Original Article

Computed Tomographic (CT) Based Morphological and Morphometric Variations of the Sacral Hiatus and its Clinical Implications in Caudal Epidural Anaesthesia

Insha Majeed[1], Ghulam Mohammad Bhat[2], Shaziya Afzal[1]

[1]Senior Resident, Department of Anatomy, Government Medical College, Srinagar, Jammu and Kashmir, India. [2]Professor, Department of Anatomy, Government Medical College, Srinagar, Jammu and Kashmir, India.

Abstract

Background: The sacral hiatus (SH) shows considerable variation in morphology and morphometry, which is of direct importance for procedures such as caudal epidural anesthesia. Detailed knowledge of its dimensions and apex level is crucial for improving clinical safety and efficacy. **Material and Methods:** A retrospective cross-sectional study was conducted on 420 Computed Tomographic (CT) scans of the lumbosacral spine. Morphological classification of the SH was performed, and length, width, and depth were measured. Sex-specific differences were evaluated, and the level of the SH apex was recorded. Correlation of morphometry with apex level was statistically assessed. **Results:** The inverted U-shape was the most common morphology (61.9%), followed by inverted V (26.2%), irregular (9.5%), and bilobed (2.4%). Morphometric dimensions varied with shape: the greatest length was observed in the bilobed type (28.40 ± 4.10 mm) and the least in the inverted V type (23.80 ± 5.20 mm). The widest hiatus was found in the irregular type (18.60 ± 2.20 mm) and the narrowest in the bilobed type (15.20 ± 2.60 mm). The greatest depth occurred in the bilobed type (4.10 ± 0.80 mm) and the least in the inverted V type (3.60 ± 0.70 mm). Sexual dimorphism was observed: males had significantly greater length (26.90 ± 7.00 mm vs. 24.30 ± 6.40 mm, $p < 0.001$) and width (17.20 ± 2.60 mm vs. 16.60 ± 2.80 mm, $p = 0.024$) compared to females, while depth showed no significant difference (M: 3.88 ± 0.92 mm, F: 3.95 ± 0.85 mm, $p = 0.424$). The apex of the sacral hiatus was most frequently located at S4 (76.1%), followed by S3 (19.9%), S5 (2.25%), and S2 (1.75%). No significant correlation was observed between apex level and morphometric dimensions. **Conclusion:** The sacral hiatus demonstrates considerable variation in morphology and dimensions, with males showing greater length and width than females. The apex was most commonly located at S4, but its level did not influence morphometry. These findings enhance anatomical understanding and may improve the precision and safety of caudal epidural anesthesia.

Keywords: Sacral hiatus, Morphology, Morphometry, CT scan, Retrospective study, Apex level, Sexual dimorphism, Caudal epidural anesthesia, Clinical anatomy.

Received: 20 March 2025 **Revised: 22 June 2025** **Accepted: 20 August 2025** **Published: 06 September 2025**

Introduction

The sacrum, a large triangular bone formed by the fusion of five sacral vertebrae, constitutes a key structural component of the vertebral column and pelvis. Its posterior surface is marked by the sacral hiatus, a variable anatomical feature resulting from the incomplete fusion of the laminae of the fifth (and occasionally the fourth) sacral vertebra.[1] The sacral hiatus serves as the terminal opening of the sacral canal and provides access to the sacral and lumbar epidural spaces. Because of its clinical relevance, particularly in the administration of caudal epidural anaesthesia (CEA), the morphology of the sacral hiatus has been extensively studied but continues to reveal significant anatomical variability across populations.[2] Caudal epidural anaesthesia is a well-established technique widely employed in clinical practice for providing perioperative analgesia, obstetric pain relief, and chronic pain management. The procedure requires accurate localization of the sacral hiatus to ensure safe and effective administration of anaesthetic agents.[3] Despite its routine use, the success rate of CEA is not absolute, with reported failure rates ranging from 5% to 25%, largely attributable to anatomical variations in the sacral hiatus, such as differences in its shape, size, apex location, or depth.[4-7] These variations may obscure or hinder needle placement, leading to technical difficulties, procedural failures, or complications such as dural puncture, intravascular injection, and inadequate analgesia.

From a clinical perspective, understanding the morphometric parameters of the sacral hiatus including its length, width, anteroposterior diameter, and shape has a direct impact on

Address for correspondence: Dr. Ghulam Mohammad Bhat, Professor, Department of Anatomy, Government Medical College, Srinagar, Jammu and Kashmir, India.
E-mail: gmbhat144@gmail.com

DOI:
10.21276/amit.2025.v12.i3.37

How to cite this article: Majeed I, Bhat GM, Afzal S. Computed Tomographic (CT) Based Morphological and Morphometric Variations of the Sacral Hiatus and its Clinical Implications in Caudal Epidural Anaesthesia. Acta Med Int. 2025;12(3):67-72.

improving procedural safety and success. Traditionally, cadaveric studies have provided foundational knowledge on sacral hiatus morphology; however, with advances in imaging, radiological techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) now offer a non-invasive and highly precise means of studying these anatomical features in vivo.[8,9] Radiological assessments not only corroborate findings from morphometric studies but also allow clinicians to appreciate population-specific variations that may influence clinical practice. Previous studies have demonstrated notable ethnic, racial, and sex-related differences in sacral hiatus morphology, emphasizing the importance of region-specific data for guiding clinicians.[3,10,11] In many cases, the standard anatomical descriptions in classical texts may not reflect the actual variations encountered in daily practice. Thus, a detailed morphometric and radiological evaluation of the sacral hiatus in a defined population becomes crucial, both for enhancing anatomical knowledge and for optimizing the efficacy and safety of caudal epidural anaesthesia. In this context, the present study aims to perform a comprehensive morphometric and radiological analysis of the sacral hiatus in adult human sacra and to highlight its clinical implications in caudal epidural anaesthesia. By correlating anatomical and imaging data, this study intends to provide valuable insights for anatomists, radiologists, and anaesthesiologists, ultimately contributing to improved procedural outcomes and patient safety.

Materials and Methods

The present study was a retrospective observational analysis conducted in the Department of Anatomy in collaboration with the Department of Radiology, Government Medical College, Srinagar. High-resolution computed tomography (CT) scans of the lumbosacral spine were retrieved from the departmental imaging database. Ethical approval was obtained from the Institutional Ethics Committee prior to the commencement of the study.

CT scans of adult patients aged 18 years and above, who had undergone lumbosacral spine imaging for various clinical indications, were screened. Only those scans demonstrating optimal alignment and free from congenital spinal deformities, traumatic injuries involving the sacrum, or previous spinal surgeries were included. Patients with incomplete imaging data or poor-quality scans were excluded. Based on these criteria, a total of 420 CT scans were selected, comprising 235 males and 185 females, with ages ranging from 18 to 84 years. The scans were further classified into groups according to gender for comparative analysis. All CT scans had been performed with patients in the supine position. The scan protocol included a topogram oriented parallel to the lumbosacral spine, a tube voltage of 120 kV, a tube current of 100–140 mA, craniocaudal scan direction, field of view of 220 × 180 mm, slice thickness of 0.75–1.0 mm, pitch of 1.0, and scan time of 5.0 seconds. Multiplanar reconstruction (MPR) in axial, sagittal, and coronal planes was carried out to enable detailed morphometric and morphological assessment of the sacral hiatus. All scans were analyzed using Syngovia imaging software (Siemens Healthcare, Erlangen, Germany). Measurements were taken by a single radiologist with more than 10 years of expertise in musculoskeletal imaging. Each parameter was measured twice, and the mean of the two values was considered for analysis to reduce intra-observer variability. Discrepancies, if present, were re-evaluated to ensure accuracy.

The morphological parameters studied included the shape of the sacral hiatus, which was classified as inverted U, inverted V, irregular, dumbbell-shaped, or bilobed, and the vertebral level of its apex. The morphometric parameters included the height or length of the sacral hiatus, measured on coronal reconstructions from the apex to the midpoint of the base; the width, measured as the horizontal intercornual distance between the inner edges of the sacral cornua at the base of the hiatus; and the depth, defined as the anteroposterior diameter, measured on sagittal images at the level of the apex of the hiatus.

Statistical Analysis: All collected data were compiled and entered into Microsoft Excel and subsequently analyzed using the Statistical Package for the Social Sciences (SPSS, version 20; IBM Corp., Armonk, NY, USA). Descriptive statistics were applied to summarize the morphometric parameters of the sacral hiatus, including mean, standard deviation, minimum, and maximum values. Categorical variables such as the shape of the sacral hiatus and the vertebral level of its apex were expressed as frequencies. Comparative analysis between male and female groups was performed using the independent sample t-test for continuous variables. A p-value of less than 0.05 was considered statistically significant.

Results

Figure 1: MRI of the Scral Region showing Sacral hiatus- circle (A) and arrows (B)

In the present study, a total of 420 CT scans were analyzed for morphological and morphometric variations of the sacral hiatus. The inverted U-shaped hiatus was the most common, observed in 260 cases (61.9%), followed by the inverted V type in 110 cases (26.2%), the irregular type in 40 cases (9.5%), and the bilobed type in 10 cases (2.4%). The mean length of the sacral hiatus was greatest in the bilobed type (28.40 ± 4.10 mm), while the inverted V type showed the smallest mean length (23.80 ± 5.20 mm). The inverted U and irregular types demonstrated intermediate values, with mean lengths of 26.10 ± 6.50 mm and 24.60 ± 4.30 mm, respectively. The mean width of the hiatus varied among the different morphological types. The irregular type showed the maximum mean width (18.60 ± 2.20 mm), followed by the inverted U (17.40 ± 2.80 mm) and inverted V (16.10 ± 2.40 mm) types, while the bilobed type displayed the least mean width (15.20 ± 2.60 mm). With respect to depth, values ranged between 3.60 ± 0.70 mm and 4.10 ± 0.80 mm. The bilobed type demonstrated the greatest depth (4.10 ± 0.80 mm), closely followed by the irregular (4.00 ± 0.85 mm) and inverted U (3.90 ± 0.90 mm) types, whereas the inverted V type exhibited the lowest mean depth (3.60 ± 0.70 mm) (table 1). Evidently, the inverted U type was the most prevalent morphological pattern, and although the bilobed hiatus was rare, it tended to exhibit comparatively greater length and depth than the other shapes.

Table 1: Distribution of various shapes of the sacral hiatus and their morphometric dimensions

Parameter [mm]	Shape of the hiatus	Number of cases	Value (Mean ± SD)
Length	Bilobed	10	28.40 ± 4.10
	Inverted U	260	26.10 ± 6.50
	Inverted V	110	23.80 ± 5.20
	Irregular	40	24.60 ± 4.30
Width	Bilobed	10	15.20 ± 2.60
	Inverted U	260	17.40 ± 2.80
	Inverted V	110	16.10 ± 2.40
	Irregular	40	18.60 ± 2.20
Depth	Bilobed	10	4.10 ± 0.80
	Inverted U	260	3.90 ± 0.90
	Inverted V	110	3.60 ± 0.70
	Irregular	40	4.00 ± 0.85

[Table 2] presents the sex-stratified morphometric data of the sacral hiatus. The mean length of the sacral hiatus was significantly greater in males (26.90 ± 7.00 mm; range 9.50–52.00 mm) compared to females (24.30 ± 6.40 mm; range 12.00–44.50 mm) with a p-value of <0.001. Similarly, the mean width was also higher in males (17.20 ± 2.60 mm; range 12.00–24.00 mm) than in females (16.60 ± 2.80 mm; range 11.00–22.50 mm), and this difference was statistically significant (p=0.024). In contrast, the mean depth showed no significant sex difference, being 3.88 ± 0.92 mm (range 2.00–6.20 mm) in males and 3.95 ± 0.85 mm (range 2.20–6.00 mm) in females (p=0.424). The mean age of the study population was 45.60 ± 17.80 years (range 18–84 years) in males and 44.80 ± 16.20 years (range 18–83 years) in females, with no statistically significant difference between the two groups (p=0.634).

Table 2: Sex-stratified morphometric data of sacral hiatus

Parameters	Sex	Numbers	Mean±SD	Minimum	Maximum	p-value
length [mm]	F	185	24.30 ± 6.40	12.00	44.50	<0.001
length [mm]	M	235	26.90 ± 7.00	9.50	52.00	
Width [mm]	F	185	16.60 ± 2.80	11.00	22.50	0.024
Width [mm]	M	235	17.20±2.60	12.00	24.00	
Depth [mm]	F	185	3.95±0.85	2.20	6.00	0.424
Depth [mm]	M	235	3.88±0.92	2.00	6.20	
Age	F	185	44.80±16.20	18.00	83.00	0.634
Age	M	235	45.60±17.80	18.00	84.00	

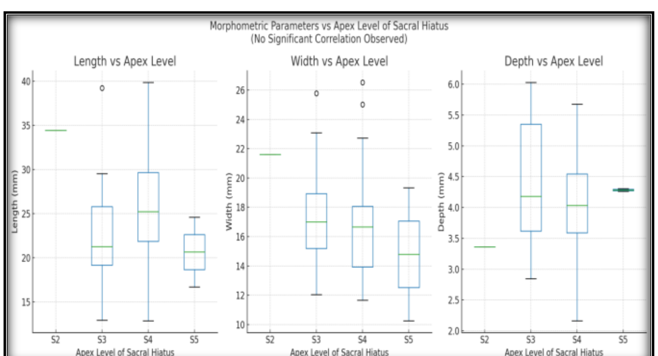

Figure 2: Box plot analysis of sacral hiatus morphometry in relation to the level of the apex

Box plot analysis of sacral hiatus morphometry in relation to the level of the apex demonstrated no significant correlation between the apex level and the measured parameters of length, width, and depth. The apex of the sacral hiatus was most frequently located at the level of the S4 vertebra in 76.1% of cases, followed by the S3 vertebra in 19.9%, the S5 vertebra in 2.25%, and the S2 vertebra in 1.75%. Despite this distribution, the morphometric dimensions remained relatively consistent across different apex levels, indicating that the location of the apex did not influence the length, width, or depth of the sacral hiatus.

Discussion

In the present CT-based evaluation of 420 adult sacra, the inverted U-shaped sacral hiatus was identified as the predominant morphological variant (61.9%), followed by the inverted V (26.2%), irregular (9.5%), and bilobed or bifid forms (2.4%). These findings are consistent with observations from previous anatomical and radiological investigations across diverse populations. For instance, Bagoji et al.[8] reported an inverted U configuration in approximately 42% of cases, inverted V in 26%, and bifid (dumbbell) types in 5%.8 Similarly, Yadav et al. in their cadaveric and radiographic analysis, documented the inverted U type in 52.14%, inverted V in 23.57%, irregular in 7.14%, elongated in 7.14%, and dumbbell-shaped in 8.57% of cases.[2] Patra et al. likewise described the inverted U as the most frequent form (68.83%), followed by the inverted V (20.77%), irregular (9%), and bilobed types (1.2%), which is akin to our study.[3] The predominance of the inverted U morphology across studies likely reflects the typical developmental pattern of incomplete fusion of the posterior sacral laminae, resulting in a broadly open hiatus. Clinically, this morphology offers greater ease of access for caudal epidural procedures. By contrast, the inverted V configuration, although also relatively common, presents a more constricted and tapered aperture that may increase the technical challenge of needle placement. Such anatomical variations therefore hold both morphometric and clinical relevance, particularly in contexts requiring caudal epidural interventions.

In the present study morphometric data were analyzed according to the specific shape of the sacral hiatus. The bilobed (bifid) variant demonstrated the greatest mean length (28.40 ± 4.10 mm), followed by the inverted U (26.10 ± 6.50 mm) and irregular (24.60 ± 4.30 mm) morphologies, whereas the inverted V type exhibited the shortest mean length (23.80 ± 5.20 mm). Shape-specific morphometric analysis is rarely reported in the literature due to the low frequency of bilobed variants; however, Patra et al. documented similar trends. In their series, the bilobed form demonstrated the longest hiatus (46.00 mm in a single case), while the inverted V exhibited the shortest mean length (23.02 ± 5.60 mm).[3] Their corresponding values for the inverted U (26.24 ± 9.77 mm) and irregular (25.05 ± 1.30 mm) morphologies closely approximate our results.[3] Such parallels highlight the reproducibility of morphometric patterns across populations, despite minor differences in absolute measurements. Anatomically, these variations are logical: bilobed hiatuses are generally associated with wider and more extensive laminar non-fusion, resulting in a longer measurable opening, while inverted V shapes correspond to a narrower, tapered defect with inherently shorter dimensions. These distinctions are of clinical importance, as longer hiatuses may facilitate easier identification and access during caudal epidural anesthesia, whereas shorter or atypical morphologies may increase the risk of technical difficulty and procedural failure.

With respect to width, the irregular type exhibited the maximum mean width (18.60 ± 2.20 mm), followed by the inverted U (17.40 ± 2.80 mm) and inverted V (16.10 ± 2.40 mm) variants, while the bilobed type demonstrated the narrowest mean width (15.20 ± 2.60 mm). Shape-wise data on hiatus width are limited, but Patra et al. reported nearly identical patterns: the irregular type measured widest (19.60 ± 0.28 mm), followed by the inverted U (17.00 ± 2.83 mm) and inverted V (16.28 ± 2.61 mm), while the bilobed variant was narrowest (14.60 mm).[3] This concordance underscores a logical anatomical trend: irregular hiatuses, reflecting greater or asymmetric laminar deficiency, yield broader openings; inverted U shapes present as arched but relatively wide apertures; inverted V forms are narrower due to their angular morphology; and bilobed hiatuses, although elongated, tend to be constricted transversely due to their bifid configuration. Clinically, wider hiatuses such as irregular or U-shaped types may permit easier passage of the needle, whereas narrower morphologies, particularly bilobed and inverted V forms, may obscure tactile guidance and increase the risk of failure during caudal approaches.[12,13] In terms of depth, our results also demonstrated shape-specific differences. The bilobed variant had the greatest mean depth (4.10 ± 0.80 mm), followed by the irregular (4.00 ± 0.85 mm) and inverted U (3.90 ± 0.90 mm) types, while the inverted V exhibited the shallowest dimension (3.60 ± 0.70 mm). Patra et al. similarly observed the deepest measurement in the bilobed type (4.50 mm), with the irregular (3.95 ± 1.06 mm) and inverted U (3.90 ± 0.84 mm) shapes showing intermediate values, and the inverted V again being the shallowest (3.42 ± 0.77 mm).[3] The consistency between our results and those of Patra et al. strengthens the validity of these morphometric patterns. Supporting evidence from Aggarwal et al. who studied 114 cadaveric sacra, also highlights the clinical importance of hiatus depth.[14] They reported a wide range of anteroposterior depths (1.90–10.40 mm) and emphasized that a depth less than 3 mm significantly increased the likelihood of technical failure in caudal epidural blocks. The anatomical rationale for these findings is clear.[14] Bilobed and irregular morphologies, due to their broader or discontinuous laminar configuration, provide a more capacious channel and consequently greater depth. Conversely, the inverted V, with its narrow and sharply tapered defect, offers limited depth and a more challenging access route. Clinically, adequate depth facilitates safer and smoother needle passage with reduced risk of resistance or misplacement, while shallow hiatuses (<3 mm) are associated with greater procedural difficulty and potential complications.[14]

In our in vivo CT-based analysis of 420 adult sacra, significant sex-related differences in sacral hiatus dimensions were observed. Specifically, the mean length was notably greater in males (26.90 ± 7.00 mm; range 9.50–52.00 mm) compared to females (24.30 ± 6.40 mm; range 12.00–44.50 mm), with a highly significant difference ($p < 0.001$). These findings are in close agreement with those of Bagoji et al., who reported mean lengths of 27.81 ± 1.17 mm in males and 24.73 ± 2.21 mm in females, thereby confirming a consistent trend of greater sacral hiatus length in males across populations.[8] Similarly, Khan et al. found significantly longer lengths in males (28.3 ± 5.2 mm) compared to females (25.0 ± 4.8 mm; $p = 0.001$), reinforcing the consistent pattern of greater sacral hiatus length in males across populations.[10] In our study, the mean width of the sacral hiatus was significantly greater in males (17.20 ± 2.60 mm; range 12.00–24.00 mm) compared to females (16.60 ± 2.80 mm; range 11.00–22.50 mm; $p = 0.024$). This male predominance is supported by Patra et al., who reported similar findings with males (17.5 ± 2.3 mm) having a wider hiatus than females (16.1 ± 2.9 mm).[3] Conversely, Bagoji et al. documented slightly higher mean values in females (17.92 ± 2.59 mm) than in males (17.56 ± 1.81 mm), while Khan et al. observed distinctly lower widths in both sexes, yet still noted a significantly wider hiatus in males (14.5 ± 3.1 mm) compared to females (11.8 ± 2.8 mm; $p = 0.001$).[8,10] The consistent observation across most studies of a wider sacral hiatus in males than in females may be explained by sex-related differences in pelvic morphology. Males typically exhibit a more robust sacrum with greater bony dimensions, which could contribute to a wider hiatus. Additionally, hormonal influences on bone development and remodeling, as well as population-specific anthropometric variations, may account for the differences reported. The contradictory findings of Bagoji et al. could be attributed to sampling variations, measurement techniques, or regional anatomical diversity in the population studied. In the present study, the mean depth of the sacral hiatus was 3.88 ± 0.92 mm in males and 3.95 ± 0.85 mm in females, with no statistically significant sex difference ($p = 0.424$). These findings are in close agreement with the observations of Patra et al., who reported mean depths of 3.77 ± 0.94 mm in males and 3.83 ± 0.73 mm in females, also without a significant sex-related variation.[3] In contrast, Bagoji et al. reported higher mean values, with anteroposterior diameters at the apex measuring 6.24 ± 2.73 mm in males and 6.63 ± 2.81 mm in females, both markedly greater than those observed in our study.[8] The variation in reported values may be attributed to differences in methodological approaches, particularly in the anatomical landmarks selected for measuring depth. Population-specific skeletal differences, including genetic and anthropometric diversity, may also contribute to the discrepancy between studies. Furthermore, interobserver variability and differences in sample size or demographic profiles could account for the higher depths noted by Bagoji et al. compared to our findings and those of Patra et al.

Our CT-based analysis demonstrated no significant correlation between the vertebral level of the sacral hiatus (SH) apex and its morphometric parameters (length, width, depth), despite the apex being most frequently located at S4 (76.1%), followed by S3 (19.9%), S5 (2.25%), and S2 (1.75%). This distribution lies within the expected anatomical range, indicating that in most individuals the SH can be reliably localized at the S4 vertebra. Such consistency is advantageous for clinicians performing caudal epidural anesthesia (CEA), as the S4 level serves as a predictable landmark for needle insertion, enhancing procedural accuracy and safety. Our findings are strongly concordant with multiple published series both cadaveric and radiologic, which consistently report S4 as the predominant apex level in approximately 60–75% of cases.[3,13,15,16] From a clinical perspective, an apex at S4 provides a safe and accessible entry point, whereas higher locations such as S3 pose greater risk due to proximity to the termination of the dura mater at S2. Sekiguchi et al. even reported rare cases of the apex at S1 (≈1%), highlighting the potential for inadvertent dural puncture if high apices are not recognized.[17] Literature further indicates that while the location of the apex can be variable, the base of the SH demonstrates less variability, leading many authors to suggest that needle insertion be directed toward the base to minimize the impact of apex-level variations.[18] Importantly, our lack of association between apex level and SH morphometrics mirrors the observations of Patra et al. who also found no relationship between apex position and hiatus length, width, or depth in a CT-based cohort with nearly identical apex distribution (S4 ≈ 75%, S3 ≈ 21%, S5 ≈ 2–3%, S2 ≈ 1%).[3] Additional studies in dry sacra and radiologic cohorts Shanmugam et al. and Rathod et al. likewise confirm that although the SH apex is most commonly located at S4, morphometric dimensions vary independently of this vertebral level.[19,20] This reinforces that apex position and SH size metrics are not directly coupled, emphasizing the importance of patient-specific assessment during CEA. The biological plausibility of this dissociation is clear: apex level represents the cranio-caudal termination of posterior sacral laminar fusion, whereas morphometric dimensions (length, width, depth) depend on factors such as intercornual spacing, sacral canal caliber, and local remodeling patterns.[21,22] These processes do not necessarily covary with the vertebral level at which laminae fail to fuse. Furthermore, minor methodological influences, including imaging plane selection, multiplanar reconstruction alignment, and landmarking conventions, may dilute subtle correlations in population-level data. Clinically, these findings carry important implications. While identifying the apex level (commonly at S4) provides a reliable external landmark, it does not predict the ease of needle passage, which depends on hiatus dimensions. Therefore, pre-procedural evaluation through palpation or imaging remains essential to ensure safe and successful caudal access. This individualized approach helps anesthesiologists anticipate anatomical variability, avoid technical failures, and reduce the risk of complications.

Strengths and Limitations

The large sample size and use of high-resolution CT enhance the reliability of our findings. Double measurement reduced intra-observer bias. However, the absence of inter-observer reliability testing is a limitation. Furthermore, the study did not link anatomical findings with actual procedural success or failure, which would provide stronger clinical translation. Finally, as the study population was region-specific, generalization to other ethnic groups should be approached cautiously.

Conclusion

The sacral hiatus demonstrates marked variation in shape and size, with the inverted U-shape being most common and bilobed forms rare but distinctive. Male subjects generally have longer and wider hiatuses than females, while depth remains comparable. The apex most consistently occurs at S4, but its vertebral level is independent of morphometric dimensions.

For clinicians, these findings underline the importance of appreciating sex- and morphology-related differences and relying on individualized anatomical assessment rather than apex level alone. Pre-procedural imaging or careful palpation may improve the safety and accuracy of caudal epidural anesthesia.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Abera Z, Girma A, Bekele A, Oumer M. Assessment of Morphological and Morphometrical Variations of Sacral Hiatus in Dry Human Sacrum in Ethiopia. Local Reg Anesth. 2021;14:25-32.

doi: 10.2147/LRA.S277556. PMID: 33658843; PMCID: PMC7917331.
2. Yadav N, Jasuja VR, Rani M, Srivastava M, Srivastava N, Yadav A. Morphometric Study of Sacral Hiatus in Dry Adult Human Sacra: Its Clinical Relevance in Caudal Epidural Block. Cureus. 2022;14(10):e29910. doi: 10.7759/cureus.29910. PMID: 36348896; PMCID: PMC9632678.
3. Patra A, Kaur H, Chaudhary P, Asghar A, Samagh N, Walocha JA, et al. Morphological and morphometric analysis of the Sacral Hiatus using lumbosacral spine CT scans: clinical relevance in Caudal Epidural Analgesia. Folia Morphol (Warsz). 2024. doi: 10.5603/fm.101363. Epub ahead of print. PMID: 39192699.
4. Dalens B, Hasnaoui A. Caudal anesthesia in pediatric surgery: success rate and adverse effects in 750 consecutive patients. Anesth Analg. 1989;68(2):83-9.
5. Stitz MY, Sommer HM. Accuracy of blind versus fluoroscopically guided caudal epidural injection. Spine (Phila Pa 1976) 1999;24:1371-6.
6. Lewis MP, Thomas P, Wilson LF, Mulholland RC. The 'whoosh' test. A clinical test to confirm correct needle placement in caudal epidural injections. Anaesthesia 1992;47:57-8.
7. Tsui BC, Tarkkila P, Gupta S, Kearney R. Confirmation of caudal needle placement using nerve stimulation. Anesthesiology 1999;9:374-8.
8. Bagoji IB, Bharatha A, Prakash KG, Hadimani GA, Desai V, Bulgoud RS. A morphometric and radiological study of sacral hiatus in human adult sacra and its clinical relevance in caudal epidural anaesthesia. Maedica. 2020;15(4):468.
9. Ruiz Santiago F, Láinez Ramos-Bossini AJ, Wáng YXJ, Martínez Barbero JP, García Espinosa J, Martínez Martínez A. The value of magnetic resonance imaging and computed tomography in the study of spinal disorders. Quant Imaging Med Surg. 2022;12(7):3947-86. doi: 10.21037/qims-2022-04. PMID: 35782254; PMCID: PMC9246762.
10. Khan A, Moeed K, Haris M, Muzadar S, Irshad F, Tanoli AA. Comparative assessment of gender-associated anatomical variations in sacral hiatus: A case-control study. J Popul Ther Clin Pharmacol. 2024;31(9):2086-91. doi:10.53555/fhp7qj02.
11. Nagar SK. Racial and ethnic variations in sacral hiatus morphology. J Anat Soc India. 2016;65(4):120-5
12. Singh ID, Singh LB, Devi AJ. Sacral hiatus: an anatomical study. IOSR J Dent Med Sci. 2017;16(1):35-7. doi:10.9790/0853-1601083537.
13. Shinde V, Bhusaraddi PS. A study of variations of sacral hiatus of dry human sacra in north interior Karnataka region. Natl J Clin Anat. 2014;3(4):215-9. doi:10.4103/2277-4025.297385.
14. Aggarwal A, Aggarwal A, Harjeet, Sahni D. Morphometry of sacral hiatus and its clinical relevance in caudal epidural block. Surg Radiol Anat. 2009;31(10):793-800. doi: 10.1007/s00276-009-0529-4. Epub 2009 Jul 4. PMID: 19578805.
15. Akhtar J, Fatıma N, Ritu KA, Kumar V. A morphometric study of sacral hiatus and its importance in caudal epidural anaesthesia. International Journal of Anatomy. 2016;5(1):6-11.
16. Trinh A, Hashmi SS, Massoud TF. Imaging anatomy of the vertebral canal for trans-sacral hiatus puncture of the lumbar cistern. Clinical Anatomy. 2021;34(3):348-56.
17. Sekiguchi M, Yabuki S, Satoh K, et al. An anatomic study of the sacral hiatus: a basis for successful caudal epidural block. Clin J Pain. 2004;20(1):51–4, doi: 10.1097/00002508-200401000-00010, indexed in Pubmed: 14668657
18. Desai RR, Jadhav S, Doshi M, et al. Variations in anatomical features of the sacral hiatus in Indian dry sacra. Int J Med Res Health Sci. 2014;3(3):634, doi: 10.5958/2319-5886.2014.00409.3
19. Shanmugam S, Puthuraj M. A Morphometrical study of Sacral hiatus and its clinical relevance in successful caudal epidural block. Indian Journal of Basic & Applied Medical Research. 2017;6(4).
20. Rathod DM, Patel SM, Vala M, Patel DS. Morphologic and morphometric analysis of sacral hiatus and its clinical implication in caudal anesthesia. Int J Acad Med Pharm. 2025;7(1):1095-100.
21. Lewis MPN, Thomas P, Wilson LF, et al. The ‘whoosacral hiatus’ test: a clinical test to confirm correct needle placement in caudal epidural injections. Anaesthesia. 1992;47(1):57–8, Pubmed: 1536408
22. Patil SD, Binodkumar JRH, et al. Anatomical study of sacral hiatus for caudal epidural block. Natl J Med Res. 2012;2:272–5.