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RESEARCH ARTICLE

Morphometric Analysis of Sacral Hiatus and it's Clinical Relevance

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ABSTRACT

Background: Sacral Hiatus (SH) is an arched shaped gap on the dorsal surface of Sacrum just below the fourth tubercle. It is extensively used by anesthesiologists and Surgeons for Caudal Epidural Block, for therapeutic and diagnostic purposes. The success rate of Caudal Epidural Block depends upon the accuracy of palpation of Sacal Hiatus. It is sometimes difficult to locate it in adults due to various morphological variations. Morphometric measurements of Sacral Hiatus are of prime significance in locating Sacral Hiatus. Therefore, this study is aimed at analysing the various morphometric parameters of Sacral Hiatus to help in reducing the failure rate in Caudal Epidural Block.

Aim: To evaluate the various morphometric parameters of Sacral Hiatus in dry adult human sacrum.

Materials and Methods: This study was conducted on 50 fully ossified dry adult human sacra of unknown sex obtained from Santosh Medical College and Hospital, Ghaziabad. Measurements were taken using a digital Vernier caliper (accuracy 0.01 cm) and a flexible measuring tape. The various morphometric parameters of Sacral Hiatus assessed were: the shape of Sacral Hiatus, location of Apex and Base of Sacral Hiatus, length of Sacral Hiatus, Anteroposterior diameter at apex and transverse diameter at cornua of Sacral Hiatus. Data were analyzed using mean ± standard deviation and range.

Results: The SH apex was most commonly at S4 (60%) and the base at S5 (78%). SH length was 1–2 cm in 82% (mean 1.75 ± 0.66 cm). Anteroposterior diameter at apex measured 0.3–0.6 cm in 68% (mean 0.6 ± 0.15 cm), and transverse diameter at cornua was 1–2 cm in 80% (mean 1.49 ± 0.39 cm). Inverted U shape predominated (48%).

Conclusion: Sacral Hiatus exhibits significant morphological variations which are clinically relevant for Caudal Epidural Block. Understanding these variations and considering them can improve the success rate and minimize the complications.

Keywords: Sacrum, Sacral Hiatus (SH), Morphometry, Caudal Epidural Block.

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INTRODUCTION

The term "Sacrum," meaning holy bone, is derived from the Latin translation of the Greek phrase "hieron ostoun," first mentioned in the Hippocratic collection, particularly in *On the Articulations*.[1] Since antiquity, the sacrum has remained a focus of interest among anatomists, anthropologists, and forensic medicine experts due to its pivotal role in human profiling, including sex determination, age estimation, stature assessment, and ancestry identification.[2] In *Homo sapiens*, evolutionary adaptations such as erect posture and bipedal locomotion led to significant morphological transformations of the pelvis.[3] These changes directly influenced the morphometric characteristics of the sacrum and Sacral Hiatus. Anatomically, the sacrum is a large, triangular, flat bone formed by fusion of vertebrae S1–S5, with a broad superior base (body of S1) and a tapering inferior Apex. [4,5] It has four surfaces—anterior (pelvic), dorsal, and two lateral surfaces. The anterior surface shows four transverse ridges and four pairs of pelvic sacral foramina transmitting sacral nerves.[5] The dorsal surface is convex and irregular, bearing the median sacral crest and spinous tubercles. Inferiorly on the dorsal surface, non-fusion of laminae of S5 (or occasionally S4) forms the sacral hiatus (SH), typically inverted U-shaped and palpable above the coccyx, flanked by sacral cornua—key anatomical landmarks.[6,7]

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Morphological variations in the lumbosacral region are well documented and include neural tube defects such as spina bifida, lumbosacral transitional vertebrae (LSTV), mega-transverse processes, and variations in the width and orientation of the sacral hiatus.[4,8,9] These alterations significantly influence the morphology and dimensions of SH, which holds considerable clinical importance. The sacral hiatus provides access for numerous surgical, anesthetic, neurosurgical, genitourinary, orthopedic, obstetric, pain management, and minimally invasive procedures such as thecaloscopy and trans-sacral endoscopy.[5] The hiatus contains vital structures including the S5 nerve, terminal cord, spinal nerves, and fibro-fatty tissue, making precise anatomical knowledge essential. Morphological variations increase the risk of complications such as dural puncture. Even in experienced hands, approximately 25% of caudal epidural injections are unsuccessful.[10] Reported success rates in adults range between 68–75%, with about 13% of failures attributed specifically to sacral hiatus variations.[11] Factors contributing to failure include impalpable sacral cornua, higher apex location, and reduced anteroposterior diameter.[11] Often, such variations are detected only during failed procedures or incidental imaging. Despite its clinical and forensic importance, there remains a paucity of comprehensive morphometric data on SH variations.[12] Accordingly, the present study aims to address this gap by systematically analyzing Sacral hiatus morphometry, emphasizing its significance for safer and more effective medical and surgical interventions.

MATERIALS AND METHODS

Study Design and Setting: This descriptive morphometric study was conducted in the Department of Anatomy, Santosh Medical College, Ghaziabad using dry adult human sacra obtained from the department of Anatomy.

Study Sample: A total of 50 fully ossified dry adult human sacra of unknown sex were included.

Inclusion Criteria

- Intact dry human sacrum
- Fully ossified adult bones
- Bones without visible pathological deformities

Exclusion Criteria

- Broken or damaged sacra
- Sacra with erosion or wear affecting anatomical landmarks
- Neonatal or juvenile bones
- Sacra showing lumbarization or sacralization

Table: 1

Sr. No.	*Apex of Sacral Hiatus*	*Total number*	*% (Percent)*
A	At level of S3 body	2	4.00 %
B	At level of S3 &S4	10	20.00%
C	Level of S4	30	60.00 %
D	At joint S4 -S5	8	16.00 %

Table: 2

Sr. No.	*Base of Sacral Hiatus*	*Total number*	*% (Percent)*
A	S5	39	78%
B	Intersection of (S4 -S5)	7	14 %
C	Inferior margin (S5)	4	8 %

Table: 3

Sr. No.	*Length of SH (cm)*	*Total number*	*% (Percent)*
A	1 to 2	41	82.00 %
B	>2 to 3	5	10.00 %
C	>3	4	8.00 %

Table: 4

Sr. No.	*Antero-posterior diameter at Apex of SH (cm)*	*Total number*	*% (Percent)*
A	0.1 to 0.3	1	2.00 %
B	>0.3 to 0.6	34	68.00 %
C	>0.6 to 0.9	12	24.00 %
D	>0.9	3	6.00 %

Table: 5

Sr. No.	*Transverse diameter at the level of cornua of SH (cm)*	*Total number*	*% (Percent)*
A	0 to 1	6	12.00 %
B	>1 to 2	40	80.00%
C	>2	4	8.00 %

Instruments and Measurement Technique

Measurements were taken using a digital Vernier calliper (accuracy 0.01 cm) and a flexible steel measuring tape, recorded in centimetres (cm). Each parameter was measured twice to minimize intra-observer error, and the mean of the two readings was used for statistical analysis.

Morphometric Parameters of SH analysed: (Figs 1 and 2)

- Location of apex relative to S3, S4, or S5.
- Location of base of Sacral Hiatus.

Fig 1: shows 1.location of apex , 2. Location of base, 3. length of sacral hiatus, 4. Transverse diameter at cornua, 5. Anteroposterior diameter at apex of Sacral Hiatus

Table: 6

Sr. No.	*Shapes of SH*	*Total number*	*(Percent)*
A	Inverted V	19	38.00 %
B	Inverted U	24	48.00%
C	Irregular	5	10.00%
D	Dumbbell	2	4.00 %

- Length of sacral hiatus (apex to base).
- Anteroposterior diameter at apex of SH.
- Transverse diameter at cornua.
- Shape of SH categorized as inverted U, inverted V, dumbbell and irregular.

Statistical Analysis

Quantitative variables were expressed as mean ± standard deviation and range, qualitative variables as frequencies and percentages. Statistical analysis was performed using SPSS software, and results were presented in tables and graphical formats where appropriate.

Ethical Considerations

The study involved dry adult human bones from the institutional collection; no living subjects were included. Institutional permission was obtained, and formal ethical approval was acquired.

RESULTS

Data collection was performed on 50 desiccated adult human sacra. Morphometric parameters of Sacral Hiatus are measured using vernier caliper and flexible measuring tape. The various parameters were measured and analyzed for calculating average mean, range, and (SD) standard Deviation.

Morphometric parameters of Sacral Hiatus

The morphological assessment of the sacral hiatus revealed consistent patterns regarding vertebral level, dimensions, and shape. The apex was most commonly located opposite S4 in 60% of specimens (Table 1), making it the predominant level. In 20% of cases, the apex was situated at the S3–S4 junction, while only a few sacra showed the apex at S3, indicating that higher placement was relatively uncommon.

The base of the sacral hiatus was most frequently aligned with S5, observed in more than 75% of specimens (Table 2). In 14%, it was located at the S4–S5 junction,

Fig 2: Different shapes of Sacral Hiatus

Table 7: Mean, Standard Deviation and Range for Various Parameters Evaluated in Sacral Hiatus

Sr. No.	*Parameters*	*Mean (cm)*	*Standard deviation (cm)*	*Range (cm)*
1	Length of Sacral Hiatus	1.75	0.66	4.12 – 1
2	Anteroposterior Diameter at Apex of Sacral Hiatus	0.6	0.15	1 – 0.2
3	Transverse Diameter at Cornua level	1.49	0.39	2.46 – 0.6

and in 10%, at the inferior margin of S5. Thus, although S5 was the most common level, minor variations occurred at adjacent vertebral levels.

Regarding length, over 80% of sacra exhibited a hiatus length between 1 and 2 cm, making this the most prevalent category. An additional 10% measured between >2 and <3 cm, and 8% exceeded 3 cm. The mean length was 1.7 cm (±0.66 cm), with a range of 1–4.12 cm, indicating moderate variability with occasional larger values.(Table 3)

The anteroposterior (AP) diameter at the apex ranged between 0.3 and 0.6 cm in 68% of cases, while 24% measured between 0.6 and 0.9 cm (Table 4). Only one specimen showed a value below 0.3 cm. The mean AP diameter was 0.6 cm (±0.15 cm), with a range of 0.2–1 cm, demonstrating limited dispersion.

The transverse distance between the sacral cornua measured between 1 and 2 cm in 80% of specimens. Very few cases were above 2 cm or below 1 cm. The mean transverse diameter was 1.4 cm (±0.39 cm), with a range of 0.6–2.46 cm, showing some variability but central clustering.(Table 5)

In terms of shape (Table 6), Type B was the most common variant (48%), followed by Type A (38%), consistent with previously reported trends. Overall, the sacral hiatus most frequently presented with apex at S4, base at S5, length between 1–2 cm, AP diameter 0.3–0.6 cm, transverse diameter 1–2 cm, and Type B morphology, providing clinically relevant anatomical data.

DISCUSSION

The present study evaluated major morphometric parameters of SH in 50 adult human sacra and compared findings with regional, national, and international literature. For the shape of sacral hiatus (SH), inverted U was predominant (48%), followed by inverted V (38%), Irregular forms (10%) were noted with no M-shaped hiatus. These findings were comparable with Zarana K. Patel[13], Sekiguchi, Senoglu et al.[17], Jadav Mayuri et al.[18], Kumar et al.[14], and Seema et al.[19] and contrasting to the findings of Kumar et al.[14] and Chhabra[15] who reported inverted V shape as the most predominant.The apex most commonly lay at S4 (60%), consistent with Patel[13], Jadav Mayuri[18], and Vinod Kumar[14]; the base corresponded to S5 in 76%, comparable to Patel[13], Seema[19], Nagar S.K.[20], and Vinod Kumar[14]. The inverted U and inverted V-form SH configurations facilitates seamless introduction of the needle in CEB [16]

SH length was 1–2 cm in 82% (mean 1.75 cm; range 1–4.12 cm; SD 0.66 cm), comparable to Jadav Mayuri[18], Nagar S.K.[20], Vinod Kumar[14], and Trotter et al.[21]. The length of sacral Hiatus was 1.1-3 cm in almost two-thirds of sacra in most of the studies.

Location of Apex was predominantly at the level of S4 (60%) in this study supported by similar findings by Zaran K Patel [13], Jadav Mayuri [18], Vinod Kumar [14]. Location of Base of SH for this research is documented at the level of S5 in 76% cases aligning with the findings of Zaran K Patel[13], Seema[19], Nagar S.K.[20], Vinod Kumar[14]. A-P diameter was 0.3–0.6 cm in 68% (mean 0.6 cm; SD 0.15 cm), consistent with Jadav Mayuri[18], Seema[19], Nagar S.K.[20], Patel[13], Vinod Kumar[14], and Trotter[21]. Transverse diameter at the Cornua of SH was 1–2 cm in 80% (mean 1.49 cm; SD 0.39 cm), comparable to Patel[13], Seema[19], Nagar S.K.[20], Vijisha Phalgunan[22], Trotter and Letterman[21], and Kumar et al.[14]. 12% samples in this study were found below the recommended 10 mm safety width.

CONCLUSION

Sacral Hiatus is an important anatomical landmark of clinical significance extensively used for Caudal Epidural Block. Accurate morphometric evaluation of SH is essential for precise landmark identification. Proper needle placement near the base of the SH reduces the chances of failure and complications. The needle should not advance more than 5 mm beyond the sacrococcygeal ligament to avoid dural puncture. An anteroposterior diameter below 0.3 cm or absence of the hiatus increases the risk of CEB failure. Although radiographs and ultrasound- guided approach can help to detect variations, they are costly and not feasible as routine screening tools. This study acknowledges

the significant anatomical variations in SH which is clinically relevant foe anesthesiologist and surgeons in CEB. Therefore, prior to procedure anatomical assessment for any variations is needed to enhance the success rate and prevent minimize the complications.

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