International Journal of Research in Medical Sciences
Farhat R et al. Int J Res Med Sci. 2026 Feb;14(2):625-629
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20260252

Original Research Article

A morphometric study of dry adult human sacra and its clinical relevance

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Received: 19 January 2026
Revised: 19 January 2026
Accepted: 20 January 2026

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ABSTRACT

Background: The sacrum shows considerable anatomical variability, particularly in relation to the sacral hiatus and sacral canal. These variations are clinically important, as they may influence the success and safety of procedures such as caudal epidural anaesthesia, spinal interventions and pelvic surgeries. Detailed morphometric data are therefore essential for improving procedural accuracy and reducing complications. The present study aimed to evaluate the morphometric parameters of the sacrum, with special emphasis on the sacral hiatus and its relationship to the second sacral foramen and to assess their clinical significance.
Methods: The descriptive osteological study was conducted on fifty dry adult human sacra of unknown sex obtained from the Department of anatomy, and ESIC Medical College and Hospital, Faridabad, Haryana from May 2023 to December 2023. Measurements recorded included the length and anteroposterior diameter of the sacral hiatus, intercornual distance, the median distance between the lower margin of the S2 foramen and the apex of the sacral hiatus and the distance between the midpoint of the base of the hiatus and the S2 foramen. Data were analysed using descriptive statistics.
Results: Considerable variation was observed in all morphometric parameters, with specific ranges predominating for each measurement. In the present study, the length of the sacral hiatus most commonly ranged between 11–20 mm (44%). The anteroposterior diameter of the sacral canal at the level of the hiatus was predominantly 4–6 mm in 72% of specimens. The intercornual distance at the base of the sacral hiatus most frequently measured between 11–15 mm. Such variations highlight differences in sacral anatomy among individuals.
Conclusions: The study demonstrates significant morphometric variability of the sacrum, which has important clinical implications. Awareness of these variations can aid clinicians in improving the safety and success of caudal epidural anaesthesia and other sacral procedures, while also contributing valuable data for surgical planning and forensic identification.

Keywords: Dry adult human sacra, Epidural anaesthesia, Morphometry, Surgical interventions

INTRODUCTION

The sacrum is a large, triangular bone formed by the fusion of five sacral vertebrae and is situated between the two innominate bones, forming the posterosuperior wall of the pelvic cavity. It articulates superiorly with the fifth lumbar vertebra at the lumbosacral joint and inferiorly with the coccyx.[1] The sacral canal extends throughout the length of the sacrum and opens superiorly at the base.

Inferiorly, it terminates as the sacral hiatus, which results from the failure of fusion of the laminae and spinous

processes of the fourth and/or fifth sacral vertebrae in the midline. Functionally, the sacrum plays a crucial role in maintaining pelvic stability and in transmitting body weight from the vertebral column to the pelvis and lower limbs.[2]

A comprehensive understanding of sacral morphometry is essential for clinicians across multiple specialties, including orthopaedics, neurosurgery, urology, obstetrics and anaesthesiology.[3] Accurate morphometric knowledge facilitates reliable identification of anatomical landmarks, enhances surgical accuracy and helps to minimise complications during procedures such as caudal epidural anaesthesia, iliosacral screw fixation and various pelvic surgeries.[4,5]

Furthermore, morphometric studies of the sacrum are of considerable importance in forensic science, as anatomical variations contribute to human identification. Variations in sacral dimensions, particularly those related to the sacral hiatus, may significantly influence the ease, accuracy and success of needle placement during caudal epidural blocks.[6,7]

The present study aims to assess the morphometry of the sacrum and document its anatomical variations, with the objective of improving clinical outcomes in caudal epidural anaesthesia and other sacral interventions.

METHODS

The present study was a descriptive osteological study, carried out on dry adult human sacra of to assess the morphometric features of the sacrum. A total of fifty dry adult human sacra of unknown sex were examined for a period of eight months (May 2023-December 2023) in the Department of Anatomy, ESIC Medical College and Hospital, Faridabad, Haryana. Only intact sacra with complete fusion of the sacral vertebrae were included, while specimens showing fractures and congenital anomalies were excluded.

Morphometric parameters studied (a) length of the sacral hiatus–measured from the apex to the midpoint of the base; (b) anteroposterior diameter of the sacral hiatus- measured at the level of the hiatus; (c) base of the sacral hiatus (intercornual distance)- measured as the transverse width at the base between the inner aspects of the inferior limits of the sacral cornua; (d) distance between the lower margin of the second sacral foramen and the apex of the sacral hiatus; and (e) distance between the midpoint of the base of the sacral hiatus and the second sacral foramen. All morphometric parameters were measured in millimetres with the help of vernier calliper. Each measurement was recorded carefully and entered into a data sheet for analysis. The collected data were tabulated and the frequency and percentage of each morphometric parameters were calculated. The findings were compared with previous osteological studies to evaluate population-based variations and their clinical significance.

RESULTS

The present study on fifty dry adult human sacra demonstrated notable variations in the morphometric parameters of the sacral hiatus and sacral canal. Differences in length, anteroposterior diameter and intercornual distance were observed among specimens, highlighting the inherent anatomical variability of the sacrum.

Such morphometric knowledge is clinically important, as it aids in accurate identification of sacral landmarks, improves the success of caudal epidural anaesthesia and helps minimise complications during sacral and pelvic procedures.

Length of sacral hiatus

The length of the sacral hiatus, measured from the apex to the midpoint of the base (Figure 1(a)), showed considerable variation among the 50 sacra studied. Most specimens had a length between 11–20 mm (44%), followed by 21–30 mm (26%), while shorter hiatus lengths of 0–10 mm were observed in 14% of cases (Table1).

These variations are clinically significant, as the length of the sacral hiatus influences the ease and accuracy of caudal epidural anaesthesia; extremely short or elongated hiatuses may increase the risk of procedural difficulty or failure.

Anteroposterior diameter of the sacral hiatus

The anteroposterior diameter of the sacral hiatus showed notable variation in the studied sacra. The majority of specimens had a diameter between 4–6 mm, followed by 7–9 mm (Table 2). Clinically, the anteroposterior diameter of the sacral hiatus is a critical factor in caudal epidural anaesthesia, as a narrow hiatus may hinder needle insertion or increase the risk of dural puncture, whereas a wider hiatus may facilitate safer and more effective access to the epidural space.

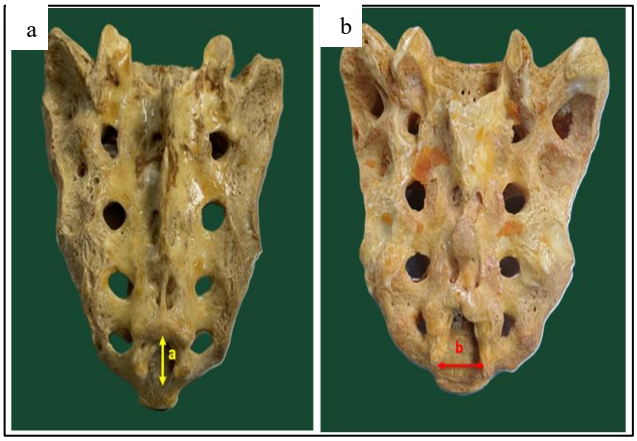

Figure 1 (a, b): Morphometric measurement of sacral hiatus. Length of the sacral hiatus and base of the sacral hiatus (intercornual distance).

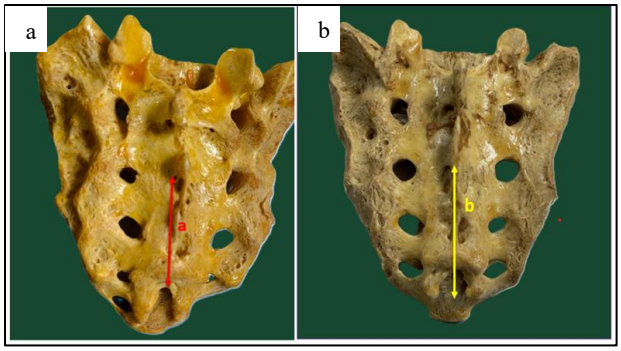

Figure 2 (a and b): Morphometric measurement of sacrum. Distance between the lower margin of the second sacral foramen and the apex of the sacral hiatus. Distance between the midpoint of the base of the sacral hiatus and the second sacral foramen.

Base of sacral hiatus (intercornual distance)

The intercornual distance at the base of the sacral hiatus exhibited considerable variation among the examined sacra (Figure 1 (b)). More than half of the specimens (52%) showed a distance between 11–15 mm, followed by values greater than 15 mm in 26% of cases (Table 3). Clinically, the intercornual distance is an important parameter for identifying the sacral hiatus during caudal epidural anaesthesia. A reduced distance may make localisation difficult and increase the likelihood of failed or traumatic needle insertion, whereas an adequate width facilitates safer and more reliable access to the epidural space.

Distance between lower margin of S2 foramen and apex of sacral hiatus

The distance between the lower margin of the S2 foramen and the apex of the sacral hiatus showed marked variation (Fig 2a). Most sacra demonstrated a distance of 21–30 mm, while shorter distances of 0–10 mm were uncommon (4%) (Table 4).

Distance between midpoint of base of sacral hiatus to the second sacral foramen

The distance between the midpoint of the base of the sacral hiatus and the second sacral foramen showed considerable variation among the studied sacra (Fig2 b). More than half of the specimens (54%) demonstrated a distance greater than 40 mm, while 32% measured between 31–40 mm (Table 5). Clinically, this measurement is of particular importance in caudal epidural anaesthesia, as second sacral foramen indicates the level of termination of the dural sac. A shorter distance increases the risk of inadvertent dural puncture, whereas adequate separation provides a safer zone for needle insertion.

Table 1: Length of sacral hiatus: measured from apex to the midpoint of the base.

S. no.	Length in mm	Number	%
1	0-10	7	14
2	11-20	22	44
3	21-30	13	26
4	31-40	6	12
5	>40	2	4
	Total	50	100

Table 2: Anteroposterior diameter of the sacral hiatus: measured at sacral hiatus.

S. no.	Antero-posterior diameter in mm	Number	%
1	0-3	2	4
2	4-6	36	72
3	7-9	11	22
4	>9	1	2
	Total	50	100

Table 3: Base of sacral hiatus (intercornual distance).

S. no.	Length in mm	Number	%
1	0 – 5	4	8
2	6-10	7	14
3	11-15	26	52
4	>15	13	26
	Total	50	100

Table 4: Distance between the lower margin of S2 foramen and apex of sacral hiatus.

S. no.	Length in mm	Number	%
1	0-10	2	4
2	11-20	9	18
3	21-30	23	46
4	31-40	11	22
5	>40	5	10
	Total	50	100

Table 5: Distance between midpoint of base of sacral hiatus to second sacral foramen.

S. no.	Length in mm	Number	%
1	0-10	0	0
2	11-20	2	4
3	21-30	5	10
4	31-40	16	32
5	>40	27	54
	Total	50	100

Table 6: Comparison between findings of different authors in morphometry of sacrum.

S. no.	Author	Length of sacral hiatus	AP diameter of sacral canal	Width/ intercornual distance
1.	Mayuri et al[8]	11-40 mm with mean of 18.45 mm	1-14 mm with mean of 4.88 mm (4-6 mm in 71%)	–
2.	Kumar et al[9]	20 mm in males, 18.9 in females	–	5-20 (mean-1.3 mm) in males, 8-18 (mean-1.25 mm) in females
3.	Seema Singh et al[10]	11-30 mm in 65%	4-6 mm in 71%	11-15 mm in 52%
4.	Trotter et al and Litterman et al[11]	0-60 mm with mean of 22.5 mm	0-11 mm with mean of 5.3 mm	7-26 mm with mean of 17 mm
5.	Lanier et al[12]	Mean-25.3 mm	Mean-6.1	Mean-19.3
6.	Vasuki et al[13]	11-20 mm in 42% of sacra	0-3 mm in 47% of sacra	11-15 mm in 48% of sacra
7.	Nagar et al[14]	11-20 mm in 35% of sacra	4-6 mm in 64% of sacra	11-15 mm in 54% of sacra
8.	Rani et al[15]	21-30 mm in 46% of sacra	4-6 mm in 75% of sacra	11-15 mm in 56% of sacra
9.	Present study	11-20 mm in 44% of sacra	4-6 mm in 72% of sacra	11-15 mm in 52% of sacra

DISCUSSION

The findings of the present study are broadly consistent with those reported in earlier anatomical investigations of the sacral hiatus. Most studies, including those by Seema Singh et al, Nagar et al, Dipali Rani et al and the present work, demonstrate that a sacral hiatus length of 11–20 mm is the most common range, although wider variations have been reported by Trotter et al, Litterman et al and Lanier et al.[10-12,14,15] Similarly, an anteroposterior diameter of 4–6 mm was the predominant finding across multiple studies indicating a relatively consistent canal depth at the hiatus (Table 6). The intercornual distance in the present study most commonly measured 11–15 mm (52%), closely aligning with several Indian studies, whereas Western studies reported larger mean values, again suggesting ethnic or regional variation. Clinically, these morphometric patterns are highly relevant for caudal epidural anaesthesia, as reduced length, narrow anteroposterior diameter or decreased intercornual distance may lead to difficulty in needle placement, failed block or complications such as dural puncture. Awareness of these variations assists anaesthetists and clinicians in improving the success and safety of caudal epidural procedures.

The findings of the present study regarding the median distance between the lower margin of the S2 foramen and

the apex of the sacral hiatus are comparable with those reported in earlier studies. A distance of 21–30 mm was most frequently observed in the present study (46%), closely corresponding with the observations of Vasuki AKM et al, while Senoglu et al, and Rani et al, reported higher mean values with a wider range.[13,15,16] Similarly, the distance between the midpoint of the base of the sacral hiatus and the S2 foramen was greater than 40 mm in more than half of the specimens in the present study (54%), which is in agreement with the findings of Vasuki et al and Rani et al.[13,15] Awareness of these variations enables anaesthetists to modify needle depth and angulation appropriately, thereby enhancing the safety, accuracy and success rate of caudal epidural blocks.

CONCLUSION

The findings of the present study demonstrate significant variations in the morphometric parameters of the sacrum, particularly those related to the sacral hiatus, sacral canal and their relationship to the second sacral foramen. These variations are of considerable clinical importance, as they directly influence the identification of anatomical landmarks and the depth and direction of needle insertion during caudal epidural anaesthesia. Inaccurate localisation of the sacral hiatus or unrecognised anatomical differences may result in failed blocks, dural puncture or other iatrogenic complications. The present study contributes valuable baseline data on sacral anatomy, which may aid clinicians in pre-procedural planning, reduce operative risks and enhance overall clinical outcomes in sacral and pelvic interventions.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Farhat R, Priyanka. A morphometric study of dry adult human sacra and its clinical relevance. Int J Res Med Sci 2026;14:625-9.