

Morphometric Study of Sacral Hiatus in Adult Dry Human Sacra

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ABSTRACT

Background- The sacral hiatus (SH) which appears as an anatomical opening on the back of the sacrum shows various shapes which affect medical procedures through caudal epidural anesthesia (CEA) and other clinical treatments. Researchers require complete knowledge about its dimensions and structure to achieve better results during their medical operations.

Methods- This descriptive cross-sectional study was conducted on 93 dry human sacra to evaluate the morphology and morphometry of the SH. Measurements included the length, transverse width at the base, anteroposterior diameter at the apex, and the shape of the hiatus. The level of the apex and base of the SH was also recorded in relation to sacral vertebrae, using Vernier calipers with an accuracy of 0.1 mm. Data were analyzed statistically to determine mean values and distribution patterns.

Results- The length of the SH ranged from 10.62 mm to 54.2 mm (mean 20.09 ± 8.43 mm). The transverse width at the base varied between 11.86 mm and 29.43 mm (mean 16.65 ± 3.35 mm). The anteroposterior diameter at the apex ranged from 1 mm to 8 mm (mean 4.73 ± 1.53 mm). The most common shape was the inverted U (47%), followed by inverted V (28%) and irregular forms (14%). The apex was predominantly located at the fourth sacral vertebra (64.52%), and the base at S5 in most cases (77.42%).

Conclusion- The SH exhibits considerable anatomical variability in shape, size, and position, which has significant clinical implications for procedures like CEA. Precise morphological understanding is vital for safe and effective clinical interventions.

Key-words: Anatomical variability, Caudal epidural anesthesia, Morphometry, Sacral hiatus, Sacrum

INTRODUCTION

The sacrum is a triangular bone created by the fusion of five sacral vertebrae. It forms the posterior wall of the pelvic cavity and is critical to the structural and functional integration of the spine and pelvis. It articulates with the iliac bones to produce the sacroiliac joints, which provide stability and weight transmission during movement ^[1]. The sacrum is anatomically diverse, notably in its posterior side, which houses the SH ^[2].

The SH is a well-studied sacral parameter. It is extremely beneficial to anaesthesiologists and surgeons since caudal anaesthesia is provided via this route. Knowing the distance between the SH and the dural sac is clinically important because it prevents inadvertent iatrogenic damage to the dural sac during the caudal epidural block (CEB) treatment ^[3].

The CEB is a widespread technique for surgical anaesthesia, paediatric patient analgesia, and adult pain management since the sacral approach to investigating the epidural area has been widely used for numerous operations. An anaesthetic medication is infused into the epidural area during the CEB by inserting a needle via the SH ^[4]. Palpating an inverted V-shaped triangular cleft directly above the sacrococcygeal gap will reveal the SH, which is located in the lower part of the sacrum's dorsal

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wall. A fibrous network of entangled Sacrococcygeal ligament fibres, both deep and superficial, covers the SH. Finding SH and identifying structural changes is therefore crucial for the successful completion of CEA. 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 [5].

The SH has well-documented morphological variety in shape, size, and position, with frequent shapes including inverted U, inverted V, and irregular forms [6]. These variations are regulated by genetic, developmental, and environmental variables, and they may have an impact on clinical intervention success [7]. The apex and base of the SH, which are normally placed between the fourth and fifth sacral vertebrae, respectively, have significant anatomical variability, confounding localisation [8]. The current study looks at the morphometric and morphological diversity of SH in dry human sacra. The study's goal is to improve anatomical understanding and contribute to better clinical practices, especially in CEA and other sacrum-related procedures, by giving thorough measurements of its shape, size, and positional fluctuations.

MATERIALS AND METHODS

This descriptive cross-sectional study was conducted in the Department of Anatomy to evaluate the morphology and morphometry of the SH. A total of 93 dry, undamaged human sacra of unknown sex were included in the study. The specimens were chosen for their integrity, free of apparent deformities, fractures, or pathological alterations.

Inclusion criteria- The study included well-preserved adult dry human sacra suitable for measurement, specifically those lacking deformities or recent surgical changes.

Exclusion criteria- Sacra with damage or fractures, pediatric, sacra exhibiting congenital anomalies affecting the sacral region and that were fused or incomplete were excluded from the study.

Methodology- To ensure precision, all measurements were taken with Vernier callipers with a 0.1-mm accuracy. The sacra were carefully examined and the following parameters were recorded: the shape of the

SH, the level of the apex and base of the SH in relation to sacral vertebrae, the length of the SH (measured from the midpoint of the base to the apex), the breadth (maximum transverse diameter at the base), and the anteroposterior diameter at the apex of the hiatus. Each sacrum was visually examined to determine whether it was an inverted U, an inverted V, irregular, or M-shaped. The apex and base of the SH were discovered and reported in reference to the sacral vertebrae. Morphometric measurements were taken with the sacrum placed on a stable surface (Fig. 1 a, b & c).

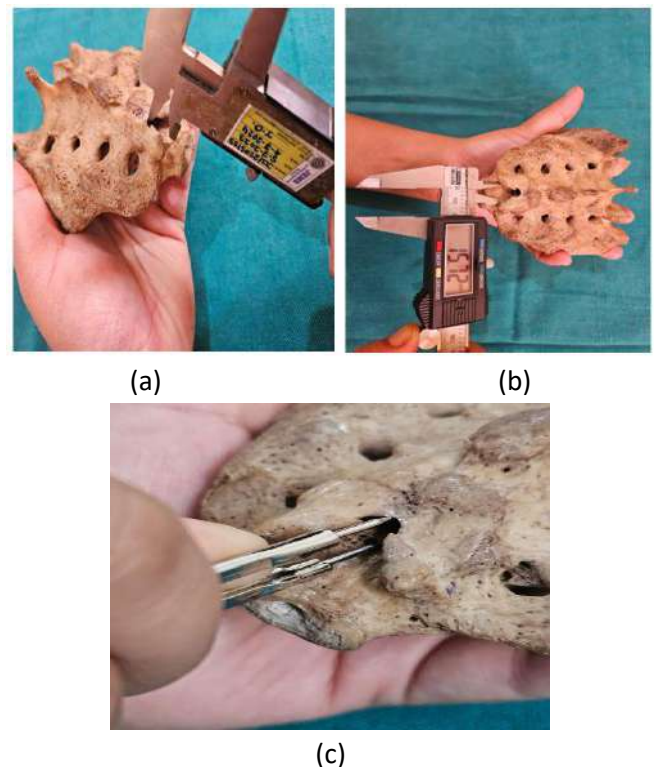


Fig. 1: (a) Height of sacral hiatus; (b) Transverse width of sacral hiatus and (c) Anteroposterior diameter of sacral hiatus.

Statistical analysis- Statistical analysis was carried out by entering data into a spread sheet and analysing it with statistical software such as Microsoft Excel to calculate mean, standard deviation, and range for quantitative variables, as well as frequencies and percentages for qualitative variables.

Ethical approval- The study was done ethically, with authorisation granted by institutional ethics authorities. Because the research utilised preserved anatomical specimens, ethical considerations about living people were not relevant.

RESULTS

The research on sacra revealed that SH lengths ranged between 10.62 mm and 54.2 mm while the average measurement turned out to be 20.09 mm. Most of the sacra, specifically 31 out of 93, had a sacral hiatus length of less than 15 mm, which accounts for approximately 33.33% of the total. The majority of the sacra (about 51.61%) had a sacral hiatus length between 15.1 mm and 30 mm. A smaller group which includes 13.98% of the samples showed lengths between 31.1 mm and 45 mm while a single sacrum sample (1.08%) showed a length of 45.1 mm to 60 mm (Table 1 & 2). The data shows that sacral hiatus lengths usually fall below 30 mm although some cases show longer measurements.

Table 1: Length of SH (from its apex to midpoint of the base)

Length of SH (mm)	No. of sacra (n=93) (%)
≤ 15	31 (33.33)
15.1 – 30	48 (51.61)
31.1 – 45	13 (13.98)
45.1 - 60	1 (1.08)

Table 2: Length of SH (Mean, standard deviation, range)

No. of sacra	Minimum (mm)	Maximum (mm)	Mean±SD
93	10.62	54.2	20.09±8.43

The transverse width of the SH at its base varied from 11.86 mm to 29.43 mm with an average of 16.65 mm. The majority of sacra (about 60.21%) had a width between 15.1 and 20 mm, indicating that this was the most common range. The sacra showed three different width ranges with 29.03% falling between 11 and 15 mm and 7.53% between 20.1 and 25 mm and 3.23% between 25.1 and 30 mm according to Table 3 and 4. Medical professionals need to conduct caudal epidural anesthesia because this study reveals a significant difference in base transverse width measurements for surgical procedures.

Table 3: Transverse width of SH at its base (distance between the inner aspect of sacral cornua).

Transverse width of SH (mm)	No. of sacra (n=93) (%)
11 – 15 mm	27 (29.03)
15.1 – 20 mm	56 (60.21)
20.1 – 25 mm	7 (7.53)
25.1 – 30 mm	3 (3.23)

Table 4: Transverse width of SH (Mean, standard deviation, range)

No. of sacra	Minimum (mm)	Maximum (mm)	Mean±SD
93	11.86	29.43	16.65±3.35

Table 5 and 6 illustrates the distribution of the anteroposterior diameter of the SH at its apex among 93 sacra. The data reveals that 6 sacra which represent 6.45% of the sample demonstrated diameters between 1 and 2 mm which shows an extremely thin passage. The data shows that 34 sacra which form 36.56% of the total had diameters between 3 and 4 mm but 39 sacra which represent 41.94% of the sample showed diameters between 5 and 6 mm. A smaller proportion, 14 sacra (15.05%), had the widest measured diameter of 7-8 mm.

Table 5: Anteroposterior diameter at apex of SH.

Anteroposterior diameter at apex of SH	No. of sacra (n=93) (%)
1-2 mm	6 (6.45)
3-4 mm	34 (36.56)
5-6 mm	39 (41.94)
7-8 mm	14 (15.05)

Table 6: Antero posterior diameter at apex of SH (Mean, standard deviation, range).

No. of sacra	Minimum	Maximum	Mean±SD
93	1	8	4.73±1.53

The distribution of SH shapes across 100 sacra appears in Fig. 2. The inverted U-shaped formed the most common pattern which appeared in 47 sacra (47%) thus showing that this shape occurs in almost half of the sacral hiatuses. The inverted V-shaped was the second most common, accounting for 28 sacra (28%), followed by the M-shaped, and observed in 4 sacra (4%).

Apart from that, 14 sacra (14%) were found to have an irregular hiatus, which may indicate irregularities in the shape or structure of the sacrum; 4 sacra (4%) had a dorsal deficient wall, which may affect the integrity of the sacral canal; and 3 sacra (3%) exhibited agenesis of the sacral hiatus, meaning that they did not have a sacral hiatus at all.

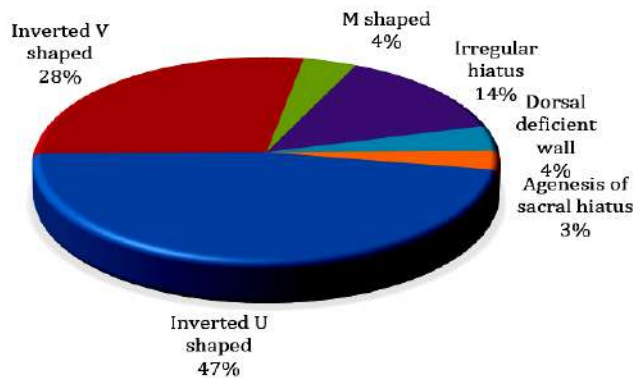


Fig. 2: Frequency distribution of shape of sacral hiatus.

The location of the apex of the sacral hiatus varied from the S2 to S5 vertebrae. The most common location was at the level of the S4 vertebra, observed in 64.52% of cases. The apex was found at the S3 vertebra in 26.88% of cases, making it the second most common position. Only 7.53% of sacra had the apex at the S5 vertebra, and a rare 1.08% at the S2 vertebra (Fig. 3).

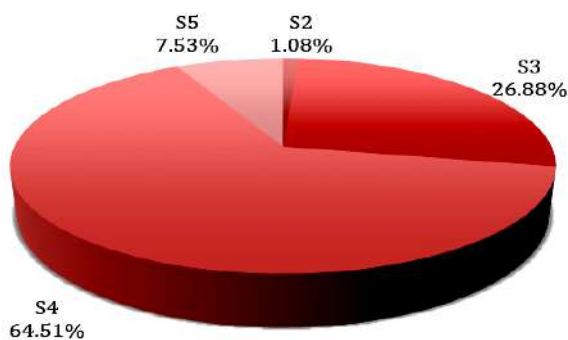


Fig. 3: Frequency distribution of level of apex of sacral hiatus

The study revealed that the location of the base of the sacral hiatus varied across different vertebral levels, with the majority of instances locating the base at the S5 vertebra. In approximately 77.42% of the cases examined (72 sacra), the base of the sacral hiatus was found at S5. Conversely, in about 22.58% of the cases (21 sacra), the base was located at the S4 vertebra (Fig. 4).

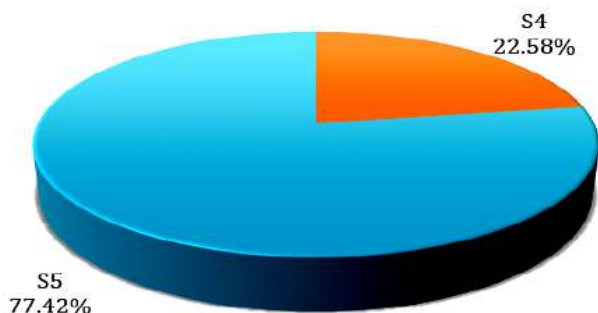


Fig. 4: Frequency distribution of level of base sacral hiatus

DISCUSSION

The present study highlights the significant anatomical variability of the SH and its clinical implications, particularly for caudal CEA. The study of SH length in the present research reveals significant variability, which is consistent with findings from other studies. The current study reports a SH length ranging from 10.62 mm to 54.2 mm, with an average of 20.09 mm, and most sacra (51.61%) having a length between 15.1 mm and 30 mm. This aligns with previous findings which reported a mean length of 21.5 mm in their study of 51 sacra, indicating a similar range and average length of the SH (Nagashree and Gireesh) [9]. Similarly, Singh *et al.* [10] found that the majority of SH lengths fell within the 11-20 mm range, with an average of 18.97 mm, further supporting the prevalence of shorter hiatus lengths. Ghosh *et al.* [11] also observed a wide range of SH lengths, from 9 mm to 103 mm, highlighting the variability in SH dimensions. Furthermore, similar study reported mean lengths of 23.44 mm in males and 20.44 mm in females, which are comparable to the current study's findings (Shewale *et al.*) [12].

The findings regarding the transverse width of the SH, which ranged from 11.86 mm to 29.43 mm with an average of 16.65 mm, align with previous studies. For instance, Yadav *et al.* [13] reported a mean transverse width of 14.19 mm in males and 13.54 mm in females, highlighting similar dimensions but with a slightly lower average compared to the current study. Majeed *et al.* [14] noted that the widest hiatus was found in irregular types, measuring 18.60 mm, which suggests that anatomical variations can significantly influence clinical outcomes. Furthermore, Dhuria *et al.* [15] emphasized the importance of understanding these variations to prevent complications during CEA, as improper identification of the hiatus can lead to adverse effects.

The anatomical diversity of the SH has significant therapeutic implications, particularly for anaesthesiologists who conduct caudal epidural injections. Gandhi *et al.* [16] proposed that a well-defined hiatus with a larger opening allows for easier needle insertion, whereas narrower or irregular hiatuses require additional imaging guidance to avoid procedural failure. Similarly, Kumar *et al.* [17] emphasised that differences in anteroposterior diameter at the apex could have a considerable impact on sacral canal accessibility, making preprocedural evaluation necessary.

In this study SH showed the inverted U shape as the most common type (47%), followed by the inverted V shape (28%). These findings are consistent with prior research, such as that conducted by Patra *et al.* [18], who found similar distribution patterns utilising lumbosacral spine CT scans for anatomical assessment. Similarly, Patil and Rao [19] found that inverted U and V forms were more common in a large sample of dry sacra. Clinicians must be aware of the documented heterogeneity in sacral hiatus shape, since irregular or narrow hiatuses might make caudal epidural block administration challenging.

In this study, the apex of the SH was most commonly found at the 4th sacral vertebra (64.52%), followed by the 3rd sacral vertebra (26.88%). These findings are consistent with those of Chilumu *et al.*, who discovered that a higher placement of the hiatus apex may lower the effective space for needle insertion, affecting the success rate of caudal epidural anaesthesia [20]. Another study by Aggarwal *et al.* found a similar distribution, implying that anatomical heterogeneity in the sacral canal may occasionally lead to procedural failure if not considered during clinical treatments [21].

The present study discovered that the base of the SH was primarily located at the 5th sacral vertebra (77.42%), followed by the 4th sacral vertebra (22.58%). Sekiguchi *et al.* [22] found a similar distribution, noting that a lower base allows for simpler access to the caudal epidural area, whereas a higher base may hinder procedural success.

CONCLUSIONS

The research provides useful information about the changes in the shape, size, and placement of the SH in dried sacrum bones, among other things. A considerable number of the bones tested exhibited shorter hiatuses, with many having inverted U- and V-shaped morphologies. The peak was most typically found at S4, whereas the base was found at S5, demonstrating the importance of anatomical variance in SH. As a result, the findings have a significant impact on aspects such as the effectiveness of CEA and the overall prognosis of sacral surgery. Furthermore, future study should address concerns such as doing assessments utilising ultrasounds and CT scans, examining samples among a wider population, and developing evidence-based guidance for professionals. Moreover, investigating the association

between SH characteristics and demographic parameters such as age, gender, and ethnicity may improve predictive accuracy for anatomical variability, contributing to the safety and efficacy of sacral-related clinical operations. In conclusion, the current study provides a good foundation for improving the accuracy of sacral methods.

CONTRIBUTION OF AUTHORS

Research concept- Dr. Kalpana Laishram

Research design- Dr. Kalpana Laishram

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Materials- Dr. Sneha Sharma

Data collection- Dr. Kalpana Laishram

Data analysis and interpretation- Dr. Kalpana Laishram

Literature search- Dr. Sneha Sharma

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Critical review- Dr. Hana Bashir

Article editing- Dr. Sneha Sharma

Final approval- Dr. Hana Bashir

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