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Prevalence and Patterns of Sacral Anomalies in the South Indian Population: A Bone-Based Study

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ABSTRACT

Introduction: Sacrum is a triangular shaped bone present in the posterior aspect of pelvis formed by fusion of five sacral vertebral segments. Sacrum articulates with lumbar vertebrae above, coccygeal vertebrae below and with two hip bones on either side. Sacral vertebra developed from ventromedial sclerotomes of somites. Developmental defect leads to anomalous sacral vertebrae with lumbarisation and Sacralisation. Variations in sacral vertebrae leads to chronic back pain, wrong level of Disc surgery and incorrect needle placement during caudal epidural block.

Aim and objective: To study the prevalence and patterns of variations in sacral vertebrae in south Indian population.

Materials and Method: The study was conducted in the Department of Anatomy, Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry. The Study designed as a descriptive study includes 105 dry bones of sacrum. The sacrum bones are observed for number of segments, pattern of fusion and other associated anomalies.

Results: This study shows sacralisation (21%) is more compared to lumbarisation (7.6 %). This study also includes abnormal curvatures of sacrum, spina bifida and incomplete fusion of adjacent sacral vertebra.

Discussion and conclusion: Sacrum is a triangular shaped bone formed by 5 vertebral segments. Vertebrae are intersegmental structures derived from portions of two adjacent somites which is regulated by HOX genes. Sacral variations can impact spinal biomechanics, leading to altered weight transmission and possible low back pain. Thorough anatomical knowledge of Sacral vertebrae is clinically important for procedures like caudal epidural anaesthesia.

Keywords: Sacrum, Lumbarisation, Sacralisation, low back pain

INTRODUCTION

The sacrum is an inverted triangular-shaped bone located in the posterior aspect of the pelvis. It is formed by the fusion of five sacral vertebral segments. The base of the sacrum articulates with the fifth lumbar vertebra to form the lumbosacral joint, while the apex of the sacrum articulates with the coccyx, forming the sacrococcygeal joint. The lateral surface of the sacrum presents an L-shaped articular surface that articulates with the ilium of the hip bone to form the sacroiliac joints. The bony pelvis is formed by the fusion of a pair of hip bones on either side, along with the sacrum at the posterosuperior part.

The superior surface of the sacrum is flanked on each side by an expanded wing-

like transverse process known as the ala of the sacrum. The sacrum exhibits a concave pelvic surface and a convex dorsal surface. The anterior surface is marked by transverse ridges, which represent the sites of vertebral fusion. The dorsal surface shows the median, intermediate, and lateral sacral crests, which are formed by the fusion of the spinous, articular, and transverse processes, respectively.[1]

Each surface has four pairs of anterior and posterior sacral foramina, through which the anterior and posterior primary rami of the spinal nerves exit. These foramina communicate with the sacral canal, which is the continuation of the vertebral canal. Vertebrae are intersegmental structures derived from portions of two adjacent somites. The sacral vertebrae develop from the ventromedial sclerotomes of somites. Each sacral segment is formed by the fusion of the caudal half of one sclerotome and the cranial half of the succeeding sclerotome. The patterning and shape of individual vertebrae are regulated by HOX genes.[2]

Partial or complete fusion of the fifth lumbar vertebra with the first sacral vertebra results in sacralisation. Occasionally, sacralisation may occur due to the fusion of the first coccygeal segment with the fifth sacral segment. Conversely, lumbarisation refers to the partial or complete separation of the first sacral segment from the sacrum, resulting in its appearance as an additional lumbar vertebra. Both lumbarisation and sacralisation are positively correlated with an increased prevalence of low back pain. Understanding the variations of the sacral vertebrae is critically important during radiological evaluations, especially for procedures such as caudal epidural blocks, in order to avoid inadvertent injury and ensure effective management of low back pain.

MATERIALS & METHODS

The study was carried out in the department of Anatomy, Sri Lakshmi Narayana institute of medical sciences, Puducherry, over a period of two years from August 2023 to September 2025. The study was designed as a prospective descriptive study which include 105 human adult dry bones of sacrum. In this present study we include all sacral vertebrae of both gender and we exclude the damaged bones and bones with fracture. The Primary objective of this research work is to study the variations of sacral vertebrae in adult dry bone of sacrum in South Indian population and to study the prevalence and patterns of lumbosacral transitional vertebrae in adult dry bone of sacrum

RESULT

A total of 105 sacral vertebrae of both genders were examined in the Department of Anatomy, Sri Lakshmi Narayana Institute of Medical Sciences. Each specimen was evaluated for the number of sacral segments and sacral foramina. Descriptive statistics were applied, and the prevalence of anomalies were expressed in both frequency and percentage. Chi-square test was used to compare the occurrence of unilateral versus bilateral anomalies, with bilateral variations being more common ($p < 0.05$).

Out of the 105 sacra studied, 52 (49.5%) showed anomalies, while the remaining 53 (50.5%) were morphologically normal. Lumbarisation was observed in 8 sacra (7.6%). Among these, 3 sacral vertebrae (2.8%) showed unilateral lumbarisation and 5 sacral vertebrae (4.7%) showed bilateral lumbarisation. Sacralisation was identified in 22 sacra (21%). Of these, 10 sacral vertebrae (9.5%) showed unilateral sacralisation and 12 sacrum (11.4%) showed bilateral sacralisation.

Apart from lumbarisation and sacralisation, 22 sacra (21%) exhibited other forms of anomalies. About 9 (11.4%) sacral vertebra showed abnormal flat articular surfaces. Around 5 (4.7%) sacral vertebrae had incomplete fusion of the first sacral segment despite a normal number of segments while 3 sacral vertebrae (2.8%) had incomplete fusion of all sacral segments. 2 sacral vertebrae (1.9%) showed both flat surface and incomplete fusion. We also found 3

sacral vertebrae (2.8%) exhibited spina bifida, where the laminae of sacral vertebrae failed to fuse, leaving the vertebral canal open.

Table 1: Distribution of Lumbarisation and Sacralisation

Anomaly	Total Cases (n)	Percentage (%)	Unilateral n (%)	Bilateral n (%)
Lumbarisation	8	7.6	3 (2.8)	5 (4.7)
Sacralisation	22	21.0	10 (9.5)	12 (11.4)

Table 2: Other Anomalous Sacrum

Anomaly Type	Cases (n)	Percentage (%)
Flat articular surface	9	11.4
Incomplete fusion of S1	5	4.7
Incomplete fusion of all sacral segments	3	2.8
Flat surface with incomplete fusion	2	1.9
Spina bifida	3	2.8

Figure 1: Ventral surface of sacrum showing Lumbarisation

Figure 2: Ventral surface of sacrum showing sacralisation of 5th lumbar vertebra

Figure 3: Dorsal surface of sacrum showing Spina bifida

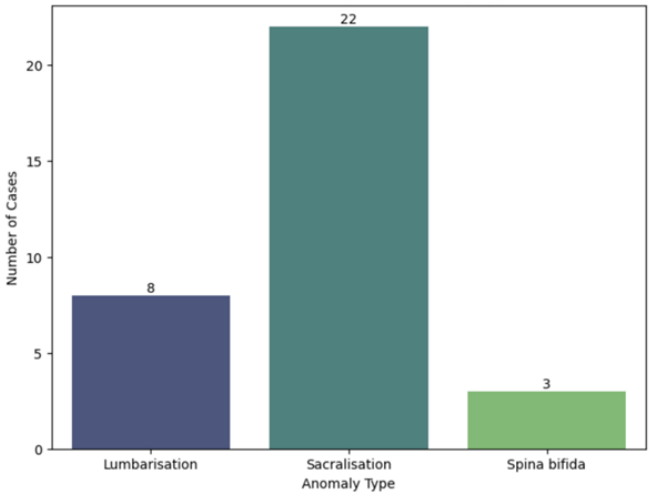

Figure 4: Number of cases for specific anomaly type

DISCUSSION

The sacral vertebrae consist of five fused vertebrae (S1–S5) that form the sacrum, a triangular-shaped bone at the base of the spine. The sacrum articulates superiorly with the fifth lumbar vertebra (L5) and inferiorly with the coccyx, forming part of the pelvic girdle. The sacral canal is the continuation of the vertebral canal and terminates at the sacral hiatus, an opening

due to the non-fusion of the laminae of S5. Sacralisation of the L5 vertebra is a common anatomical variation where L5 fuses partially or completely with the sacrum. Lumbarisation of S1 is another variation where the first sacral vertebra remains unfused, resembling a sixth lumbar vertebra. Accessory sacral articulation, partial fusion, or complete agenesis of sacral segments are other less common anomalies. Improper segmentation, fusion, or ossification of sclerotomes during 4th–8th weeks of gestation leads to sacral anomalies. Hox gene mutations and abnormal expression patterns may contribute to the failure of correct vertebral identity and fusion. Sacral variations can impact spinal biomechanics, leading to altered weight transmission and possible low back pain. Such variations may influence the effectiveness and safety of procedures like spinal anaesthesia, caudal epidural blocks, or sacral screw placement.

The present study identified a significant incidence of sacral vertebral anomalies, particularly sacralization of L5 and partial lumbarisation of S1, in the studied population. These findings suggest a higher-than-expected variation in sacral vertebral morphology. A study by Mritunjay Pandey shows lumbarisation of sacral vertebrae in 3% cases, sacralisation in 2% cases and Unilateral sacralisation seen in 1%. Their study also includes number of ventral and dorsal sacral foramina's. In their study 1% of sacral vertebra shows unilateral transitional vertebrae unpaired sacral foramina.[3] Study done by Dharathi et al shows lumbarisation is more compare to sacralisation and its more common in female. In their study 1.58% had 3 pairs of sacral foramina and unilateral sacralisation is not observed in their study.[4] In our present study unilateral lumbarisation found but it is less compared to bilateral lumbarisation. Shaileshkumar nagar et al found sacralisation is seen in 17% cases, bilateral sacralization of 5th lumbar vertebra present in 7.9%, bilateral sacralisation of coccygeal vertebrae seen in 8.9%. They also discussed 5 pairs of sacral foramina present in 16.9 cases, bilateral complete sacralisation in 5th lumbar vertebra and sacralisation of coccygeal vertebra in 7.9 % 8.9%.[5] In our present study we did not include the sacralisation of coccygeal vertebrae. Deepak T K, Martin john found that lumbosacral transitional vertebrae seen in 12.3% cases and remaining 87.7% sacrum are normal.[6] Sacral Vertebra support the vertebral column and transmits weight of the body to pelvic girdle through sacroiliac joint. The research on Sacral dimorphism done by binod kumar et al shows mean index of 1st sacral vertebra is 64.38% in male 67.68% in female. In their study morphometric analysis of sacrum such as length, breadth of sacrum etc were analysed.[7] Lumbosacral transitional vertebrae are formed by border shifts, cranial shift or caudal shift. In the present study 49.5% sacral vertebra's showing variations in number of segments and morphological variations. Gerard A malanga et al done the retrospective analysis of poor outcome following lumbar spine surgery associated with lumbosacral transitional vertebra. This lumbosacral transitional vertebra creates a slightly flexible and unstable spine.[8] A study by Jeffrey et al suggests lumbosacral transitional vertebra diagnosed with the help of patient history, imaging modalities. They also suggest surgical resection of lumbosacral transitional vertebra reserved for failure of conservative treatment and presence of anomalous pseudo articulation.[9] Study done by Sheng-chin kao et al in the sacral anomalies shows significant difficulties in giving caudal epidural blocks. They discussed the difficulties in palpating sacral cornu unilaterally or bilaterally due to sacral anomalies. In their study complete agenesis of posterior wall of sacral canal noted in 1% cases.[10] This will result in inappropriate location of sacral hiatus and failure of caudal epidural block. The person may remain asymptomatic or may present with clinical symptoms that include spinal or

radicular pain, disc degeneration, disc prolapse and lumbar extradural defects.

Anatomical anomalies may complicate childbirth in women, due to altered dimensions of the pelvic outlet. Sacral dysgenesis or agenesis is commonly seen in caudal regression syndrome, often linked to maternal diabetes during pregnancy. Improper segmentation, fusion, or ossification of sclerotomes during 4th–8th weeks of gestation leads to sacral anomalies. Hox gene mutations and abnormal expression patterns may contribute to the failure of correct vertebral identity and fusion. Genetic and environmental factors, including teratogens and nutritional deficiencies (like folate), play a role in sacral developmental anomalies. Takayuki Seki et al discussed the association of Hox genes and congenital kyphoscoliosis. Their study shows missing and fusion of vertebrae in Ishibashi rats. Their study shows transformation of 1st sacral vertebrae into 7th lumbar vertebrae and 27 % shows hemi lumbarisation and sacralisation. Their study also shows low expression of Hox 10 and Hox 11 in lumbosacral transitional areas of Ishibashi rats.[11] These kinds of severe anomalies mandates MRI and CT scans in diagnosing sacral variations, especially when symptoms like sciatica, pelvic discomfort, or gait disturbances are present. A study done by Subindra Karki et al discussed the sacralisation (8.94%) is more common compare to lumbarization (4.10%). They discussed the error in detection of lumbosacral transitional vertebrae when there is variations in the anatomical landmark. They also suggest screening by CT; MRI of whole spine allows visualization of all vertebrae's and also identifies vertebral variants.[12] Jason k. Akbar et al discussed typical localizer sequences of spine for Spine MRI are not sufficient to examine entire spine axis. They suggest sub minute automated spine survey iterative scan technique (ASSIST) along with counting the vertebrae manually with anatomic landmark to avoids numerical errors and missing the variations.[13] Tianyuan zhang et al studied the congenital lumbosacral anomalies retrospectively. Their results showed post operatively these patients developed coronal imbalance and needed revision surgery with bone grafting.[14] The study done by G.J.Paton et al demonstrate that the length of transverse process of L5 is more in lumbosacral transitional vertebra. Also, this study refines the traditional Castellvi classification. In this classification, Type IV LSTV which includes unilateral features of both Type II and Type III should be subclassified.[15] The research work done by Heath D French et al shows prevalence of lumbarisation is 9.9% compare to sacralisation 5.8%.[16] In our present study sacralisation is more 21% compare to lumbarisation 7.6%. Study done by Niladri Kumar found sacra with accessory articulations has auricular surface at higher level with load bearing features confined to upper 2 segments of sacral vertebra.[17] A study done by Jyoti et al shows the association of Sacral agenesis secondary to maternal diabetes. The sacral agenesis results in bowel and bladder disturbances which results in kidney failure and psychological distress.[18] This study highlights the early diagnosis and intervention in paediatric sacral agenesis and the importance of regular Antenatal care with frequent ultrasound checkup. This study focused on various types of anomalous variations of the sacral vertebrae and their prevalence in south Indian population. Understanding sacral vertebral variations is essential for clinicians, orthopaedic surgeons, and anaesthesiologists for accurate diagnosis and safe procedural planning.

LIMITATION

The present study is limited by the absence of involvement of sacralisation of coccygeal vertebrae; further studies are planned to incorporate this aspect in future investigations. A detailed morphometric analysis of sacrum was not performed in the

present study and will be addressed in the future research work.

CONCLUSION

Thorough anatomical knowledge of Sacral vertebrae is clinically important for procedures like caudal epidural anaesthesia. Incorrect numbering of vertebrae due to anomalous vertebrae misleads the anaesthetists during intradural and epidural anaesthesia. Developmental aspects should be considered while reporting CT, MRI, X rays for correct clinical and radiological assessment. A profound Anatomical knowledge of all possible variations of sacral vertebrae will be helpful in carrying out various surgical procedures. This minimize the iatrogenic injury of the structures during surgeries and will be helpful in good surgical outcomes.

Declaration by Authors

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