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Authors: E. Nastoulis, D. Tsiptsios, P. Chloropoulou, V. Karapepera, V. Thomaidis, P. Pavlidis, A. Fiska

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Morphological and morphometric features of sacral hiatus and its clinical significance in caudal epidural anesthesia

E. Nastoulis et al., Morphological and morphometric features of sacral hiatus

E. Nastoulis[1], D. Tsiptsios[1], P. Chloropoulou[2], V. Karapepera[1], V. Thomaidis[1], P. Pavlidis[3], A. Fiska[1]

[1]Department of Anatomy, School of Medicine, Democritus University of Thrace, Alexandroupolis, Greece

[2]Department of Anesthesiology, School of Medicine, Democritus University of Thrace, Alexandroupolis, Greece

[3]Laboratory of Forensic Sciences, School of Medicine, Democritus University of Thrace, Alexandroupolis, Greece

Address for correspondence: E. Nastoulis MD, MSc, Forensic Pathologist, doctoral student, School of Medicine, Democritus University of Thrace, Dragana, 68100, Alexandroupolis, Evros Prefecture, Greece, tel: +30 6972524316, fax: +30 25513 53824, e-mail: nastevang@yahoo.gr

ABSTRACT

Background: Caudal epidural block (CEB) failure or complications are not unheard even among experienced anesthesiologists and are usually due to sacral hiatus (SH) anatomy variations. The aim of the present study is to observe, record and analyze important anatomical features of SH and correlate them with potential CEB limitations.

Materials and methods: The SH of 155 complete and undamaged Greek adult dry sacra of known sex were included in the study. Three non-metric (shape of SH and location of hiatal apex and base in relation to level of sacral/coccygeal vertebra) and five metric parameters (height of the SH, transverse width of the SH at the base, anteroposterior diameter of the SH at the level of its apex and the distance from the sacral apex and base to the upper border of S2 foramina) were evaluated.

Results: Inverted U (34.83%) and inverted V (26.45%) were the commonest shapes. Hiatal apex and base were most commonly related to the level of S4 (78.70%) and S5 vertebra (89.03%), respectively. Mean height, depth and intercornual distance were 19.05±8.65 mm, 5.39±1.84 mm and 12.41±3.16 mm, respectively, whereas mean distance between the upper border of S2 foramen and the apex and base of the sacral hiatus were 46.34 mm and 63.48mm, respectively. Anatomical variations of sacral hiatus that might be responsible for CEB failure, such as elongated SH, absence of SH, complete dorsal wall agenesis of sacral canal and narrowing (< 3 mm) at the apex of SH were found in 17.43% of sacra (male 10.94% and female 25.22%).

Conclusions: This study suggests a potential risk of failure of CEB in Greek patients, especially in females, which should be kept in mind while giving caudal epidural anesthesia.

Key words: sacrum, sacral hiatus, anatomical variations, caudal epidural anesthesia, Greece

INTRODUCTION

The human sacrum constitutes a large triangular bone located at the base of vertebral column between the two hip bones that articulates with the fifth lumbar vertebra above and the coccyx below. Over the years, an abundance of sacral anatomical variations has been reported [29]. Embryologically, it 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 (CEB). [1]

The dorsal surface of the fifth sacral and the coccygeal vertebrae and the deep posterior sacrococcygeal membrane connecting them, form the roof of the lower sacral canal. Down to the middle of S2 vertebra the sacral canal encompasses the termination of the dural sac containing the distal portion of the cauda equina and the internal filum terminale. Caudally, the fifth sacral and coccygeal spinal nerves formed within the sacral canal and exiting via the sacral hiatus and the external filum terminale extending towards the dorsum of the coccyx are encountered. The sacral canal also contains the epidural venous plexus and is filled with adipose tissue that is subject to age-related decrease in density. [41]

The application of local anesthetic agents into the epidural space through the sacral hiatus was first described by Fernard Cathelin and Jean-Athanase Sicard predating lumbar epidural block [8] and gained popularity by Hingson who implemented it on obstetrical cases [15, 37]. Caudal epidural anesthesia produces sensory and motor blockade of the sacral roots and limited blockade of the autonomous nervous system. Thus, this type of anesthesia has a wide variety of indications [15]. Most frequently it is used to provide anesthesia in infants and children for surgery of the perineum, anus and rectum and for inguinal and femoral hernias [47]. In adults for surgery of the lumbar spine, cystoscopies, urethral and vaginal operations and for labour pain relief, although the latter has been superseded by lumbar epidural anesthesia [17]. Additionally, it is useful in providing sympathetic block to patients suffering from acute vascular insufficiency of the lower extremities due to vascular spasm or occlusion. It can be used for any acute pelvic or leg pain, but most rewardingly in chronic pain due to diabetic neuropathy, post-herpetic pain, failed back syndrome, complex regional pain syndromes and for cancer pain management including peripheral neuropathy due to chemotherapy [10].

The technique of caudal epidural anesthesia entails placing neonates and children in the lateral decubitus position, while for older children and adults the prone position is preferred [19, 39]. The sacral hiatus can be located by palpating the sacral cornua, approximately at the level of the skin folds of the buttocks. After infiltrating with local anesthetic, the epidural needle is inserted in the caudal canal by using the loss of resistance technique and its position is ascertained by fluoroscopy or ultrasound [3, 7]. After the correct placement of the needle is confirmed, a catheter is inserted to the desired depth. Special attention should be paid not to penetrate the cancellous bone of the sacrum and not to tear the dura if the needle is advanced more cephalad than the S2 level, as this level indicates the lowest extension of the dura. Complications of CEB can relate to unsuccessful technique, such as penetration of the dura, penetration, and injection of local anesthetic agents into the soft bone of the sacrum (mainly in children), perforation of the rectum or even trauma to the baby's head in parturients, if the needle is placed too anteriorly [14]. In addition, complications can arise from the spread of the anesthetic solutions and the development of systemic toxicity. This complication, although rare, seems to be more common in caudal epidural anesthesia compared to lumbar epidural anesthesia [9]. Infections such as meningitis, discitis or vertebral osteomyelitis are rare complications. Other complications such as epidural hematoma, dural puncture and post dural puncture headache, air embolism, back pain and broken or knotted catheters can occur after caudal anesthesia, as with lumbar or thoracic epidural anesthesia.

CEB failure rate approximates 5-10% and is usually attributed to technical difficulties to accurately identify the sacral hiatus due to its numerous anatomic and morphological variations. Thus, for optimal access into the sacral epidural space and successful, uncomplicated conduction of CEB, a thorough knowledge of the SH anatomical variations, as well as the use of detailed anatomical landmarks to identify them, are required. To gain this knowledge, we conducted a descriptive osteological study in dry sacra of Greek adults, aiming to observe, record and analyze several metric and non-metric features of the sacral hiatus.

MATERIALS AND METHODS

The aim of the present study is to observe, record and analyze important anatomical features of the SH in a Greek population. A total number of 155 dry sacra (82 male / 73 female) were assessed in the study from the Third Cemetery of Athens, Greece, after formal consents and official permissions were obtained. Only bones that were fully ossified, dried, intact, with no fractures or other pathology were examined.

Three non-metric and five metric parameters were evaluated on these specimens:

A) Non-metric parameters

i) Shape of sacral hiatus ii) Location of hiatal apex in relation to level of sacral vertebra.

iii) Location of hiatal base in relation to level of sacral/coccygeal vertebra.

B) Metric parameters

Five anatomical measurements were performed by two authors (EN and VT) by using a vernier caliper accurate to 0.1 mm. Minor deviations were resolved by the lead anatomist of the Department (AF):

(i) Height of the sacral hiatus: measured from the apex to the midpoint of its base. Respective measurements were classified into six subgroups: 0-10 mm, 11-20 mm, 21-30 mm, 31-40 mm, 41-50 mm and >51 mm. (Fig.1)

(ii) Transverse width of the sacral hiatus at the base (intercornual distance): measured between inner aspects of the inferior limit of the sacral cornua. Respective measurements were classified into four subgroups: 0-5 mm, 6-10 mm, 11-15 mm and >16 mm. (Fig.1)

(iii) Anteroposterior diameter (depth) of the sacral hiatus at the level of its apex. Respective measurements were classified into four subgroups: 0-3 mm, 4-6 mm, 7-9 mm and >9 mm. (Fig. 2)

(iv) Distance from the sacral apex to the upper border of S2 foramina. (Fig.1)

(v) Distance from the base of sacral hiatus to the upper border of S2 foramina; (v = i + iv). (Fig. 1)

Statistical analysis

Data were expressed as mean, (SD), median and range. Analyses were performed using IBM SPSS Statistics 26.

RESULTS

With regards to the shape of sacral hiatus nine types were recognized (Fig.3), inverted U-shaped being the most commonly observed (34.83%) followed by inverted V (26.45%) and irregular (19.99%) (Table I).

Considering hiatal apex and base location in relation to the level of sacral/coccygeal vertebra, it was detected that these were most often related to the level of S4 (78.7%) and S5 (89.03%) vertebra, respectively (Table II and Table III) (Fig.4 and Fig.5).

Furthermore, mean height of sacral hiatus was 19.05 ± 8.65 mm (range: 1.57 - 58.91 mm) (Table IV), whereas most specimens exhibited respective heights between 11-20 mm (42.6%), followed by 21-30 mm (34.2%) and 0-10 mm (14.2%) (Table V). Statistically significant differences between males (20.01 ± 9.37 mm) and females (17.8 ± 7.44 mm) were observed (p= 0.035). (Table VIII)

Mean intercornual distance was 12.41 ± 3.16 (range: 3.32 - 20.09) (Table IV) and in most instances ranged between 11-15 mm (54.8%) followed by 6-10 mm (22.6%) and >16 mm (21.9%) (Table VI). Statistically significant differences between males (12.87 ± 3.35 mm) and females (11.79 ± 2.79 mm) were not observed (p=0.109). (Table VIII)

Moreover, mean depth of the sacral hiatus at the level of its apex was 5.39 ± 1.84 (1.22-12.12) (Table IV) and in most instances ranged between 4-6 mm (55.5%) followed by 7-9 mm (32.3%) (Table VII). Statistically significant differences between males (5.62 ± 1.75mm) and females (5.07 ± 1.93mm) were not observed (p=0.067). (Table VIII)

Finally, mean distance from apex and from base of the sacral hiatus to the upper border of S2 foramina were 46.34 ± 11.06 mm (range: 12.07 – 89.11) and 63.48 ± 8.25 mm (range: 48.47 – 90.65 mm), respectively. (Table IV)

DISCUSSION

Based on the fact that SH constitutes the most important route for CEB, full understanding of its morphological and morphometrical variations across various population groups is of paramount importance in order to not only increase success rate, but also decrease complications' risks of CEB. In the present study, several metric and non-metric parameters of adult Greek dry sacra were evaluated.

As evidenced in Table I, inverted U and inverted V were the most commonly observed SH shapes (34.83% and 26.45%, respectively). In keeping with our results, several researchers worldwide have also concluded that either inverted U or inverted V are the most prevalent SH shapes (Table IX). Thus, these are considered as normal and provide enough space for needle insertion during CEB. In contrast, alternate SH shapes, like irregular (observed in 19.99% of our cases), dumbbell (6.45%), bifid (3.22%) and "M" pattern (1.29%), may lead to CEB failure. The extreme case of absent (or closed) SH that may be caused by boney overgrowth and complete fusion of S4 and S5 laminae, thus precluding needle insertion into the caudal epidural space, was observed in 5 cases (3.22%- 2 males, 3 females). Furthermore, complete agenesis of the dorsal wall of the sacral canal was found in 3 cases (1.93%- 2 males, 1 female). This variation may also lead to CEB failure as bony landmarks are missing. Moreover, elongated SH was observed in 4 cases (2.58%- 1 male, 3 females). This variance may result in CEB complications as the closer the apex of SH to the dural sac is, the more likely it is for an unintentional dural puncture to happen.

Concerning hiatal apex location, in keeping with the majority of available studies this was most commonly related to the level of S4 vertebra (78.70%) and less frequently to the level of S3 (10.96%) or S5 (9.03%) vertebra (Table II) (Fig.4). Nadeem G [26] and Malarvani et al., [23] having evaluated dry sacra belonging to Caucasian Germans and Nepalis, respectively, were the only ones to observe that hiatal apex location is most often related to the level of S3, and not S4, vertebra (Table X). Hiatal apex comprises an important bony landmark during CEB. However, in obese patients it may be hard to palpate. Exact knowledge of hiatal apex level is of paramount importance as this ensures dura safety during CEB. More specifically, the higher the hiatal apex is located, the shorter the distance between it and the dural sac termination is, thus increasing the risk of accidental dural puncture during CEB. In case dural puncture occurs and goes undetected, the entire volume of local anesthetic will get injected into the subarachnoid space leading to total spinal anesthesia [19, 43].

Abiding to the aforementioned mechanism, the risk of intrathecal injection of anesthetic during CEB is high in case of dural sac termination caudally to the expected middle S2 level, as in 1-5% of humans it extends to S3 level or below, or in the presence of an incidental Tarlov cyst, a perineural cyst filled with cerebrospinal fluid (CSF) that communicates with the dural sac and is usually found at or below S3 level [16, 41].

With regards to hiatal base location, in agreement with available literature (Table X) this was most commonly related to the level of S5 vertebra (89.03%) (Table III) (Fig.5). Moreover, the mean distance between the upper border of S2 foramen and the apex and base of the sacral hiatus were 46.34 mm and 63.48mm, respectively (Table IV). These findings signify the importance of advancing the needle only a few millimeters after penetrating the sacrococcygeal membrane in adults, in order to reduce the frequency of dural puncture during CEB.

Mean height of sacral hiatus was 19.05 (range: 1.57 - 58.91) (Table IV), whereas heights < 20 mm were observed in 56.8% of dry sacra (Table V). Our results approach respective measurements from Indian (Shewale et al, Vasuki et al) [42, 46] and Ethiopian (Abera et al) [2] dry sacra (Table XI). The longer the sacral hiatus is, the shorter the sacral canal is, thus increasing the possibility of accidental dural puncture during CEB. In obese individuals, extreme fat deposition within the sacral canal makes elevating potential risk of CEB complications [2].

In our study, mean transverse width of the SH at the base (intercornual distance) was 12.41 mm (range: 3.32 - 20.09 mm) (Table IV), whereas most sacra (54.8%) exhibited respective distances between 11 and 15 mm (Table VI). Ours resemble measurements from Indian sacra confirmed by Nasr et al [28], Shewale et al [42] and Seema et al [38] (Table XI).

Finally, mean depth of sacral hiatus at the level of its apex was 5.39 mm (range 1.22 -12.12 mm) (Table IV). Our findings were close to those reported by Abera et al from Ethiopia [2] and Rajeev et al from India [35]. (Table XI). Anteroposterior diameter at the level of hiatal apex is clinically important, as in case it is < 3.7 mm, it is associated with technical difficulties while attempting to insert the needle into the caudal epidural space by blind technique. [20] However, under ultrasound guidance, such difficulties are encountered in case of depths < 1.6 mm [12]. It is noteworthy that in our study, anteroposterior diameters <3mm were observed in 15 (9.7%) of sacra (4 males, 11 females) (Table VII). Thus, in these patients it would have been difficult to advance a 22G needle during CEB.

Due to the aforementioned anatomical variations, failure and complication rates when conventional blind technique for CEB is applied in adults are high even among experienced anesthesiologists. According to the literature, fluoroscopy guided CEB has markedly increased CEB success rates. However, routine use of fluoroscopy is limited by radiation exposure, cost and special space requirements. On the other hand, ultrasound guided CEB does not face those limitations, being able to image accurately sacral anatomy and needle positioning in the caudal space, thus has risen in popularity since its introduction in 2003 [19].

CONCLUSIONS

The anatomy of the SH and caudal canal is highly variable, and thorough appreciation of this is critical to performing effective and safe CEBs. Despite its widespread use, the knowledge of extent of variability in this area remains limited even among experienced clinicians. In the present osteological study, all the anatomical variations of the SH reported in the international literature were found and recorded in the Greek population, in both sexes.

The variations of the SH that mainly might be responsible for CEB failure, such as elongated SH, absence of SH, complete dorsal wall agenesis of the sacral canal, and narrowing (<3 mm) at the apex of SH were recognized and found in significant percentage. This study notes a potential risk of failure of CEB in the Greek population, especially in females, which should be taken into consideration before the administration of caudal epidural anesthesia and in the preoperative evaluation of patients.

In order to calculate the exact percentage that each anatomical variation causes complications during CEB, clinical studies (anesthesiological- radiological) should be performed, where each time a complication occurs during anesthesia the morphology and morphometry of the SH will be recorded.

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Conflict of interest: None declared

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Shape of SH	**Male**		**Female**		**Total**	
	Number	**(%)**	**Number**	**(%)**	**Number**	**(%)**
Inverted ‘U’	30	36.58	24	32.87	54	34.83
Inverted ‘V’	22	26.82	19	26.02	41	26.45
Irregular	17	20.73	14	19.17	31	19.99
Elongated	1	1.21	3	4.10	4	2.58
Dumbbell	6	7.31	4	5.47	10	6.45
Bifid	2	2.43	3	4.10	5	3.22
Pattern ‘M’	0	0	2	2.73	2	1.29
Complete Dorsal Wall Agenesis	2	2.43	1	1.36	3	1.93
Absence of Sacral Hiatus	2	2.43	3	4.10	5	3.22
Total	82	100	73	100	155	100

Table I. Shape of sacral hiatus

Table II. Location of hiatal apex in relation to the level of sacral vertebra

Vertebral level	Male		Female		Total	
	Number	(%)	Number	(%)	Number	(%)
S2	1	1.21	1	1.36	2	1.29
S3	9	10.97	8	10.95	17	10.96
S4	66	80.48	56	76.71	122	78.70
S5	6	7.31	8	10.95	14	9.03
Total	82	100	73	100	155	100

Table III. Location of hiatal base in relation to level of sacral / coccygeal vertebra

Vertebral level	**Male**		**Female**		**Total**	
	Number	**(%)**	**Number**	**(%)**	**Number**	**(%)**
S4	1	1.21	1	1.36	2	1.29
S5	74	90.24	64	87.67	138	89.03
C1	7	8.53	8	10.95	15	9.67
Total	82	100	73	100	155	100

Table IV. Evaluated morphometrical parameters of dry sacra

Parameters	**Mean (mm)**	**Median (mm)**	**SD (mm)**	**Range (mm)**
Height of sacral hiatus	19.05	18.8	8.65	1.57-58.91
Transverse width of sacral hiatus (intercornual distance)	12.41	12.71	3.16	3.32-20.09
Anteroposterior diameter (depth) of sacral hiatus at the level of its apex	5.39	5.48	1.84	1.22-12.12
Distance from sacral apex to the upper border of S2 foramina	46.34	45.87	11.06	12.07-89.11
Distance from the base of sacral hiatus to the upper border of S2 foramina	63.48	62.74	8.25	48.47-90.65

Table V. Height of sacral hiatus from apex to midpoint of base

Height of Sacral Hiatus (mm)	**Male**		**Female**		**Total**	
	Number	**(%)**	**Number**	**(%)**	**Number**	**(%)**
0-10	10	12.19	12	16.43	22	14.2
11-20	36	43.90	30	41.09	66	42.6
21-30	27	32.92	26	35.61	53	34.2
31-40	7	8.53	5	6.84	12	7.7
41-50	1	1.21	0	0	1	0.65
>51	1	1.21	0	0	1	0.65
Total	82	100	73	100	155	100

Table VI. Transverse width of sacral hiatus (intercornual distance)

Transverse Width (mm)	**Male**		**Female**		**Total**	
	Number	**(%)**	**Number**	**(%)**	**Number**	**(%)**
0-5	1	1.21	0	0	1	0.65
6-10	18	21.95	17	23.28	35	22.6
11-15	44	53.65	41	56.16	85	54.8
>16	19	23.17	15	20.54	34	21.9
Total	82	100	73	100	155	100

Anteroposterior diameter (mm)	Male		Female		Total	
	Number	(%)	Number	(%)	Number	(%)
0-3	4	4.87	11	15.06	15	9.7
4-6	48	58.53	38	52.05	86	55.6
7-9	27	32.92	23	31.50	50	32.2
>9	3	3.65	1	1.36	4	2.5
Total	82	100	73	100	155	100

Table VII. Anteroposterior diameter (depth) of sacral hiatus at the level of apex

Table VIII. Sexual Dimorphism

Parameters (mm)	**Sex**	**Mean (mm)**	**Median (mm)**	**SD (mm)**	**Range (mm)**	***P* value (K-S test)**	**Normality**	***P* value***
Height of sacral hiatus	M	20.01	19.02	9.37	1.57-58.91	0.2	Yes (t-test)	0.035
	F	17.8	17.14	7.44	5.66-35.66			
Transverse Width of sacral hiatus (intercornual distance)	M	12.87	13.29	3.35	3.32-20.09	0.2	Yes (t-test)	0.109
	F	11.79	11.8	2.79	5.43-16.34			
Anteroposterior diameter (depth) of sacral hiatus at the level of its apex	M	5.62	5.61	1.75	1.38-12.12	0.2	Yes (t-test)	0.067
	F	5.07	5.32	1.93	1.22-8.98			

*Differences among groups were considered statistically significant at P values of less than 0.05.

Table IX. Comparison between different studies regarding shapes of sacral hiatus

Author	Ethnicity/ Race	Inverted "U"	Inverted "V"	Irregular	Dumbbell	Bifid
Kumar [21]	India	46.53%	29.7%			
Nagar [27]	India	27%	41.5%	14.1%	13.3%	1.5%
Patel [33]	India	49.3%	20%		4%	
Njihia [30]	Kenya	16.7%	32.1%	19%	31%	
Seema [38]	India	42.95 %	27.51%	16.10%	13.41%	
Suwanlikhid [44]	Thailand	54.47%	19.57%	11.06%	2.13%	3.83%
Shewale N [42]	India	40.69%	32.35%	9.31%	5.89%	0.98%
Phalgunan V [34]	India	35%	35%	28%		
Bhattacharya [6]	India	65%	23%	12%		
Ukoha [45]	Nigeria	48.2%	34.9%	4.8%	4.8%	4.8%
Nasr A [28]	Egypt	31.33%	38.66%	15.33%	12%	2.66%
Mayuri J [24]	India	42.37%	27.11%	16.1%	12.71%	1.69%
Rajeev R [35]	India	42.12 %	35.43%	12.99%	4.00%	5.51%
Osunwoke [31]	Nigeria	24.1%	33.1%	13%	9.3%	5.6%
Kamal A [18]	Bangladesh	38.00%	35.10%	15.20%	5.30%	0.60%
Nadeem G [26]	Caucasians Leaving in Germany	56%	14%	16%	10%	2%
Malarvani T [23]	Nepal	35%	32%	14%	3%	2%
Vasuki [46]	India	36%	20%	33%	23%	3%
Laishram D [22]	India	39.35%	16.77%	24.51%	7.091%	
Saha D [36]	India	70.09%	14.53%	12.82%	0.85%	1.71%
Bagheri H [5]	Turkey	33.3%	19.45%	19.45%	6.9%	3.45%
Dhuria [13]	India	35.22%	29.54%	14.77%		
Bagoji IB [4]	India	42,02%	26,08%	7,24%	12.31%	5.07%
Abera [2]	Ethiopia	37.7%	41%	4.9%	11.5%)	3.3%

Table X. Comparison between different studies regarding the location of hiatal apex and base in relation to the level of sacral/ coccygeal vertebra

		Location of hiatal apex in relation to level of sacral vertebra				**Location of hiatal base in relation to level of sacral/coccygeal vertebra**		
Author	**Ethnicity/ Race**	**S2**	**S3**	**S4**	**S5**	**S4**	**S5**	**C1**
Nagar [27]	India	3.4%	37.3%	55.9%	3.4%	11.1%	72.6%	16.3%
Patel [33]	India	0.66%	26.6%	53.3%	12.67%	10.67%	79.33%	
Seema [38]	India	4.02%	35.57%	56.36%	4.02 %	13.42%	70.46%	16.10%
Suwanlikhid N [44]	Thailand	1.18%	16.2%	58.4%	15.01%	7.50%	71.14%	8.69%
Shewale N [42]	India	4%	15%	66%	14.5%	2%	82%	16%
Phalgunan V [34]	India	7.1%	46%	46%				
Bhattacharya S [6]	India		5%	72%	23%			
Ukoha [45]	Nigeria	2.04%	20.05%	69.9%	4.8%	2,4%	88%	7.2%
Nasr A [28]	Egypt	1.33%	14.66%	54.00%	27.33%	12%	70%	18%
Mayuri J [24]	India	4.23%	35.39%	56.77%	3.38%			
Rajeev R [35]	India	5.60%	17.71%	60.23%	16.53%	4.33%	75.19%	21.25%
Osunwoke E [31]	Nigeria	5.6%	20.4%	66.6%	7.4%	11.1%	59.3%	29.6%
Kamal A [18]	Bangladesh	4.70%	30.40%	60.20%	4.70%	0.60%	91.20%	8.20%
Nadeem G [26]	Caucasians living in Germany	2%	62%	34%	2%	62%	24%	14%
Malarvani T [23]	Nepal	3%	42%	39%	13%	31%	54%	1%
Vasuki [46]	India	3%	43%	48%	5%	16%	64%	20%
Bagheri H [5]	Turkey	1.15%	10.34%	71.11%	11.49%	2.3%	82.76%	8.05%

Dhuria [13]	India	5.68%	21.59%	57.95%	9.09%		92.04%	7.95%
Bagoji IB [4]	India	2.89%	26.81%	58.69%	6.52%	18.11%	70.28%	6.52%
Abera [2]	Ethiopia	3.3%	26.2%	60.7	9.8%		78.7%	21.3%

Table XI. Morphometric sacral hiatus measurements from various investigators worldwide

		Anteroposterior diameter (depth) of SH at the level of apex				**Height of sacral hiatus**						**Transverse width (intercornual distance) of SH at the level of base**			
Author	**Ethnicity/ Race**	**0-3 mm**	**4-6 mm**	**7-9 mm**	**>9 mm**	**0 to 10 mm**	**11 to 20 mm**	**21 to 30 mm**	**31 to 40 mm**	**41 to 50 mm**	**>51 mm**	**0 to 5 mm**	**6 to 10 mm**	**11 to 15 mm**	**>15 mm**
Nagar [27]	India	15.6%	64.2%	19.8%	0.4%	10.3%	35%	30.8%	17.1%	4.9%	1.9%				
Senoglou [40]	Turkey						4.4%	35.6%	36.7%	20%	3.3%				
Seema [38]	India	5.36%	71.81%	22.14%	0.67%	11.4%	34.8%	29.5%	16.7%	4.6%	2.6%	9.39%	30.20%	51.67%	8.72%
Shewale [42]	India	7.5%	76%	16%	0.67%	5.5%	40%	37%	10.5%	5%	2%	1%	22%	56%	21%
Phalgunan [34]	India		57%	39%	3.5%										
Nasr [28]	Egypt	18.66%	60.66%	20.66%		8%	36.6%	30%	16.6%	5.3%	3.3%	6%	33.33%	53.33%	7.33%
Rajeev [35]	India	10.62%	79.13%	9.84%	0.4%	11.02%	31.10%	39.76%	12.16%	5.51%		15.35%	38.20%	6.92%	10.23%

Mayuri [24]	India	5.08%	71.18%	22.03%	1.69%	11.01%	34.74%	29.66%	16.94%	4.23%	3.38%				
Chhabra [11]			50%	40%	10%	3.33%	30%	33.33%	30%	3.33%			10%	63.33%	26.67%
Nadeem [26]	India	5%	60%	30%	5%										
Mishra [25]	India	23.86%	63.63%	12.51%		9.09%	44.31%	30.70%	14.77%	1.13%		1.14%	20.46%	57.95%	20.45%
Parashuram[32]	India	29.9%	68.1%	2.1%											
Vasuki [46]	India					8%	42%	33%	6%	6%			9%	48%	43%
Dhuria [13]	India	5.68%	47.72%	28.4%	10.22%	10.22%	15.9%	37.5%	25%	2.27%	5.68%		4.54%	30.68%	64.76%
Bagoji [4]	India	4.34%	54.34%	25.36%	10.14%										
Abera [2]	Ethiopia	8.2%	60.07%	31.1%		4.9%	45.9%	34.4%	13.1%	1.6%			19.7%	63.9%	14.8%

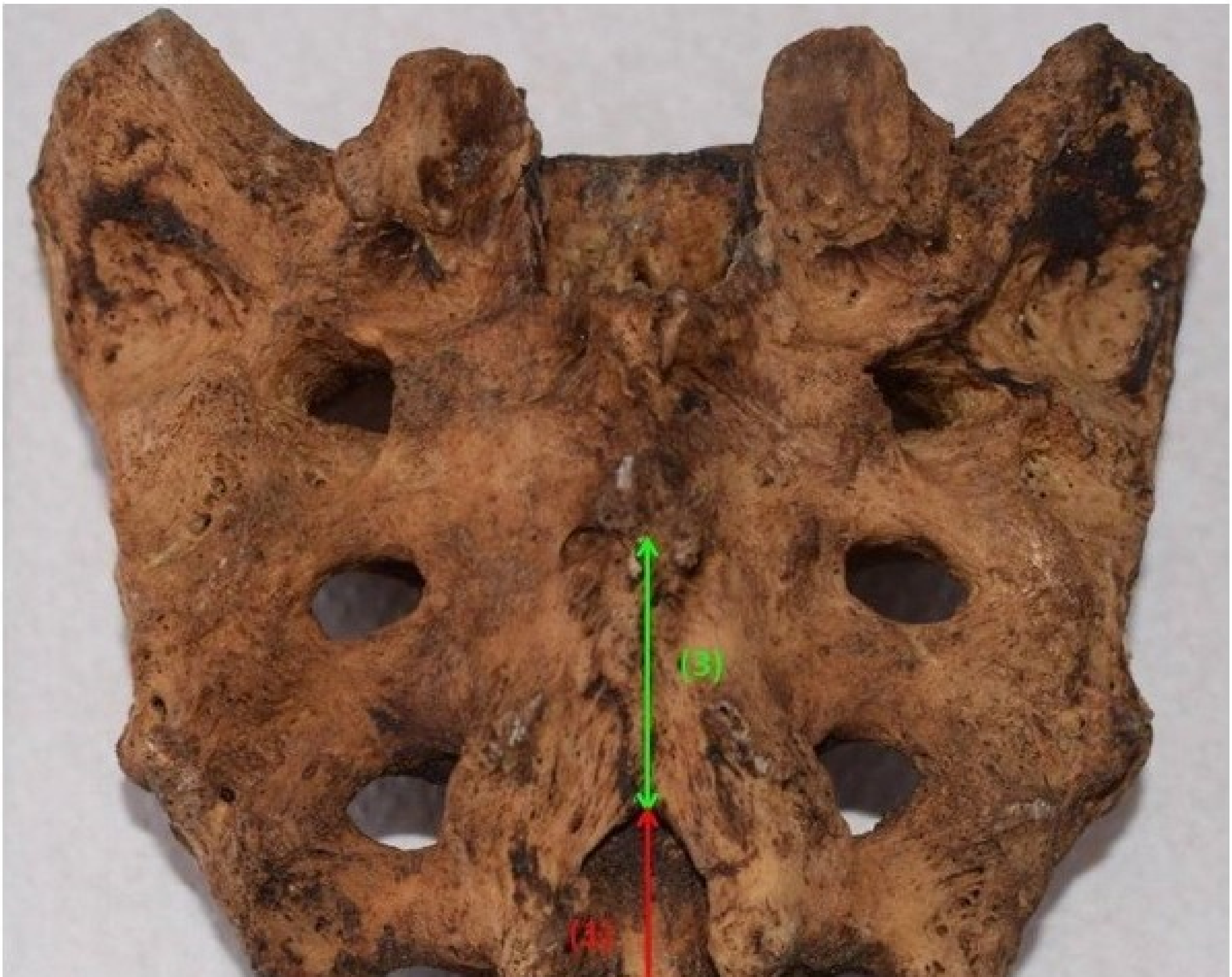
Figure 1. Metric parameters evaluated: (1) Height of sacral hiatus, (2) transverse width of the sacral hiatus at the base (intercornual distance), (3) distance from sacral apex to the upper border of S2 foramina (4) Distance from the base of sacral hiatus to the upper border of S2 foramina; (4 = 1 + 3)

Figure 2. Anteroposterior diameter (depth) of the sacral hiatus at the level of its apex.

Figure 3. Observed sacral hiatus shapes: a. inverted U, b. inverted V, c. irregular, d. dumbbell, e. bifid, f. M pattern, g. elongated, h. complete dorsal wall agenesis and i. absence of sacral hiatus.

Figure 4. Level of sacral hiatus apex at S4.

Figure 5. Level of sacral hiatus base at S5.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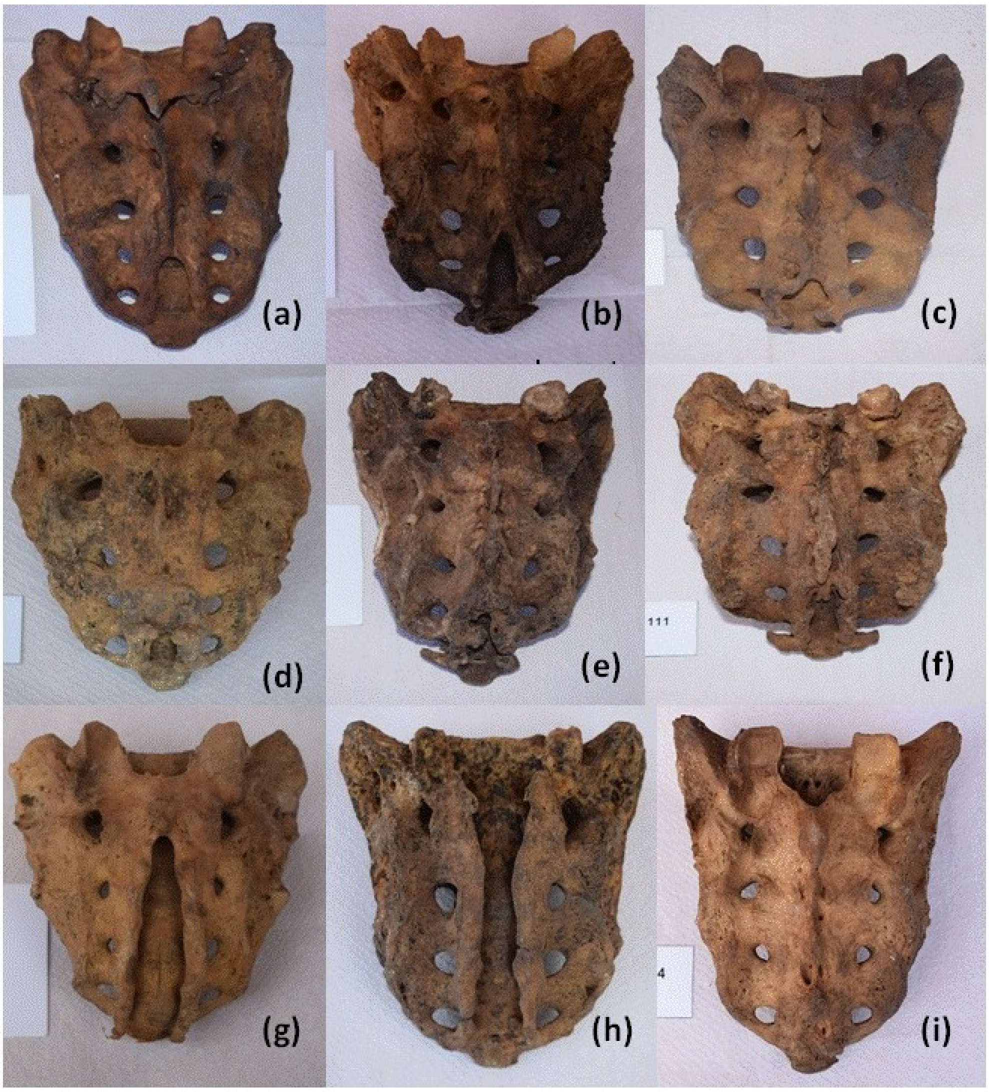
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