ORIGINAL ARTICLE CODEN: AAJMBG

An osteological study on morphometry, anatomical variations and applied importance of sacral hiatus and sacral canal in the state of West Bengal

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Received: 17th July 2025; ***Accepted:*** 19th September 2025; ***Published:*** 01st October 2025

Abstract: *Introduction:* Sacral hiatus is the opening present at the posterior aspect of lower end of sacral canal. It is formed due to non-fusion of laminae of fifth sacral vertebrae. Caudal epidural anaesthesia is accessed through sacral hiatus but anatomical variations of sacral hiatus can result in problems. Present study was done to find out the anatomical variations of sacral hiatus which could help anaesthesiologists in the clinical field. *Aim and Objectives:* To study different morphological and morphometric variations of sacral hiatus. *Materials and Methods***:** A cross sectional, observational, osteological study was performed on 100 (final sample size 87) dry, adult, human sacra of West Bengal state. Various parameters were studied like shape of sacral hiatus, level of apex of sacral hiatus, level of base of sacral hiatus, length of sacral hiatus, anteroposterior depth of sacral hiatus, transverse width of sacral hiatus. All measurements were taken using Vernier calipers of 0.2 mm accuracy. *Results:* In the present study most common shape of sacral hiatus was inverted U shape (51.7%). Most frequently occurring level of apex of sacral hiatus was opposite S4 body (46%) and base of sacral hiatus was typically located opposite S5 body (92%). Length of sacral hiatus had a mean of 2.36 cm and standard deviation of 0.93 cm. Mean of anteroposterior diameter of sacral hiatus was 0.65 cm with a standard deviation of 0.22 cm. Transverse diameter of sacral hiatus had a mean of 1.49 cm and standard deviation of 0.30 cm. *Conclusion:* Inverted U shape of sacral hiatus which is most common in our study makes caudal epidural anaesthesia easier. Knowledge of anatomical variations of sacral hiatus improves success rate of caudal epidural anaesthesia and helps in avoiding complications.

Keywords: Sacralhiatus, Sacral canal, Morphometry, Osteological study.

Introduction

The word Sacrum means 'Sacred' in Latin and in English it is the large heavy bone at the base of the spine. The Romans called the bone, "OS Sacrum" and Greeks called it, the "Hieron Osteon" both literally meant- "The holy bone". It was used in sacrificial rites and in protecting the genitalia (considered sacred) in ancient times.

Although the basic meaning of Hieron is holy, it can also alternately mean large, great or magnificent. To conclude, due to its huge size, the sacrum may resist decomposition, more, as compared to other vertebrae. Thus, ancient researchers may have believed that it might serve as the source of resurrection in the afterlife (Stross, 2017)

Sacrum is a large shield shaped bone, formed by fusion of five sacral vertebrae, positioned between lumber and coccygeal segments of the vertebral column. It constitutes the postero- superior wall of pelvic cavity wedged between the two hip bones [1].

Developmentally, fusion of five pieces of sacral vertebrae gets completed by third to early fourth decade of life. The inverted U-shaped opening present at the posterior aspect of caudal end of sacral canal is known as sacral hiatus (SH), which is formed due to the non-fusion of laminae of the fifth (occasionally 4th) sacral vertebra. It is located inferior to the fourth (or third) fused sacral spines or at the lower end of median sacral crest. The sacral hiatus contains lower sacral

and coccygeal nerve roots, filum terminale externa and fibrofatty tissue [1-3]. SH lies about two inches above the tip of coccyx beneath the skin of natal cleft [4].

The hiatus is covered posteriorly by skin, a subcutaneous fatty layer and the sacrococcygeal membrane [5]. Usually the dural sac and subarachnoid space extends up to S2 segment but the dural sac may end as high as the L5 vertebra. Nevertheless, Sacrum is a bone that exhibits unique sex differences and so is used in the identification of skeletal remains imparting great medicolegal significance to it[6]. Caudal Epidural Anesthesia (CEA), introduced in 1900, involves injection of medications into the epidural space through the sacral hiatus to provide analgesia and anesthesia in various clinical settings [7].

The introduction of continuous caudal analgesia in obstetrics by Edwards and Hingson in 1942 has revived the interest of clinicians in the anatomy of Sacrum and its related structures. This interest on the part of clinicians has stimulated anatomists to make a more comprehensive study of the sacral region and to evaluate the occurrence of variations and/ or malformations, in their association with technical difficulties encountered by the anaesthetists, while giving CEA. The sacral canal contains the epidural venous plexus, interspersed with adipose tissues which decreases in density along with advanced age. This change in viscosity of adipose tissue, might be detrimental in the effective spread of local anesthetics administered for caudal anesthesia.

Considerable variability in the anatomy of sacral hiatus exists between stature of individuals and races. The sacral hiatus may be closed, asymmetrically open or widely open. As age advances, the overlying ligaments and the cornua (margins) thicken, making the identification of the hiatal margins more challenging. Anatomical variations in size, shape and orientation of sacral canal pose problems in caudal anesthesia. The large sacral hiatus due to abnormal development, sacral bifida or otherwise will reduce the area for the attachment of extensor muscle at back causing painful conditions [8]. Sacral hiatus with guide wire assistance is an accessible channel for uncomplicated entry into the subarachnoid and basal cisternal space without damaging the surrounding structures [9].

Hence a thorough knowledge of the anatomical features in the dorsal region of sacrum in male and female sex will inevitably lead to the reduction in the caudal epidural block failure rate. The present study is undertaken to clarify the anatomic variations of sacral hiatus for successful conduction of CEA. Search terms used for surfing the literature were as follows-Sacral hiatus, variations of sacral hiatus, anatomical features of sacral hiatus and sacral hiatus and its clinical implications [10].

Aim and Objectives: The aim of present study is to generate a database on different morphological variation and morphometric parameters of sacral hiatus, sacral canal and sacral foramina in the state of West Bengal population which might help anesthetists to improve success rate of caudal epidural anesthesia and also might help clinician to understand various neurological symptoms.

Objectives of the study are:

1. To study the morphometry of sacral hiatus
2. To study the morphometry of sacral canal

Material and Methods

This cross-sectional, observational study was conducted for a period of 6 months from July 2020-December 2020at Diamond Harbor Government Medical College, after getting Institutional Ethical Committee approval vide memo no DHGMC/2020/349/7.

Hundred (100) adult dry, human sacra collected from Department of Anatomy and from first year students of Government Medical Colleges of West Bengal for this study.

Sampling technique: Complete enumeration.

Inclusion criteria: All intact dry adult human sacra are included in the study.

Exclusion criteria: Bones showing wear and tear, fractures, any pathology, total posterior closure defect and agenesis of hiatus will be excluded from this study. After excluding damaged bones, the final sample size came Eighty-Seven (87).

Study tools:

- Vernier calipers of 0.2mm accuracy
- Digital camera

Parameters to be measured: Different parameters of each sacrum have to studied and recorded under the following headings:

1. Segmental composition of sacrum - by naked eye appearance.
2. Shape of sacral hiatus - by naked eye appearance.
3. Level of apex of sacral hiatus to be noted with respect to sacral vertebra.
4. Level of base of sacral hiatus to be noted with respect to sacral vertebra.
5. The length of sacral hiatus to be measured from midpoint of base to apex with the help of vernier calipers.
6. Anteroposterior depth of sacral hiatus at the apex to be measured with the help of vernier calipers.
7. Transverse width of sacral hiatus at the base to be measured between the inner aspects of inferior limit of sacral cornua with the help of vernier calipers.
8. Length of sacral canal measured by estimating the distance between the upper border of S1 and sacral apex.

The diameters were measured by movable external jaws, internal jaws of Vernier Calipers. Length of the sacral canal was measured by depth measuring blades of the Calipers and linear measurement was taken. Digital camera was utilized for taking the pictures for documentation.

Statistical analysis: The present study is a descriptive & cross-sectional study. All parameters measured by using standard methods. The collected data was compiled in Microsoft (MS) Excel and codified for analysis. The data was summarized by estimating the Mean and Standard Deviation (SD) for continuous variables and percentages for categorical variables. Microsoft Excel and SPSS version 25 used for analysis of the data.

Results

Out of Eighty-seven ((87) dried specimen, 83(95.4%) sacrum - composed of five (5) segments. Only 4(4.6%) sacrum - had four (4) segments. Sacralization was present in only 1 specimen (1.1%). In rest 86 (98.9%) of bones sacralization was absent [Table 1].

Table-1: Distribution of sacrum on the basis of sacral segments and sacralisation (N=87)

	Number of bones N=87	Percentage	Total
Number of Sacral segments			**87 (100%)**
1. Five segments	83	95.4	
2. Four segments	4	4.6	
Sacralisation			**87 (100%)**
1. Absent	86	98.9	
2. Present	1	1.1	

The sacral hiatus of each specimen was classified according to shape (Fig 1). The most common shape was inverted U found in 45 bones (51.7%) followed by irregular 18 (20.7%) and dumbbell 14 (16.1%) shapes. Inverted V shape was least common (11.5%) [Table 2].

The level of apex of sacral hiatus varied from S2 to S5. It was as high as opposite S2 body in 1 (1.1%) sacrum and as low as opposite junction of S4 and S5 in 25 (28.7%) specimens. Most common location was opposite S4 body 40 (46%) [Table 2].

Fig-1: Different shape of Sacral Hiatus

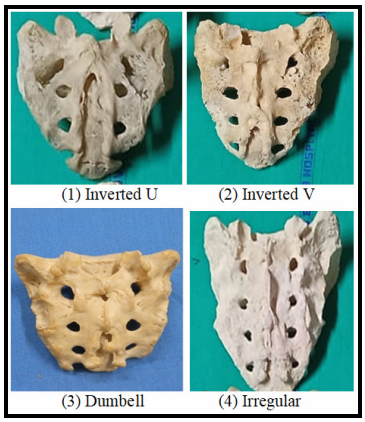

Table-2: Distribution of sacrum in respect to shapeofsacral hiatus, location of apex of sacral hiatus and location of base of sacral hiatus (N=87)			
Sacrum	**No. of bones**	**Percentage**	**Total**
Shapeofsacral hiatus			
1. Inverted V	10	11.5	87 (100%)
2. Inverted U	45	51.7	
3. Irregular	18	20.7	
4. Dumbbell	14	16.1	
Location of apex of sacral hiatus			
1. Opposite S2 body	1	1.1	87 (100%)
2. Opposite S3 body	10	11.5	
3. Opposite junction of S3 &S4	11	12.6	
4. Opposite S4 body	40	46	
5. Opposite the junction of S4 & S5	25	28.7	
Location of base of sacral hiatus			
1. Opposite S4 body	4	4.6	87 (100%)
2. Opposite junction of S4 and S5	3	3.4	
3. Opposite S5 body and below	80	92	
Location of Base Opposite S5 (N=80)			
1. Opposite S5	63	72.4	80 (100%)
2. Opposite lower border of S5	3	3.4	
3. S5-Cx Junction	5	5.7	
4. Opposite Coccygeal body	5	5.7	
5. Till lower end of Coccygeal body	4	4.6	

The level of base of sacral hiatus was commonly located opposite S5 body and below which was found in 80 (92%) sacral specimen**.** In 4 (4.6%) cases the base was located opposite body of S4 vertebra followed by opposite the junction of S4 and S5 in 3 specimens. (3.4%) [Table-2]. Location of base opposite S5 and below, varied from opposite body of S5 to coccygeal body. Most common location was opposite S5 body 63 (72.4%). In rest of the cases, it was located opposite lower border of S5 3(3.4%), S5-Cx junction 5 (5.7%), opposite coccygeal body 5(5.7%) and till lower end of coccygeal body 4 (4.6%) [Table-2].

1. Length of sacral hiatus varied from 0.96 cm to 5.03 cm. Mean 2.36 cm with standard deviation 0.93 cm.
2. AP diameter of sacral hiatus at apex varied from 0.24 cm to 1.71 cm with Mean 0.65 cm and standard deviation 0.22 cm.
3. Transverse diameter of cornu varied from 0.87 cm to 2.57 cm with Mean value 1.49 cm and standard deviation 0.30 cm.
4. Length of sacral canal varied from 1.84 cm to 10.68 cm with Mean value 6.43cm with a standard deviation of 1.34 cm [Table 3]

Table-3: Length of sacralhiatus, antero-posterior diameter of sacral hiatus at apex transverse diameter of cornue length of sacral canal (N=87) [Measurements are in centimetre]					
	N	**Minimum (cm)**	**Maximum (cm)**	**Mean (cm)**	**Std. Deviation (cm)**
Length of Sacral Hiatus	87	0.96	5.03	2.36	0.93
AP Diameter of Sacral Hiatus at apex	86	0.24	1.71	0.65	0.22
TD of Cornue	87	0.87	2.57	1.49	0.30
Length of Sacral Canal	87	1.84	10.68	6.43	1.34

Discussion

Caudal Epidural Block (CEB) and Caudal Epidural Anesthesia (CEA) which are accessed through the sacral hiatus, have a wide range of clinical applications [11]. Epidural space is approached to give analgesia and anesthesia in-treatment of lumbar spine disorders and management of chronic back pain, in obstetrics for painless deliveries, perineal surgeries, colposcopy, orthopedic procedures like treatment of sciatica to give corticosteroid injections, to provide pre and post operative analgesia in adults and children [12].

Nevertheless, because of anatomical variations of sacral hiatus, insertion of a needle in the sacral canal through the sacral hiatus during CEA becomes more challenging. Locating the apex of sacral hiatus also poses problem, because of its variation. Hence precise knowledge of anatomical structure of sacral hiatus is essential for successful clinical procedures [11].

The shape of sacral hiatus is one of the most important landmarks. In the present study inverted "U" shape is the most common type (51.7%), followed by irregular shape (20.7%). This result is to some extent similar with the results of another South Indian study conducted by Yadav et al. who showed inverted "U" (52.1%) shape is the commonest followed by inverted "V" (26.45%) shape [12] [Table 4]. Inverted "U" and inverted "V" shapes provide enough space for inserting the needle into the sacral canal during caudal epidural block without obstacle and considered as normal [11]. The alternate shapes of sacral hiatus like irregular, dumbbell etc. may lead to caudal epidural block failure [13] [Table 4].

In the present study the apex of sacral hiatus is most commonly seen opposite to the body of S4 vertebra (46%), and the results are similar with the observation of S.J. David where it is found to be 51.70% [14] [Table 4]. Awareness of vertebral level of apex of sacral hiatus isdecisive, as higher level may be risky because of closeness to duramater which ends at S2. Consequently, there are increased possibilities of dural puncture if apex of sacral hiatus is situated at S2 or S3 [14] [Table 4].

Base of sacral hiatus is commonly located opposite body of S5 (92%) in the present study. Level of base of sacral hiatus reported by other researchers like Abera et al.(S5-78.7%) [11] and Ukoha et al (S5-88%) also have similar findings [15][Table 4].

During caudal epidural block, needle should be inserted at the base of sacral hiatus to minimize the complications arising from variable levels of apex. The antero-posterior diameter of sacral canal at apex of sacral hiatus is important as it should be sufficiently large to admit a needle [14] [table 4].

Table-4: Comparison between different studies regarding shape, position of apex and base of sacral hiatus

Author and year of study	Country of study population	Number of specimens	Shape of sacral hiatus	Percentage	Position of apex of sacral hiatus	Percentage	Position of base of sacral hiatus	Percentage
Abera et al. 2021 [11]	Ethiopia	61	Bifida Complete bifida Dumbbell Inverted-U Inverted-V Irregular	3.3 1.6 11.5 37.7 41 4.9	S1 S3 S4 S5	3.3 26.2 60.7 9.8	Co1 S5	21.3 78.7
Yadav et al. 2022 [12]	India	140	Inverted –U Inverted-V Irregular Elongated Dumbbell Absent hiatus	52.14 23.57 7.14 7.14 8.57 1.43	N/A	N/A	N/A	N/A

Author and year of study	Country of study population	Number of specimens	Shape of sacral hiatus	Percentage	Position of apex of sacral hiatus	Percentage	Position of base of sacral hiatus	Percentage
Nastoulis et al. 2022 [13]	Greece	155	Inverted-U Inverted-V Irregular Elongated Dumbbell Bifid Pattern-M Complete dorsal wall agenesis Absence of sacral hiatus	34.83 26.45 19.99 2.58 6.45 3.22 1.29 1.93 3.22	S2 S3 S4 S5	1.29 10.96 78.70 9.03	S4 S5 Co1	1.29 89.03 9.67
S.J.David 2019 [14]	South India	61	Elongated Irregular Inverted-U Inverted-V Bifid Dumbbell	33.30 23.30 23.30 13.30 3.30 3.30	S4 S3 S5 S2	51.70 33.30 11.70 3.30	S5 Coccyx	66.70 33.30
Ukoha et al. 2014 [15]	Nigeria	83	Absent Bifid Complete spina bifida Dumbbell Inverted-U Inverted-V Irregular	1.2 4.8 1.2 4.8 48.2 34.9 4.8	None S2 S3 S4 S5	2.4 2.4 20.5 69.9 4.8	None Coccyx S4 S5	2.4 7.2 2.4 88
Bagoji et al. 2020 [17]	South India	138	Inverted-U Inverted-V Dumbbell Irregular Bifid M Absent Agenesis	42.02 26.08 12.31 7.24 5.07 2.17 2.17 2.89	S2 S3 S4 S5 Absent Agenesis	2.89 26.81 58.69 6.52 2.17 2.89	S4 S5 Coccyx Absent Agenesis	18.11 70.28 6.52 2.17 2.89
Malarvani T et al. 2015 [18]	Nepal	100	Inverted -U Inverted-V Dumbbell Bifid Irregular Partial deficient Complete deficient Absent	35 32 3 2 14 0 3 11	S1 S2 S3 S4 S5 Deficient	0 3 42 39 2 14	S3 S4 S5 Co1 Deficient	0 31 54 1 14
Present study 2025	Eastern India	87	Inverted-V Inverted-U Irregular Dumbbell	11.5 51.7 20.7 16.1	S2 S3 S3-S4 Junction S4 S4-S5 Junction	1.1 11.5 12.6 46 28.7	S4-S5 Junction S5 and below S4 Lower border	3.4 92 4.6

The mean of antero-posterior diameter of sacral hiatus at apex is 0.65 cm in the present study which is almost similar to the finding of Mishra et al.-0.624 cm [16] [Table-5]. The mean length of sacral hiatus and mean transverse diameter of sacral hiatus at cornuaare 2.36 cm and 1.49 cm respectively in present study. It is almost similar to the study of Bagoji et al [17] who noted mean length of sacral hiatus and mean width at the base as 2.68 cm and 1.77 cm respectively [Table 5].

Table-5: Comparison of different studies regarding length, transverse width and antero-posterior diameter of sacral hiatus

Author and year of study	Country of study population	Number of specimen	Mean length (in cm)	Mean width (in cm)	Mean antero-posterior diameter (in cm)
Abera et al. 2021 [11]	Ethiopia	61	2.267	1.314	0.557
Yadav et al. 2022 [12]	India	140	Male-2.326 Female-2.238	Male-1.419 Female-1.354	Male-0.457 Female-0.432
Nastoulis et al. 2022 [13]	Greece	155	1.905	1.241	0.539
David SJ 2019 [14]	South India	61	2.86	1.568	0.625
Ukoha et al. 2014 [15]	Nigeria	83	2.005	1.235	0.552
Mishra et al. 2023 [16]	North India	110	2.019	1.339	0.624
Bagoji et al. 2020 [17]	South India	138	2.680	1.770	0.680
Present study 2025	Eastern India	87	2.36	1.49	0.65

Conclusion

Precise knowledge of anatomical variations of sacral hiatus is necessary and it might help to improve both reliability and safety of caudal epidural anesthesia. It will also prevent the iatrogenic injury of dural sac during caudal epidural anesthesia. Present study data will be helpful while performing various procedures.

Limitation of the study: The present study has some limitations such as inability to assess gender variation, didn't include a sample from the pediatric population and the bones studied belonged to Bengalee population - did not include other races. Thus, the results derived cannot be generalized for both genders and for Indian subcontinent.

Acknowledgement

We are thankful to our departmental authority and the students for providing the bones for the study. We also express our gratitude to the donors and their families who have contributed to the science by donating the cadavers [19].

Financial Support and sponsorship: Nil

Conflicts of interest: There are no conflicts of interest.

References

1. Gray H, Standring S. Gray's anatomy: the anatomical basis of clinical practice. 40th Edition. *Edinburgh: Churchill Livingstone-Elsevier.* 2008; 724.
2. Waldman SD. Caudal epidural nerve block: prone position. Atlas of Interventional Pain Management. 4rth Edition. *Philadelphia: Saunders.* 2015; 105:551-563.

3. Ellis H. The sacrum and the caudal block. *Anaesth Intensive Care Med.* 2006; 7:397-398.
4. Newell RL. The Back. In: Standring S, editor. The Anatomical basis of clinical practice. *London: Churchill Livingstone Elsevier.* 2008; 724-728.
5. Sekiguchi M, Yabuki S, Satoh K, Kikuchi S. An Anatomical Study of the Sacral Hiatus: A Basis of Successful Caudal Epidural Block. *Clinical Journal of Pain.* 2004; 20(1):51-54.
6. Mishra SR, Singh PJ, Agrawal AK, Gupta RN. Identification of Sex of Sacrum of Agra Region. *Journal of Anatomical Society of India.* 2003; 52(2):132-136.
7. Edwards WB, Hingson RA. Continuous Caudal Anaesthesia in Obstetrics. *American Journal of Surgery.* 1942; 57:459-464.
8. Brailsford JF. Deformities of lumbosacral region of spine. *Br J Surg.* 1929; 16:562-627.
9. Layer L, Riascos R, Firuzbakht F et al. Subarachnoid and Basal Cistern navigation through the sacral hiatus with guidewire assistance. *Neurol Res.* 2011; 33:633-637.
10. Nagar SK. A study of sacral hiatus in dry humansacra. *J Anat Soc India.* 2004; 53:18-21.
11. Abera Z, Girma A, Bekele A and Oumer M. Assessment of Morphological and Morphometrical Variations of Sacral Hiatus in Dry Human Sacrum in Ethiopia. *Local and Regional Anesthesia.* 2021; 14:25-32.
12. Yadav N, Jasuja V R, Rani M, Srivastava M, Srivastava N and Yadav A. Morphometric Study of Sacral Hiatus in Dry Adult Human Sacra: Its Clinical Relevance in Caudal Epidural Block. *Cureus*. 2022; 14(10):e29910.
13. Nastoulis E, Tsiptsios D, Chloropoulou P, Karapepera V, Thomaidis V, Pavlidis P, Fiska A. Morphological and morphometric features of sacral hiatus and its clinical significance in caudal epidural anaesthesia. *Folia Morphol Warsz).* 2023; 82(3):603-614.
14. David SJ. Morphometric Measurements of Sacral Hiatus in South Indian Dry Human Sacra for Safe Caudal Epidural Block. *International Journal of Anatomy and Research.* 2019; 7(3.3):6911-617.
15. Ukoha U, Okafor J, Anyabolu A, Ndukwe G, Eteudo A and Okwudiba N. Morphometric Study of the Sacral Hiatus in Nigerian Dry Human Sacral Bones. *International Journal of Medical Research and Health Sciences.* 2014; 3(1):115-119.
16. Mishra MN, Srivastava G and Yadav AK. A Morphometric Study of Sacral Hiatus and Its Clinical Relevance in Successful Caudal Epidural Block. *International Journal of Academic Medicine and Pharmacy.* 2023; 5(3):2386-2389.
17. Bagoji IB, Bharatha A, Prakash KG, Hadimani GA, Desai V and Bulgoud RS. A Morphometric and Radiological Study of Sacral Hiatus in Human Adult Sacra and Its Clinical Relevance in Caudal Epidural Anaesthesia. *MEDICA-a Journal of Clinical Medicine*. 2020; 15(4):468-476.
18. Malarvani T, Ganesh E, Nirmala P. Study of Sacral Hiatus in Dry Human Sacra in Nepal. Parsa Region. *International Journal of Anatomy and Research.* 2015; 3(1):848-855.
19. Wanaga J, Singh V, Ohtsuka A, Hwang Y, Kim HJ, Moryś J et al. Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. *Clin Anat.* 2021; 34(1):2-4.

Cite this article as: Pradhan A, Datta P, Mandal S, Choudhury S and Majumdar S. An osteological study on morphometry, anatomical variations and applied importance of sacral hiatus and sacral canal in the state of West Bengal. *Al Ameen J Med Sci* 2025; 18(4): 277-284.

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