Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v31i2.4614

MORPHOMETRIC STUDY OF SACRAL HIATUS IN ADULT INDIAN HUMAN DRY SACRA AND ITS SIGNIFICANCE IN CAUDAL ANESTHESIA

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Abstract

Introduction: Caudal epidural block (CEB) not achieving the desired outcome or causing complications can occur, even when administered by experienced anesthesiologists. These occurrences are typically attributed to Sacral hiatus (SH) anatomy variances.

Objective: The present study aimed to observe, document and analyze significant anatomical characteristics of SH and establish connections between these features and potential restrictions in the effectiveness of CEB.

Materials and methods: The observational study included the SH of 53 adult dry Indian sacra. The characteristics examined in the study included shape, width, and linear distances. The collected measurements were organized and categorized based on sacral indices. Statistical Package for the Social Sciences (SPSS) software, version 25.0, was employed for the analysis. The mean and standard deviation (SD) were calculated for each measurement. A comparison of the measurement values was conducted using Student's t-test.

Results: The most common types of Sacral hiatus were the inverted V (N= 21), inverted U (N= 29) and dumbbell-shaped (N= 3). In all groups of dry Sacra, the most frequently observed position of the Apex of the SH was at the Sacral 4th vertebral level, while the base of the SH was commonly found at the Sacral 5th vertebral level. Width of SH was 11.8±2.1, 12.5±2.4 mm and 11.6±3.5mm, respectively, with a P-value of 0.1. The mean SH length was 20.3 ±2.4mm in the inverted V shape, 21.5±2.1mm in the inverted U shape and 21.6±2.0mm in dumbbell-shaped SH with a p-value of 0.8. The distance between the S2 foramen and the Apex of the SH was 36.3±6.5, 34.8±5.3mm and 43.0±12.0 mm, respectively, with a P-value of. 0.001. The distance between the apex to the right superolateral Sacral crest was 59.8±10.7, 57.2±11.8 and 55.0±7.5mm, respectively, with a P-value of 0.1.

Conclusions: In adult Indians and other populations, sacrum and SH revealed morphometric differences. Understanding these variances could help caudal epidural anesthesia work better.

Documenting the morphology and morphometry of the Sacral hiatus (SH) will provide valuable information in understanding its role in CEB-related complications.

Keywords: Scaral hiatus, sacral vertebra, apex of sacral hiatus, Scaral foramina

Introduction

Five sacral vertebrae fuse to form the sacrum, a big triangular bone at the lower part of the spinal column [1]. The sacrum has a base, apex, dorsal, pelvic, and lateral surfaces and a sacral canal. [2] It is wedged between the two hip bones. The sacrum's dorsal (posterior) surface has convexity, while the pelvic (anterior) surface is concave. Although the apex is extended downward, the pelvic cavity's size is increased by a posterior tilt. [3] The apex of the sacrum articulates with the coccyx below, while the base of the sacrum articulates with the fifth lumber vertebra above. [4] The lower opening of the sacral canal is known as the sacral hiatus. The sacral canal contains the cauda equina, the sacral and coccygeal nerve roots, the spinal meninges, and the epidural venous plexus. [5] The fifth sacral vertebra and, sporadically, the fourth sacral vertebra's distal portions fail to fuse, resulting in the inverted V-shaped sacral hiatus. [6] Following a subcutaneous fatty layer, the sacrococcygeal membrane, which serves as the roof of the sacral canal, covers the hiatus on the posterior side.

The sacral approach to exploring the epidural region has been widely adopted for various operations, making the Caudal epidural block (CEB) a common technique for surgical anesthetic, pediatric patient analgesia, and adult pain management. During the caudal epidural block, a needle is placed via the sacral hiatus to infuse an anesthetic drug into the epidural space. [7] The SH is situated in the lower portion of the dorsal wall of the sacrum and can be easily felt by palpating an inverted V-shaped triangular cleft just above the sacrococcygeal space. The SH is covered by a fibrous arrangement of entangled fibers, both superficial and deep fibers of the Sacrococcygeal ligament. So, the necessity to find SH and identify anatomical variations is essential for safe and accomplishment of caudal epidural anesthesia. The identification of borders of SH becomes a great challenge and its practical problems related to CEB are recognized because there are many variations in sacral shape and size. [6]

Embryologically, the sacrum is formed by the fusion of the five sacral vertebrae that is complete between the third or early fourth decade of life. Failure of fusion of the fifth, and occasionally the fourth, sacral vertebral laminae creates an opening on the posterior aspect of the lower end of the sacrum, known as sacral hiatus. The remnants of the inferior articular processes of the fifth sacral segment extend downwards on both sides of the sacral hiatus forming the two sacral cornua. These constitute its lateral margins and define important clinical landmarks during caudal epidural anesthesia or block. [6] The SH is recognized by palpation of the sacral cornua and felt at the superior end of the natal cleft just above five cm from the tip of the coccyx. It may also be recognized by making an equilateral triangle based on a line fused between the posterior superior iliac spines; the inferior apex of the triangle is present above the SH. The Sacral cornua are the prominent landmark to identify the sacral hiatus and are easily palpated as it is covered by subcutaneous adipose tissue. [8] Additionally, the sacral hiatus has been used for several medical operations, including treating hernias with endoscopy using a trans-sacral route and minimally invasive spinal surgeries, showing a better success rate and fewer surgical complications. [9] Numerous studies have demonstrated a direct connection between variations of the sacral hiatus with urinary incontinence and lower back pain in some patients, further emphasizing the importance of morphometric research on the sacral hiatus. [10]

Materials and Methods

The objective of the current study was to examine, document, and analyze the anatomical characteristics of the SH within the Indian population. Institutional Review Board cleared the study vide communication: IRB/GMC/ANAT 70, dated: 13-05-2023. This observational study was conducted using 53 dry sacra sourced from the bone bank of the Department of Anatomy, Government Medical College XYZ. Only dry sacra with an intact, undamaged, and visible SH were included in the study, while any bones exhibiting signs of wear and tear were excluded from the analysis**.** The characteristics examined in the study included the shape of the SH, the length of the SH measured from its apex to the midpoint of its base, the width of the base of the SH measured between the inner aspects of the inferior limit of sacral cornua, the linear distance from the apex of the SH perpendicular to a line drawn between the midpoints of the medial margins of the second dorsal sacral foramina, and the linear distance between the apex of the SH and the left superolateral sacral crest. The linear distance between the apex of the SH and the right and left superolateral sacral crests (Figure 1a).

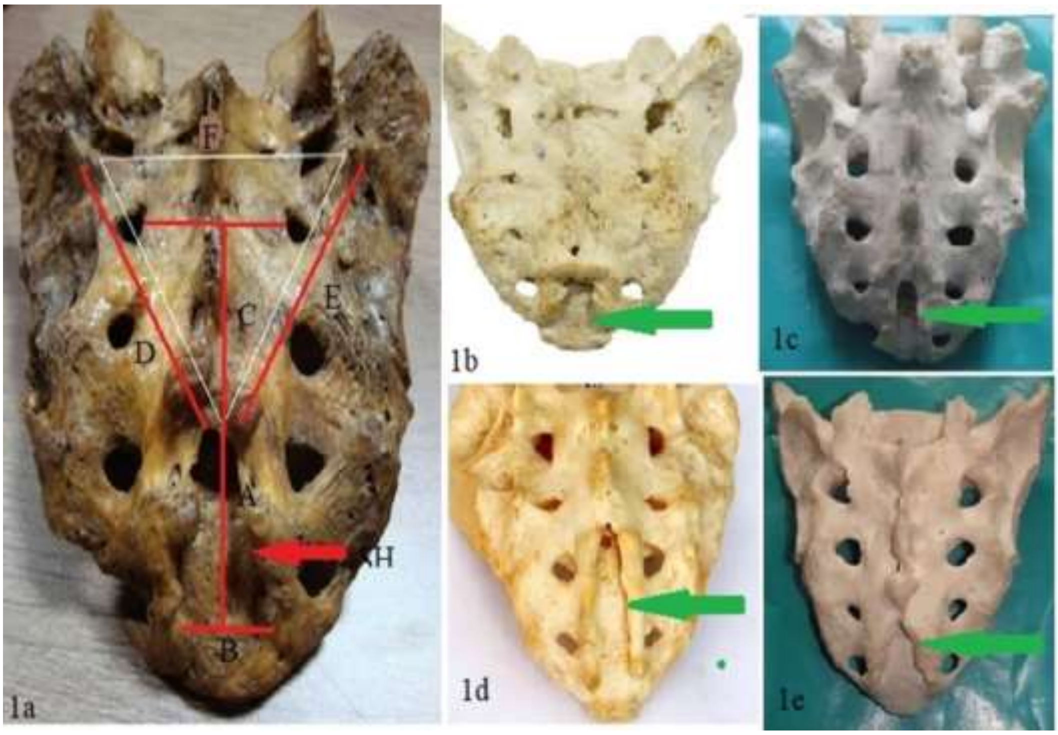

*Figure 1***.** *Posterior surface of sacrum showing morphometric parameters of the sacral hiatus.*
1a: showing measurements of various parameters: A) height of sacral hiatus; B) width of sacral hiatus at the level of sacral cornua; C) linear distance from hiatus apex to the level of S2 foramina; D) Linear distance between the left superolateral sacral crest and sacral hiatus apex; E) distance between the right superolateral sacral crest and sacral hiatus apex; and E) distance between two superolateral sacral crests (base of the triangle).
1b and 1c shows inverted U-shaped Sacral hiatus with apex at the level of S4
1d shows inverted V shape of Sacral Hiatus at the level between S2and S3
1e shows dumbbell shaped Sacral Hiatus with its apex at the level of S3.

Statistical analysis
The collected measurements and their frequencies were organized and categorized based on sacral indices. Statistical Package for the Social Sciences (SPSS) software, version 25.0, was employed for the analysis. The mean and standard deviation (SD) were calculated for each measurement. A comparison of the measurement values was conducted using Student's t-test.

Results
Out of the 53 dry sacra studied, the most common shape of SH recorded in the present study was an inverted U shape (N= 29, 54.71%), followed by an inverted V shape (N= 21, 11.13%) and dumbbell shape (N= 3, 1.59%). Table 1 and Figure 1 show the Anatomical measurements & various Parameters of SH in consolidated form.

Table 1: The Anatomical measurements & various Parameters of Sacral Hiatus in

consolidated form

PARAMETERS	INVERTED "V" (N=21) (mm)	INVERTED "U" (N=29) (mm)	DUMBELL SHAPED(N=3) (mm)	P VALUE
Length of Sacral hiatus	20.3 ±2.4	21.5±2.1	21.6±2.0	0.8
The transverse width of the Sacral hiatus	11.8±2.1	12.5±2.4	11.6±3.5	0.1
Apex to second Sacral foramina	36.3±6.5	34.8±5.3	43.0±12.0	0.001
Apex to right superolateral Sacral crest	59.8±10.7	57.2±11.8	55.0±7.5	0.1
Apex to left superolateral Sacral crest	63.3±7.9	63.0±7.6	58.0±7.5	0.05
Left superolateral Sacral crest	61.4±8.6	56.3±8.6	58.3±3.7	0.3
Right superolateral Sacral crest	63.0±8.8	57.5±9.9	56.6±6.	0.8

Table 2 shows the parameters of the inverted U type of SH—width of SH 12.5±2.4mm, mean SH length was 21.5±2.1mm. The distance between the S2 foramen and the Apex of the SH was 34.8±5.3 mm. The distance between the apex to the right superolateral Sacral crest was 57.2±11.8. The distance between the apex and left superolateral sacral crest was 63.0±7.6mm. The linear distance between the left and right superolateral sacral crests were 56.3±8.6 and 57.5±9.9 mm, respectively.

Table 2. Showing the parameters of INVERTED U-shaped SH

Parameter	**N**	**Range**	**Mean**	**Std. deviation**
Length of Sacral hiatus	29	8.00	21.5862	2.11318
width of Sacral hiatus	29	7.00	12.5517	2.41404
Apex to second Sacral foramina	29	21.00	34.8621	5.35673
Apex to right superolateral Sacral crest	29	35.00	57.2069	11.83632
Apex to left superolateral Sacral crest	29	23.00	63.0690	7.69940
Left superolateral Sacral crest	29	32.00	56.3103	8.63177
Right superolateral Sacral crest	29	37.00	57.5517	9.97707
Valid (N)	**29**			

Table 3 shows the parameters of the inverted V type of SH- width of SH 11.8 mm with SD of ±2.1mm. The mean SH length was 20.3 ±2.4. The distance between the S2 foramen and the Apex of the SH was 36.3±6.5. The distance between the apex to right superolateral sacral crest was 59.8±10.7, The distance between the apex to the left superolateral sacral crest was 63.3±7.9mm. The linear distance between the left and right superolateral Sacral crests was 61.4±8.6 and 63.0±8.8mm.

Table 3 showing Inverted V parameters showing

Parameters	**N**	**Range**	**Mean**	**Std. deviation**
Length of Sacral hiatus	21	9.00	20.3810	2.141819
Width of Sacral hiatus	21	8.00	11.8095	2.13586
Apex to second Sacral foramina	21	21.00	36.3333	6.50641
Apex to right superolateral Sacral crest	21	29.00	59.8095	10.73601
Apex to left superolateral Sacral crest	21	27.00	63.38	7.99047
Left superolateral Sacral crest	21	33.00	61.4762	8.67536
Right superolateral Sacral crest	21	35.00	63.0000	8.89382

Valid (N)	**21**			

Table 4 shows the parameters of dumbbell shaped type of SH. Width of SH was11.6±3.5 resp. The mean SH length was 21.6±2.0 in dumbbell-shaped SH. The distance between the S2 foramen and the Apex of the SH was 43.0±12.0. The distance between apex to right superolateral Sacral crest were 55.0±7.5. The distance between the apex to the left superolateral Sacral hiatus was 58.0±7.5 The linear distance between the left and right superolateral Sacral crests were 58.3±3.7 and 56.6±6.1 for dumbbell shaped Sacral hiatus.

Table 4. Showing the parameters of INVERTED V-shaped SH

D	N	Range	Mean	Std. deviation
Length of Sacral hiatus	3	4.00	21.6667	2.08167
width of Sacral hiatus	3	7.00	11.6667	3.51188
Apex to second Sacral foramina	3	24.00	43.0000	12.00000
Apex to right superolateral Sacral crest	3	15.00	55.0000	7.54983
Apex to left superolateral Sacral crest	3	15.00	58.0000	7.54983
Left superolateral Sacral crest	3	7.00	58.3333	3.78594
Right superolateral Sacral crest	3	12.00	56.6667	6.11010
Valid (N)	3			

Discussion

SH is the primary route for CEB; it is crucial to fully comprehend the morphological variances across different demographic groups to improve success rates and reduce the likelihood of complications [4]. In clinical scenarios requiring CEB for various diagnostic and therapeutic operations of the lumbosacral spine, understanding SH anatomy is essential to prevent failure and Dural damage. The SH has various sizes and shapes. The entire Sacral Vertebra's laminae may merge in the middle, eliminating the SH, or they may fail to fuse, leaving the sacral canal's bony dorsal wall incomplete. These two extremes have seen numerous variations in the SH [6]. According to the data presented in the present study, the inverted U and inverted V shapes were the most frequently observed configurations of the SH. These findings are consistent with the conclusions of multiple researchers worldwide, who have also reported the inverted U or inverted V as the most prevalent shapes of the SH. These are therefore regarded as typical and offer sufficient room for needle insertion during CEB. In contrast, alternate SH shapes, like dumbbells, may lead to CEB failure. The variation in the anatomy of the sacral hiatus (SH) can potentially lead to complications in the caudal epidural block (CEB). This is because when the apex of the SH is closer to the dural sac, there is an increased risk of unintentional puncture of the dura, which can contribute to complications during the procedure. In all examined groups of dry sacra, the apex of the sacral hiatus (SH) was most frequently found at the S4 level, while the base of the SH commonly appeared at the S5 level- width of SH 11.8±2.1, 12.5±2.4 and 11.6±3.5, respectively, with a P-value of 0.1. The mean SH length was 20.3 ±2.4 in inverted V, 21.5±2.1 in inverted U, and 21.6±2.0 in dumbbell-shaped SH with a p-value of 0.8.

The distance between the S2 foramen and the Apex of the SH was 36.3±6.5, 34.8±5.3 and 43.0±12.0, respectively, with a p-value of. 0.001. The distance between the apex to the right superolateral sacral crest were 59.8±10.7, 57.2±11.8 and 55.0±7.5, respectively, with a p-value of 0.1. The distance between the apex to the left superolateral sacral crest was 63.3±7.9, 63.0±7.6, and 58.0±7.5, respectively, with a p-value of 0.05. The linear distance between the left and right superolateral sacral crests were 61.4±8.6 and 63.0±8.8 for Inverted V, 56.3±8.6 and 57.5±9.9 for inverted U, 58.3±3.7 and 56.6±6.1 for dumbbell-shaped SH with a p-value of 0.3 and 0.8 respectively.

In the current study, an equilateral triangle was drawn by the linear distances between the SH apex and superolateral sacral crests. Each superolateral sacral crest, the SH apex, and the linear separation between the two superolateral sacral crests were all the same length. The outcomes of Senoglu et al. (2005) [11] and Abd El-Monem et al. (2006) [12] were in agreement with these findings. Lines connecting three depressions on the lower back of the human body—which stood in for the two

posterior superior iliac spines and the SH apex—formed an equilateral triangle that can be seen on the body surface. [12]
The most often used method for identifying the caudal epidural space is based on feeling the "pop" after piercing the sacrococcygeal membrane, following confirming the sacral hiatus by palpating the sacral cornua. Various researchers have reported an estimated 25% failure rate. Even skilled practitioners cannot always identify the caudal epidural space, and anatomical variance may play a role. The sacral hiatus' apex is a crucial bone landmark for the success of CEB, although it can be challenging to palpate, especially in patients who are obese. Therefore, additional significant anatomical landmarks like the sacral triangle produced by the posterior superior iliac spines and the sacral hiatus's apex may be helpful. Our measurements show that this triangle is equilateral. This practical manual will simplify identifying the sacral hiatus and raising the CEB's success rate. Transferring the needle into the sacral hiatus will be challenging if the sacral hiatus cannot be precisely detected. In adult Indian and other populations, the sacrum and SH revealed morphometric differences. Understanding these variances could help caudal epidural anesthesia work better. Identifying a particular bony feature might not aid the location of SH. The equilateral triangle, created by drawing lines from the posterior superior iliac crests to the SH apex, is a useful tool that could help quickly detect SH and improve CEB success rates. To avoid anatomic changes at its apex, inserting a needle into the SH at its base for caudal blocks is advised.
The size of the anteroposterior diameter of the sacral canal at the apex of the sacral hiatus is crucial, as it needs to be adequately wide to accommodate a needle. Different diameters result in the subcutaneous deposition of anesthetic drugs [13]. The anteroposterior diameter of the sacral canal at the apex of the sacral hiatus is essential as it should be sufficiently large to admit a needle. Various diameters lead to the subcutaneous deposition of anesthetic drugs [13]. The local anesthetic will be delivered into the subarachnoid area if a dural puncture happens but is not noticed, resulting in complete spinal anesthesia. [14]
Based on the described mechanism, when the dural sac does not end at the anticipated middle S2 level, which occurs in approximately 1-5% of individuals, it may extend to the S3 level or even lower. In addition, the presence of an incidental Tarlov cyst, which is a cyst containing cerebrospinal fluid (CSF) and communicates with the dural sac, typically found at or below the S3 level, increases the risk of inadvertent intrathecal injection of anesthetic during Caudal epidural block (CEB). About the hiatal apex site, keeping in view the majority of studies, it was mainly related to the S4 vertebral level (78.70%) and less often to the S3 level (10.96%) or S5 level (9.03%). Nadeem (2014) [16] and Malarvani et al. (2015) [17] evaluated dry sacra of Caucasian Germans and Nepalis, respectively; they were the ones to note that hiatal apex is most often at the level of S3 and not S4, vertebra. The hiatal apex is an important landmark during CEB.
Anterior-posterior diameter at the level of the hiatal apex is crucial therapeutically because if it is less than 3.7 mm, it is linked to technical challenges when attempting to use the blind approach to place the needle into the caudal epidural region [18]. However, using ultrasound guiding, the same issues arise when the depth is less than 1.6 mm [19]. Therefore, advancing a 22G needle during CEB in these patients would have been challenging.
The literature indicates that fluoroscopy-guided CEB has significantly raised CEB success rates. However, there are restrictions due to radiation exposure, expense, and unique space needs. In contrast, ultrasound-guided CEB does not encounter these limitations and enables the production of precise images. As a result, the popularity of ultrasound-guided CEB has increased since its introduction in 2003 due to its ability to accurately visualize sacral anatomy and guide needle placement in the caudal space. [20]

As the length of the sacral hiatus increases, the corresponding length of the sacral canal decreases, raising the likelihood of unintended dural puncture during the CEB. In obese individuals, the accumulation of excess fat within the sacral canal further elevates the potential risk of complications during CEB. [21]

However, it can be challenging to palpate in obese persons. It is crucial to accurately identify the Hiatal apex level since doing so ensures absolute safety during CEB. More critically, the likelihood of an unintentional Dural puncture during CEB administration increases the higher the apex is positioned and the closer it is to the Dural sac terminating. [19] The clinician's identification of the landmarks enables the determination of the sacral hiatus, which improves the success of CEB. Numerous writers have noted that structural variations of the sacral hiatus are necessary for caudal epidural anesthesia to be successful and reliable. To avoid anatomic changes at its apex, inserting a needle into the SH at its base for caudal blocks is advised. The needle should not be inserted farther than 5 mm after entering the canal through the SH apex and piercing the sacrococcygeal ligament. Radiographs of the lumbosacral spine can be used to detect the configuration of SH, identify alternative forms, and determine the distance between SH apex and base. [16]

Conclusion

In adult Indians and other populations, SH revealed morphometric differences. Understanding these variances could help caudal epidural anesthesia work better. Identifying a particular bony feature might not aid the location of SH. The equilateral triangle, formed by the lines joining the posterior superior iliac crests and the SH apex, is a useful tool that could help quickly detect SH and improve the success rate of CEB. To accurately determine the contribution of each anatomical variation in causing complications during CEB, conducting clinical investigations involving both anesthesia and radiology measures is recommended. These investigations should has be performed whenever complications arise during anesthesia. This approach will enable the precise calculation of the percentage of complications caused by each specific anatomical variance. Documenting the SH morphology and morphometry will provide valuable information in understanding its role in CEB-related complications.

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