. La Radiologia Medica 1917; 4:113–44
12) Jeffrey M. Jancuska, BA,1 Jeffrey M. Spivak, MD,2 John A. Bendo, MD2 A Review of Symptomatic Lumbosacral Transitional Vertebrae: Bertolotti's Syndrome. International Journal of Spine Surgery,2015 Volume 9 Article 42 doi: 10.14444/2042
13) Sacralization Lumbosacral Fusion - Back Painwww.cure-back-pain.org
14) Johannes L. Bron, barend J. Van royen, paul I J. M. Wuismanthe clinical significance of lumbosacral transitional anomaliesActaorthop. Belg., 2007, 73, 687-695.
15) Adibatti, M. &Asha, K. Lumbarisation of the first sacral vertebra a rare form of the lumbosacral transitional vertebra. Int. J. Morphol., 33(1):48-50, 2015.
16) Apazidis A, Ricart PA, Diefenbach CM, Spivak JM. The prevalence of transitional vertebrae in the lumbar spine. Spine J. 2011; 11: 858–862.
17) Vijay Sekharappa, RohitAmritanand, Venkatesh Krishnan, and Kenny Samuel David Lumbosacral Transition Vertebra: Prevalence and Its Significance Asian Spine J. 2014 Feb; 8(1): 51–58.
18) Juhi V. Patel, Chetan M. Mehta, Nandakishore G. Patil, Shreya R. Sehgal. Transverse sacralization of lumbar vertebrae: prevalence according to Castellvi classification DOI:http://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20164835
19) Castellvi AE, Goldstein LA, Chan DP. Lumbosacral transitional vertebrae and their relationship with lumbar extradural defects. Spine. 1984☹5):493-5
20) Transitional Vertebrae-Lumbarization – Learning Radiology learning radiology. com/notes/bone notes/transitionalvertebrae.htm
21) G.P. Konina and D.M. Walza Lumbosacral Transitional Vertebrae: Classification, Imaging Findings, and Clinical Relevance American Journal of Neuroradiology 2010 Nov;31(10):1778-86.
22) Does Sacralization Cause Back Pain www.cure-back-pain.orgoes sachttps://www.cure-back-pain.org/does-sacralization-cause-back-pain.html
23) Back Pain. What is Lumbarization and how can it Be Treated? - ePainAssisthttps://www.epainassist.com › Back Pain › Low Back Pain
24) Sacralization of the L5 vertebral body - Neurology - MedHelpwww .medhelp.org/posts/Neurology/Sacralization-of-L5-vertebral-body-/.../731643
25) Heath D. French, Arjuna J. Somasundaram,[2] Nathan R. Schaefer,[2] and Richard W. Laherty[3]Lumbosacral Transitional Vertebrae and Its Prevalence in the Australian Population, Global Spine J. 2014 Dec; 4(4): 229–232.

26) Williams, P. C. The lumbosacral spine, emphasizing conservative management. New York, McGraw-Hill Book Company, 1965. Pp.27-32, 149-50.
27) Wigh, R. E. & Anthony, H. F. Jr. Transitional lumbosacral discs. The probability of herniation. Spine (Phila Pa 1976), 6(2):168-71, 1981.
28) Meschan, I. An Atlas of Anatomy Basic to Radiology. Philadelphia, W. B. Saunders, 1985. Pp.511-2.
29) Peh W C, Siu T H, Chan J H. Determining the lumbar vertebral segments on magnetic resonance imaging. Spine (Phila Pa 1976) 1999;24(17):1852–1855
30) M. U. Eyo A. Olofin, C. Noronha, A. Okanlawonincidence of lumbosacral transitional vertebrae in low back painpatientsWest African Journal of RadiologyApril 2001 Vol. 8 No. 1
31) Cheng, J. S. & Song, J. K. Anatomy of the sacrum. Neurosurg. Focus, 15(2):E3, 2003.
32) Khanna, J. &Chauvan, R. Anatomical variations and clinical relevance of dorsal sacral foramina in North Indians. Int. J. Res. Med. Sci., 1(3):263-6, 2003
33) Elva G. Delport, MD, Tony R. Cucuzzella, MD, Nancy Kim, MD, Julie Marley, PT, Dip MDT, Christine Pruitt, RN, MS, and Anton G. Delport, PT, Dip MDT Lumbosacral Transitional Vertebrae: Incidence in a Consecutive Patient Series Pain Physician. 2006; 9:53-56.
34) Bron J L, van Royen B J, Wuisman P I. The clinical significance of lumbosacral transitional anomalies. Acta Orthop Belg. 2007; 73(6):687–695.
35) Lorenzo Nardo, MD, HamzaAlizai, MD, Warapat Virayavanich, MD, Felix Liu, MS, Alexandra Lumbosacral Transitional Vertebrae: Association with Low Back Pain Radiology, Nov 2012, Vol. 265:645–646, https:
36) Deepa TK, Martin K John a study of lumbarisation of first sacral vertebra among the south Indians International Journal of Medical Research &Health Sciences 2014; 3(1): 1-4.
37) Renu Gupta, Rajnees Garg et al. Incidence of lumbarization and sacralization in normal and low backache patients-A roentgenogram study IJBR> (2014) Vol. 5, No 9
38) Jeffrey M. Jancuska, BA, 1 Jeffrey M. Spivak, MD, 2 and John A. Bendo, MD2 A Review of Symptomatic Lumbosacral Transitional Vertebrae: Bertolotti'sSyndromeInt J Spine Surg. 2015; 9: 42.
39) Son KM, Lee SM, Lee GW, Ahn MH, Son JH. The Impact of Lumbosacral Transitional Vertebrae on Therapeutic Outcomes of Transforaminal Epidural Injection in Patients with Lumbar Disc Herniation. Pain Pract. 2016 Jul; 16(6):688-95.
40) F. de Bruin, S. ter Horst, J. L. Bloem Prevalence and clinical significance of lumbosacral transitional vertebra (LSTV) in a young back pain population with suspected axial spondyloarthritis. Results of the SPondyloArthritis Caught Early (SPACE) cohort Skeletal Radiol (2017) pp 1–7. doi:10.1007/s00256-017-2581-1
41) Balachandar Gopalan and Janardhan Srinivas Yerramshetty Lumbosacral Transitional Vertebra-Related Low Back Pain: Resolving the Controversy Asian Spine J. 2018 Jun; 12(3): 407–415. Published online 2018 Jun 4. doi: 10.4184/asj.2018.12.3.407.