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Original Research Article

MORPHOMETRIC ANALYSIS OF THE SACRAL HIATUS IN INDIANS: ITS CLINICAL IMPORTANCE

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ABSTRACT

Introduction: Sacral hiatus (SH) is a significant landmark during caudal epidural block (CEB) which is employed for analgesia and anaesthesia during a wide range of clinical conditions. This requires a thorough knowledge of morphometric characteristics of SH and surrounding landmarks, but variability in morphometric dimensions exists among different populations.

Aim: The aim of this study was to identify different anatomical landmarks to detect the location of SH and provide a reference database for morphometric dimensions of SH in Indian population.

Materials and Methods: The study was done on 108 dry adult human sacra. Linear measurements of the sacra were taken with the help of digital vernier caliper and angular parameters were determined with a goniometer.

Results: The most common shape of the sacral hiatus was inverted 'V' shaped (59.3%) with the level of the apex at S4 in 66.7% and base at S5 in 86.1% cases. Morphometric dimensions of SH were found to be smaller in present study as compared to reports by other researchers. Left crest-apex angle was observed to be significantly greater than the right crest-apex angle. ($p < 0.001$).

Conclusion: Multiple bony landmarks and their morphometric dimensions should be considered to locate the SH during CEB. Values for various morphometric parameters of SH are less in Indians in comparison to other populations, which should be contemplated during caudal epidural injections and trans-sacral thecaloscopy.

KEY WORDS: Bony landmarks, Morphometric dimensions, Caudal epidural block, Caudal epidural injection, Sacral hiatus

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INTRODUCTION

The sacrum is a large triangular bone formed by union of five vertebrae. It is flanked by the two hip bones and outlines the posterosuperior wall of the pelvic cavity. The dorsal wall of the sacral canal presents an arched sacral hiatus (SH) below the third or fourth spinous tubercle. SH is formed due to failure of fusion of laminae of fifth sacral vertebra which exposes the posterior surface of the body of vertebra [1]. The SH has lower sacral and coccygeal nerve roots, filum terminale externa and fibro-fatty tissue. It is roofed by skin, subcutaneous fat and sacrococcygeal membranes. The lateral boundaries of the hiatus are constituted by two sacral cornua which are the remnants of the inferior articular processes [2].

SH is an important clinical landmark used during caudal epidural block (CEB) for analgesia and anaesthesia during various surgeries. It exhibits significant anatomical variations resulting in differences in the size and shape of hiatus which may cause difficulty in its identification and insertion of needle into the sacral canal. Clinicians experience a constant challenge during identification of SH. Recognition of the surrounding bony landmarks is a crucial step for localization of sacral hiatus and caudal epidural space [3].

The reliability and success of CEB depends upon the comprehensive knowledge of anatomic variations of SH and surrounding bony landmarks [4, 5]. Furthermore, trans-sacral thecaloscopy necessitates a thorough acquaintance of morphometric parameters of SH for the atraumatic usage of flexible endoscopes [6].

Hence, awareness of the morphometric characteristics of SH is vital for management of lower back pain by minimally invasive diagnostic and therapeutic methods.

So far, out of the studies available, few determine the comprehensive morphometry of SH. The purpose of this study is to recognize maximum anatomical landmarks for accurate localization of SH. Furthermore, the present study quantifies morphometric characteristics of the SH in Indians and also enables comparison with other populations. Simultaneously, a variety of morphometric measurements around SH were also considered which are crucial for CEB.

MATERIALS AND METHODS

A cross-sectional observational study was conducted on 108 dry adult human sacra in the department of Anatomy. Sacra showing damage or bony outgrowth were excluded from study. Linear measurements were taken with the help of digital vernier caliper with 0.01 mm precision while angular measurements were recorded with a goniometer. Mean and standard deviation of the morphometric parameters were calculated.

Each sacrum was studied for the following features of the SH:

Non-metric parameters

Shape of hiatus: Different shapes of hiatus were observed (Fig. 1).

Apex of hiatus: Vertebral level of apex of hiatus was noted.

Base of hiatus: Vertebral level of base of hiatus was noted.

Metric parameters (Fig. 2, 3)

Length of SH: It was measured vertically from apex to the base of hiatus.

Width of SH: It was noted as the maximum transverse distance at the level of sacral cornua of the hiatus.

Anteroposterior diameter (APD) of SH at the apex.

Median distance between the superior border of S1 and apex of SH **(MD1)**

Median distance between the level of lower border of second sacral foramina and apex of SH **(MD2)**

Median distance between caudal end of median sacral crest and apex of SH **(MD3)**

Transverse distance between lateral sacral crest (TDC): Measured as the transverse distance between right and left lateral sacral crest at the level of first sacral foramina

Right crest-apex distance (CAD): Measured as the distance between right lateral sacral crest at the level of first sacral foramen and apex of hiatus

Left crest-apex distance (CAD): Measured as the distance between left lateral sacral crest at the level of first sacral foramen and apex of

hiatus

Right crest-apex angle (CAA): Measured as the angle between TDC & right CAD

Left crest-apex angle (CAA): Measured as the angle between TDC and left CAD

Fig. 1: Posterior surface of sacra showing different shapes of SH.

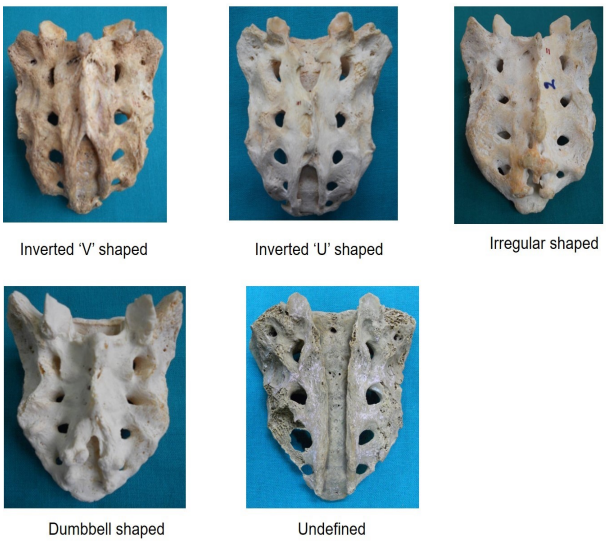
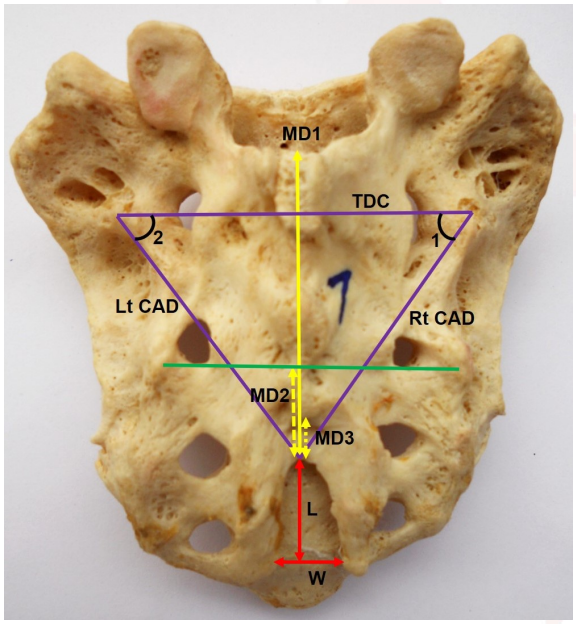
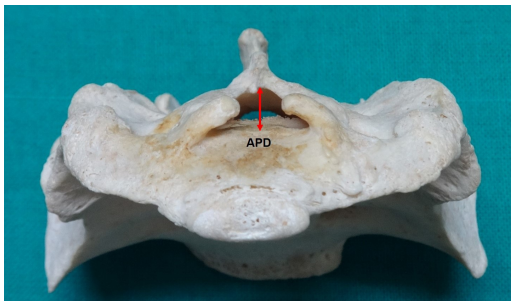


Fig. 2: Posterior surface of sacrum showing morphometric parameters.



L: Length of SH, **W:** Width of SH, **MD1:** Median distance between the superior border of S1 and apex of SH, **MD2:** Median distance between the level of second sacral foramina and apex of SH, **MD3:** Median distance between caudal end of median sacral crest and apex of SH, **TDC:** Transverse distance between right and left lateral sacral crest at the level of first sacral foramina, **Rt CAD:** Distance between right lateral sacral crest and apex of hiatus, **Lt CAD:** Distance between left lateral sacral crest and apex of hiatus, **1:** Angle between TDC & Rt CAD, **2:** Angle between TDC & Lt CAD.

Fig. 3: Inferior view of sacrum showing.



APD: Anteroposterior diameter of SH at the apex.

Statistical Analysis: The mean and standard deviations of the linear and angular parameters were calculated. The comparison of morphometric dimensions of the right and left sides was performed using Student's t-test and p-value was calculated.

RESULTS

A total of 108 sacra were examined and analysed for the above-mentioned parameters in the present study. The most common type of sacral hiatus observed in the present study was inverted 'V' shaped and was seen in 59.3% sacra. The apex of sacral hiatus was commonly noticed at the level of S4 vertebra in 66.7% sacra while the base of sacral hiatus was at S5 level in 86.1% sacra (Table 1-3).

Table 1: Shape of the sacral hiatus.

Shape	Total (n=108)	Percent
Inverted V	64	59.3
Irregular	21	19.4
Inverted U	18	16.7
Dumbbell	3	2.8
Undefined	2	1.8

Table 2: Vertebral level of the apex of sacral hiatus.

Vertebral level	Total (n=108)	Percent
S3	24	22.2
S3-S4 Junction	6	5.6
S4	72	66.7
S5	4	3.7
Undefined	2	1.8

Table 3: Vertebral level of the base of sacral hiatus.

Vertebral level	Total (n=108)	Percent
S4	7	6.5
S4-S5 Junction	6	5.6
S5	93	86.1
Undefined	2	1.8

The mean length of the sacral hiatus was 19.60 ± 7.85 mm. Mean width of the sacral hiatus was 10.74 ± 2.98 mm. Mean anteroposterior diameter (APD) of the sacral canal at the apex of SH was 4.54 ± 0.94 mm. Median distance between superior aperture of sacral canal and apex of SH (MD1) was observed to be 64.57 ± 9.13 mm. Median distance between level of lower margin of second sacral foramina and apex of SH (MD2) was found to be 23.49 ± 7.05 mm while median distance between median sacral crest and apex of SH (MD3) was 11.45 ± 2.69 mm. Mean transverse distance between lateral sacral crest (TDC) was 63.27 ± 4.69 mm. Furthermore, mean crest-apex distance (CAD) was 59.85 ± 6.08 mm and 59.73 ± 6.28 mm on the right and left side respectively. There was no significant difference between the crest-apex distance of the two sides. Ultimately, the right crest-apex angle (CAA) was observed to be 55.36 ± 5.05 degree while left crest-apex angle was 56.82 ± 4.97 degree. Additionally, it was noticed that left CAA was significantly greater than right CAA (p value < 0.001) (Table 4).

Table 4: Morphometric parameters of sacral hiatus.

Parameters	Range (Min-Max)	Mean	Standard Deviation	Significance (p value)
Length (mm)	6.49-52.65	19.6	7.85	-
Width (mm)	3.61-18.6	10.74	2.98	-
APD (mm)	2.20-6.62	4.54	0.94	-
MD1 (mm)	42.43-88.13	64.57	9.13	-
MD2 (mm)	10.83-47.88	23.49	7.05	-
MD3 (mm)	7.64-15.84	11.45	2.69	-
TDC (mm)	56.39-72.02	63.27	4.69	-
Right CAD (mm)	42.62-85.81	59.85	6.08	0.6
Left CAD (mm)	42.6-84.32	59.73	6.28	
Right CAA (degree)	41.25-63.87	55.36	5.05	<0.001
Left CAA (degree)	37.54-66.15	56.82	4.97	

DISCUSSION

CEB necessitates comprehensive anatomical knowledge of SH and adjacent bony landmarks. But variability in its shape and morphometric dimensions exist amongst different populations which may be due to different genetic endowment. Variations in morphometric parameters prevent the standardization of measurements. This has led many researchers to describe the characteristics of the SH and study its morphometric dimensions. In the present study, we have endeavoured to analyse SH morphometry which is vital for successful administration of caudal epidural injections (CEI).

There is wide disparity as to the shape of the SH in different population. Many authors have reported the inverted 'U' shape as the most common variety (Mustafa MS et al. in Egyptian population, Suwanlikhid N et al. in Thai population, Kamal AHMM et al. in Bengali population, Nadeem G in Arab population and Bagheri H et al. in Turkish population); while in the present study inverted 'V' shaped sacral hiatus was the commonest type, similar to findings Njihia BN et al. and Osunwoke EA et al. in African population [7-13] (Table 5). Shape of hiatus is important due to the fact that an irregular shaped hiatus might obstruct the successful administration of caudal epidural injections. However, in inverted 'U' or 'V' shaped hiatus, there would be greater ease of access for CEB.

Table 5: Comparison of hiatus shape between previous & present studies.

Researcher	Population	Most common shape of hiatus	Frequency
Njihia BN et al. [7] [2011]	African	Inverted 'V'	32.10%
Mustafa MS et al. [8] [2012]	Egyptian	Inverted 'U'	26%
Suwanlikhid N et al. [9] [2013]	Thai	Inverted 'U'	54.47%
Kamal AHMM et al. [10] [2014]	Bengali	Inverted 'U'	38%
Nadeem G [11] [2014]	Arab	Inverted 'U'	56%
Osunwoke EA et al. [12] [2014]	African	Inverted 'V'	33.10%
Bagheri H et al. [13] [2017]	Turkish	Inverted 'U'	33.33%
Present study	Indian	Inverted 'V'	59.30%

Table 6: Comparison of level of apex of hiatus between previous & present studies.

Researcher	Population	Range of level of apex of SH	Most common level of apex of SH
Shinohara H [14]	Japanese	S4-S5	S4 (44%)
Sekiguchi M et al. [15] [2004]	Japanese	-	S4 (64%)
Njihia BN et al. [7] [2011]	African	S3-S5	S4 (62.7%)
Mustafa MS et al. [8] [2012]	Egyptian	S2-S5	S4 (70%)
Suwanlikhid N et al. [9] [2013]	Thai	S2-S5	S4 (62.98%)
Kamal AHMM et al. [10] [2014]	Bengali	S2-S5	S4 (60.20%)
Nadeem G [11] [2014]	Arab	S2-S5	S3 (62%)
Osunwoke EA et al. [12] [2014]	African	S2-S5	S4 (66.6%)
Bagheri H et al. [13] [2017]	Turkish	S2-S5	S4 (70.11%)
Present study	Indian	S3-S5	S4 (66.7%)

Different researchers have reported different vertebral levels of apex of SH ranging from S2-S5, S3-S5 and S4-S5 but the most common level of apex of SH was found at S4 [7-10, 12-15]. In the present study, we also observed the most common level of apex of SH at S4 in 66.7% sacra, but Nadeem G found it at S3 (Table 6). Awareness of vertebral level of apex of SH is crucial, as higher level may be hazardous because of close proximity of dura mater which terminate at S2. Hence, there are increased

chances of dural puncture when the apex of SH is located at S2 or S3. Furthermore, the level of apex of SH is extremely significant while deciding length of needle during CEB as lower level of apex requires long needle during CEB [3].

Many researchers noticed the vertebral level of base of SH ranging from S4-Co1 but we observed it ranging S4-S5. However, we found the most common level of base of SH to be at S5 in 86.1% sacra, which was similar to the finding of other investigators (Table 7). The vertebral level of SH apex was observed to be more variable ranging from S2-S5 than its base (S4-Co1) in most studies. Hence during CEB, needle should be inserted at the base of SH to minimize the complications arising from variable levels of apex [8].

Table 7: Comparison of level of base of hiatus between previous & present studies.

Researcher	Population	Range of level of base of SH	Most common level of base of SH
Mustafa MS et al. [8] [2012]	Egyptian	S4-Co1	S5 (91%)
Suwanlikhid N et al. [9] [2013]	Thai	S4-Co1	S5 (76.6%)
Kamal AHMM et al. [10] [2014]	Bengali	S4-Co1	S5 (91.2%)
Nadeem G [11] [2014]	Arab	S4-Co1	S5 (62%)
Osunwoke EA et al. [12] [2014]	African	S4-Co1	S5 (59.3%)
Bagheri H et al. [13] [2017]	Turkish	S4-Co1	S5 (82.76%)
Present study	Indian	S4-S5	S5 (86.1%)

Length and width of SH are crucial morphometric parameters for CEI. Longer and wider SH facilitate the injections in caudal epidural space while shorter and narrower SH may offer hindrance during CEB. Senoglu N et al. reported greater length and width of SH in Turkish population, while in present study in the Indian population, we observed lower values for these parameters in comparison to other population [5, 7, 8, 10, 11]. Sekiguchi M et al also found smaller width of SH (10.2 mm) in Japanese population [15]. Further, the APD of SH at the apex was also observed to be shorter (4.54 mm) in Indians when compared to other populations. Njihia BN et al. reported higher value (6.4 mm) for APD of SH in African population (Table 8). The APD of SH is a vital parameter, as it should be adequate to give access to the needle in caudal epidural space during CEB. Variable dimensions of this parameter may cause subcutaneous or outside deposition of anaesthetic drug [8].

Median distance between superior border of S1 and apex of SH (MD1) is important to locate the SH when other bony landmarks are not defined. We observed the MD1 to be less in Indians (64.57 mm) in comparison to the finding of Senoglu N et al in Turkish population (68.74 mm) (Table 8). Additionally, the median distance between the level of second sacral foramina and apex of SH (MD2) is a vital parameter during CEB, as it determines the length of needle that can be safely passed into the canal after piercing sacrococcygeal membrane. Hence, awareness of this parameter can minimize the risk of puncture of dura mater which usually terminates at S2. The MD2 was noticed to be less in Indians (23.49 mm) when compared to Turkish, Egyptian and African populations (Table 8). It ranged between 10.83 to 47.88 mm in the present study. So, we propose that the needle should not be moved forward more than 10 mm after penetrating sacrococcygeal membrane. Ultimately, the median sacral crest can also be utilised as an alternate bony landmark to detect the location of SH [3].

So, the median distance between caudal end of median sacral crest and apex of SH (MD3) is a significant morphometric parameter to find SH. In comparison to the other Indian studies, we found the MD3 in present study (11.45 mm) to be analogous to the finding of Clarista MQ et al. (11.76 mm) but less than the value reported by Aggarwal A et al. (14.51 mm) [3,16] (Table 9). The apex of the SH is a principal bony landmark for successful CEB, but sometimes it is difficult to palpate, especially in obese patients. Therefore, other important bony landmarks can be utilised, such as the triangle created between the posterior superior iliac spines and the apex of SH. Posterosuperior iliac spine is situated close to lateral sacral crest, so lines joining right and left sacral crests with apex of SH form a triangle which can be utilised to locate the SH [5].

Therefore, transverse distance between lateral sacral crest (TDC), right and left crest-apex distance (CAD) and right and left crest-apex angle (CAA) are crucial parameters for localizing the SH during CEB. Mustafa MS et al. reported greater and almost equal values of TDC, Right and left CAD in Egyptians while we found

Table 8: Comparison of morphometric parameters of SH between previous & present studies.

Parameters	Researchers (Populations)						
	Mustafa [8] (Egyptian)	Kamal [10] (Bengali)	Nadeem [11] (Arab)	Senoglu [5] (Turkish)	Sekiguchi [15] (Japanese)	Njihia [7] (African)	Present study (Indian)
Length (mm)	21	26.02	25.2	32.09	-	-	19.6
Width (mm)	17	17.62	19.5	17.47	10.2	12.6	10.74
APD (mm)	4.8	4.83	5.53	4.46	6	6.4	4.54
MD1 (mm)	-	-	-	68.74	-	-	64.57
MD2 (mm)	41	-	-	35.37	-	43.1	23.49
MD3 (mm)	-	-	-	-	-	-	11.45
TDC (mm)	75.5	-	-	66.51	-	-	63.27
Right CAD (mm)	75	-	-	67.1	-	-	59.85
Left CAD (mm)	75	-	-	67.53	-	-	59.73
Right CAA (degree)	-	-	-	61.89	-	-	55.36
Left CAA (degree)	-	-	-	61.22	-	-	56.82

Table 9: Comparison of parameters of SH with other Indian studies.

Parameters of SH	Researchers					
	Aggarwal [3]	Patil [17]	Clarista [16]	Ramamurthi [18]	Akhtar [19]	Present study
Most common shape	Inverted U	-	Inverted U	Inverted U	Inverted U	Inverted V
Most common level of Apex	S4	-	S4	S4	S4	S4
Most common level of base	S5	-	S5	S5	S5	S5
Length (mm)	18.81	34.13	24.73	29.5	26.92	19.6
Width (mm)	11.95	13.71	16.87	16.2	12.14	10.74
APD (mm)	5.03	4.26	5.58	5	5.39	4.54
MD1 (mm)	-	64.77	-	-	-	64.57
MD2 (mm)	30.16	32.88	32.16	30.2	-	23.49
MD3 (mm)	14.51		11.76		-	11.45
TDC (mm)	50.96	60.61	64.96	69.5	-	63.27
Right CAD (mm)	59.92	61.95	62.64	61.4	-	59.85
Left CAD (mm)	59.99	61.4	62.33	57.4	-	59.73
Right CAA (degree)	-	-	57.26	-	-	55.36
Left CAA (degree)	-	-	58.65	-	-	56.82

lesser dimensions of these parameters in Indians. Furthermore, the equilateral triangle was not formed between these parameters in Indians in contrast to the observations of Mustafa MS et al. and Senoglu N et al. Therefore, equilateral nature of triangle cannot be trusted upon in Indians to determine the location of SH. Ultimately, we observed lesser values of right CAA (55.36 degree) and left CAA (56.82 degree) when compared to the findings of Senoglu N et al. (Right CAA: 61.89 degree; Left CAA: 61.22 degree) (Table 8). So, we suggest that slightly less angulations should be undertaken to locate the SH in Indians. (Table 9) exhibits the comparison of morphometric parameters of SH between different Indian studies and offers a range of each parameter for Indians which should be mulled over while giving caudal epidural injections [3, 16-19].

CONCLUSION

There is wide variability in morphometric characteristics of the SH in different populations. Cognizance of these variable parameters may enhance the success rate of CEB. Single bony landmark may not be suitable for detecting the location of SH. Various morphometric parameters, such as median distances from apex of SH (MD1, MD2, MD3), TDC, right and left CAD and CAA should be utilised for localising SH. In present study in the Indian population, we found the most common shape of the SH to be the inverted 'V' shaped with the level of the apex was at S4 and base at S5. Our study showed the SH to have the least anatomic dimensions in Indians as compared to other populations which should be pondered during caudal epidural injections. We anticipate that our study will be

able to provide reference database of morphometric dimensions in Indians which could be vital for minimally invasive diagnostic and therapeutic procedures at SH.

Present study was done on 108 dry adult human sacra due to limited availability in the institute. We propose further morphometric studies on large number of sacra to provide a reference database in Indian population.

ABBREVIATIONS

APD: Anteroposterior diameter

CAD: Crest-apex distance

CAA: Crest-apex angle

CEB: Caudal epidural block

CEI: Caudal epidural injections

SH: Sacral hiatus

Conflicts of Interests: None

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