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ORIGINAL ARTICLE

Significance of Different Sacral Measurements in Sex Identification and Its Correlation with Caudal Epidural Block; An Egyptian Anatomical Study

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ABSTRACT

Background: Sacrum is an important bone of the human skeleton. It contributes in the formation of the pelvic girdle. It has many clinical applications. So this study was performed to demonstrate the different dimensions and measurements of the sacrum to make it easy for identifying sex and performing caudal epidural block.

Methods: An anatomical study on 50 adult Egyptian dry complete undamaged sacra was performed in the Human Anatomy and Embryology department, Faculty of Medicine, Zagazig University, Egypt. The parameters used in this study were the different dimensions of the sacrum including the morphology of the sacral hiatus, the extensions of the auricular surface, the sacral index and the auricular index. All the measurements were performed by using a Vernier digital caliper with accuracy of 0.1mm. The measurements were recorded and their mean and standard deviations were calculated.

Results: It was found that the mean values of sacrum width and height, transverse diameter of the wing and the base of sacrum were more in males than females. While auricular surface length, sacral and auricular indices were higher in females than in males. Also the mean values of width and height of the sacral hiatus were more in males than females.

Conclusions: The sacral index and the maximal sacral length and width were the most significant of all the parameters used for sex identification**.** Also**,** the determination of the anatomical variations of the sacral hiatus may be helpful in increasing the success rate of caudal epidural anaesthesia.

Key words: Sacrum- sacral index- auricular index.

INTRODUCTION

The Sacrum is a large triangular shaped bone which forms the posterosuperior wall of the pelvic cavity, presents between the two hip bones. It is formed by the union of five sacral vertebrae and forms the vertebral column's caudal end. In males, it is larger than in females, whereas width of ala is more in females than in males. The sacrum articulates above with the 5th lumbar vertebra and the coccyx below. The sacrum consists of trabecular bone enveloped by a shell of compact bone of varying thickness **[1].**The vertebral foramina of sacrum form the sacral canal that lodges the cauda equina, spinal meninges, sacral and coccygeal nerve roots. The opening at the caudal end of sacral canal is called sacral hiatus. Its formation is found to be due to failure of fusion of laminae of the fifth (occasionally 4th) sacral vertebra. It is situated inferior to the 4th (or 3rd) fused sacral spines or lower end of median sacral crest. Its shape is variable but generally it is triangular in shape with apex directed upward and base downward. It contains fifth pair of sacral nerve, coccygeal nerve and filum terminale. The site of the sacral hiatus is marked by palpation of the sacral cornua which are the remnants of the inferior articular process that elongate downwards on both sides of the sacral hiatus **[2]**.The sacral cornua represent important c linical landmarks during Caudal Epidural Block (CEB). Palpating the bilateral sacral cornua is necessary to localize the sacral hiatus in the conventional landmark-

based technique of CEB. However, the sacral cornua are not always palpable. On the body surface the sacral hiatus can be identified two inches above the tip of coccyx beneath the skin of natal cleft**.** Alternatively, the sacral hiatus may be recognized by forming an equilateral triangle based on a line joining the two posterior superior iliac spines: the inferior apex of this triangle overlies the sacral hiatus. The sacral hiatus is covered by superficial posterior sacrococcygeal ligament which is attached to the edges of the sacral hiatus and the deep posterior sacrococcygeal ligament which is attached to its floor **[3].** The sacral hiatus is covered posteriorly by skin, a subcutaneous fatty layer and the sacrococcygeal membrane **[4].** The dural sac terminates at the level of the S2 vertebra. The sacral canal inferior to this level contains extradural fat, vertebral venous plexus, lower sacral nerve roots and the filum terminale **[5].**Lateral to the intermediate crest on the posterior aspect of sacrum are 4 dorsal sacral foramina which give passage to the posterior divisions of sacral nerves and there are 4 pairs of ventral sacral foramina which give passage to the anterior divisions of sacral nerves **[6].** Occasionally, the first sacral piece is not fused with other 4 sacral pieces (lumbarization of first sacral vertebra) giving rise to 3 pairs of sacral foramina or the 5^{th} lumbar vertebra fuses with the first sacral piece (sacralization of 5^{th} lumbar vertebra) resulting in formation of 5 pairs of dorsal sacral foramina. Therefore, since sacral foramina provide an important anatomical landmark in spinal surgery and can also be used to block sacral nerves in order to minimize pain and perform anesthesia in pelvic area surgeries, it is vital to know the percentage of variations in the number of dorsal sacral foramina. The caudal epidural block is achieved by inserting a needle into the epidural space via the sacral hiatus to deliver medications into it. This epidural space technique is not only commonly used in pediatric patients for surgical anesthesia and analgesia but is also popular in the treatment of a wide range of chronic pain conditions in adults. So CEB has a wide range of clinical applications, it is sometimes difficult to identify the anatomical position of the sacral hiatus and the caudal epidural space, especially in adults. The identification of the landmarks by the clinician enables him to locate the sacral hiatus and may increase the success rate of CEB. So the Aim of the Work was to estimate the variations in metrical values of different sacral parameters in order to make it easy to identify sex and performing caudal epidural and trans-sacral block with a high success rate **[4].**

METHODS

50 adult Egyptian dry complete undamaged human sacra (25 males and 25 females) were obtained from the Human Anatomy and Embryology Department, Faculty of Medicine, Zagazig University, Egypt. The study was approved by the research ethical committee of Faculty of Medicine, Zagazig University. The sex of the sacrum was determined at the beginning of the study by using the following points: Some were taken from previously known human skeleton. Others were taken depending on the general features of sacrum as female sacra are less curved, curvature being most marked between 1-2 sacral segments and 3-5 segments with region in between flat. While male sacra are more curved, long and narrow. Auricular surface in females extends to the level of upper 3 or more sacral segments while in males extends to about upper 2 sacral segments. Sacral index in males is lesser than that in females [1]. At the end of the study, after taking measurements, they were compared again with the results in order to decrease inter and intra observer errors and the different sacra were replaced by other known sacra. Using a Vernier digital caliper with accuracy of 0.1mm as shown in figure (1) the following parameters were measured: the maximum transverse diameter of the sacrum, the maximum length of the sacrum, the vertical length of auricular surface, the vertical and transverse distances between different anterior and posterior sacral foramina, the transverse diameter of ala and base of sacrum, number of sacral foramina (ventral and dorsal), morphology and dimensions of sacral hiatus. By using the above mentioned parameters sacral index, auricular index on either side were calculated. Sacral index= Width × 100 / Height. Auricular index= Length of auricular surface × 100 / Width. The readings were recorded and statistically analyzed. The above mentioned parameters were measured as follow: The maximum transverse diameter of the sacrum: was measured on the upper surface with the caliper by taking two points at the most lateral part of alae of sacrum as shown in figure(2).

The maximum length of the sacrum: was measured along the midline from the antero- superior border of the promontory to the center of antero-inferior edge of last sacral piece as shown in figure (3). The vertical length of the auricular surface: was determined on the sacrum lateral surface by taking one point on the upper majority of the auricular surface and another point on the lower majority of the auricular surface as shown in figure(4).

The vertical distances between the different anterior sacral foramina: were measured by taking one point on the lower most margin of one anterior sacral foramen and the upper most margin of the next one. The vertical distances between the different posterior sacral foramina: were measured by taking one point on the lower most margin of

one posterior sacral foramen and the upper most margin of the next one. The transverse distances between the different anterior and posterior sacral foramina: were measured by taking one point on the medial margin of one anterior sacral foramen and the medial margin of the other one. The same was done for the posterior sacral foramina.

The transverse diameter of the ala (wing) of the sacrum: was determined on each side by taking one point on the most lateral part of the upper surface of the body of 1st sacral vertebra and another point on the most lateral part of the alae. The transverse diameter of the sacrum base: was determined by taking one point on each side of the most lateral part on the upper body surface of the 1st sacral vertebra. The Sacral Hiatus (SH) was evaluated in each sacrum in both sexes according to its shape, length (from its apex to midpoint of the base) and transverse width at its base (between the inner aspects of inferior limit of sacral cornua).

STATISTICAL ANALYSIS

All measurements were tabulated and statistically analyzed for mean and standard deviation by using Statistical Package for the Social Science (version 10) software (SPSS).A comparison of the values of all the measurements was made among both sexes using Student's t test. Differences among groups were considered statistically significant at P values of less than 0.05.

RESULTS

The mean and standard deviations of various parameters are given in Table1.

The mean values of the sacrum's width (maximum transverse diameter) and height (maximum length), transverse diameter of the wing (ala) and sacrum base were more in males when compared with females. While the length of auricular surface in females was more than in males. The mean values of sacral and auricular indices are higher in females than in males as shown in table (1).

Morphology of the sacral hiatus has also been studied as shown in (Figures 5-9) and tabulated in Table (2).Also the mean values of width and height of the sacral hiatus were more in males when compared with females as seen in table (3).The mean values of the vertical distance between different anterior sacral foramina were more in females when compared with males as seen in table (4).While the mean values of vertical distance between different posterior sacral foramina were variables between both males and females as shown in table (5).Also the mean values of transverse distance between different anterior sacral foramina were variables between both males and females as shown in table (6).While the mean values of transverse distance between different posterior sacral foramina with the exception of transverse distance between first sacral foramina were more in males when compared with females as seen in table (7). In addition, as regard number of sacral foramina (ventral and dorsal), the present study showed 3 male sacra with 5 pairs of sacral foramina as a result of sacralization of the 5th lumbar vertebra as shown in figure (2).

Table 1: Showing the mean and standard deviation of various parameters included in this study.

Parameters	Mean (mm) ± S.D	
	F	M
The maximum transverse diameter of the sacrum	108±3.08*	115±4.12*
The maximum length of the sacrum	102.6±7.23**	119.6±6.46**
The vertical length of the auricular surface of the sacrum	61.4±8.47(NS)	60.6±4.61(NS)
The transverse diameter of the ala of the sacrum	28.2±5.80(NS)	30.4±3.20(NS)
The transverse diameter of the base of the sacrum	52.6±9.02(NS)	53±5.38(NS)
Sacral index	105.62±6.78*	96.34±5.93*
Auricular index	56.72±6.53(NS)	52.76±5.12(NS)

Student's t test: Significant differences between female and male sacra. * Significant $P<0.05$, **Highly Significant $P<0.001$, Non Significant (NS) $P>0.05$.

F: Female **M: Male** **S.D: Standard Deviation**

Table 2: Showing the morphology of the sacral hiatus.

Morphology	Female %	male %
Inverted V shaped	38.46%	50%
Inverted U shaped	30.77%	26.67%
Elongated V shaped	7.69%	13.33%
Elongated U shaped	15.38%	6.67%
Irregular	7.69%	6.67%

Table 3: Showing the mean and standard deviation of the width and the height of the sacral hiatus

Parameters Sacral hiatus	Mean (mm) ± S.D	
	F	**M**
Height	28.8±6.38(NS)	34.4±5.17(NS)
Width	13.4±2.07(NS)	14.6±6.69(NS)

Student's t test: Significant differences between female and male sacral hiatus. Non significant (NS) *P>0.05.*

F: Female **M: Male** **S.D: Standard Deviation**

Table 4: Showing the mean and standard deviation of vertical distance between the different anterior sacral foramina.

Parameter Anterior sacral foramina Vertical Distance	Mean (mm) ± S.D	
	F	**M**
R S1-S2	11±3.08	10±1.22
R S2-S3	5.6±0.89	5.4±0.89
R S3-S4	8±2.12	7±1.87
R S4-S5 (In case of Sacralization only)		7.7±0.57
L S1-S2	12±2.44	12.2±2.16
L S2-S3	6±1	5.8±0.83
L S3-S4	9.4±3.20	7.96±0.11
L S4-S5 (In case of Sacralization only)		10±1.41

N.B: Sacralization of 5th lumbar vertebra is seen only in 3 male sacra; so R S4-S5 and L S4- S5 are measured only in males.

F: Female **M: Male** **S.D: Standard Deviation**
R: Right **L: Left** **S: Sacral verteb**

Table (5): Showing the mean and standard deviation of vertical distance between the different posterior sacral foramina.

Parameter Posterior sacral foramina Vertical Distance	Mean (mm)± S.D	
	F	**M**
R S1-S2	17±3.46	17±2.23
R S2-S3	12.8±2.16	14±1.41
R S3-S4	12.4±3.04	13±2
R S4-S5 (In case of Sacralization only)		13.5±3.53
L S1-S2	16.2±5.40	17.2±3.11
L S2-S3	14.4±1.81	13±2.91
L S3-S4	12.4±1.94	11.2±2.77
L S4-S5 (In case of Sacralization only)		15.7±2.51

N.B: Sacralization of 5th lumbar vertebra is seen only in 3 male sacra; so R S4-S5 and L S4- S5 are measured only in males**.**

F: Female **M: Male** **S.D: Standard Deviation**
R: Right **L: Left** **S: Sacral vertebra**

Table 6: Showing the mean and standard deviation of transverse distance between the different anterior sacral foramina.

Parameter Anterior sacral foramina Transverse Distance	Mean (mm) ± S.D	
	F	M
R S1-L S1	30±5.61	30.6±2.70
R S2-L S2	29±1.41	28.8±2.39
R S3-L S3	26.8±0.45	27.4±3.13
R S4-L S4	24.2±2.05	26.4±2.88
R S5-L S5 (In case of Sacralization only)		22.5±0.71

N.B: Sacralization of 5th lumbar vertebra is seen only in 3 male sacra; so R S5- L S5 is measured only in males.

F: Female **M: Male** **S.D: Standard Deviation**
R: Right **L: Left** **S: Sacral vertebra**

Table 7: Showing the mean and standard deviation of transverse distance between the different posterior sacral foramina.

Parameter Posterior sacral foramina Transverse Distance	Mean (mm) ± S.D	
	F	M
R S1-L S1	40.4±7.76	39.8±3.03
R S2-L S2	32.4±2.70	33.6±6.02
R S3-L S3	27.2±2.77	31.2±7.08
R S4-L S4	27.6±1.52	29±3.74
R S5-L S5 (In case of Sacralization only)		27.5±3.53

N.B: Sacralization of 5th lumbar vertebra is seen only in 3 male sacra; so R S5- L S5 is measured only in males.

F: Female **M: Male** **S.D: Standard Deviation**
R: Right **L: Left** **S: Sacral vertebra**

Table 8: Comparison of morphometric measurements of sacrum between previous and present study.

Parameters (in mm)	Researchers		
	Arman Cet al., [2009]	Present study	
		female	male
Transverse distance between 1st ASF	30.48±2.78	30±5.6	30.6±2.7
Transverse distance between 2nd ASF	28.31±2.81	29±1.4	28.8±2.3
Transverse distance between 1st PSF	38.32±3.63	40.4±7.7	39.8±3
Transverse distance between 2nd PSF	31.62±3.27	32.4±2.7	33.6±6

ASF: Anterior Sacral Foramen **PSF: Posterior Sacral Foramen**

Fig I: Showing a Vernier digital calipers with an accuracy of 0.1mm**.**

Fig 2: Showing a pattern of measuring maximum transverse diameter (width) of male sacrum; distance between points **(A and B).** Also, it shows 5 pairs of anterior sacral foramina.

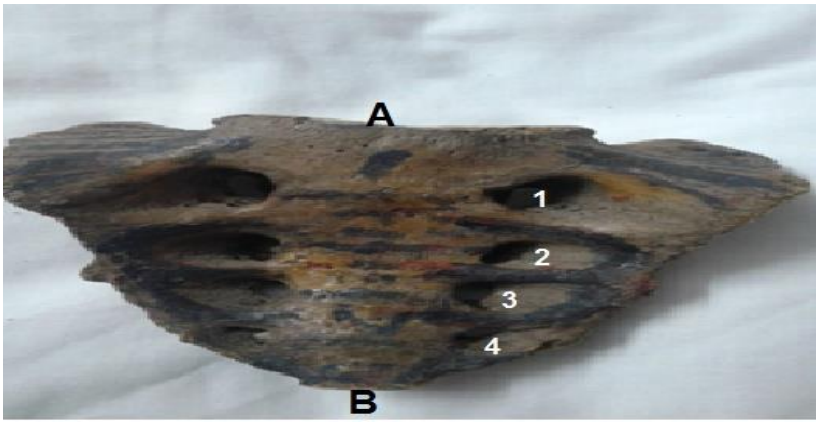

Fig 3: Showing a pattern of measuring maximum length (height) of female sacrum; distance between points **(A** and **B).** Also, it shows 4 pairs of anterior sacral foramina.

Fig 4: Showing a pattern of measuring the auricular surface length of sacrum; distance between points **(A and B).**

Fig 5: Showing an inverted U shaped sacral hiatus.

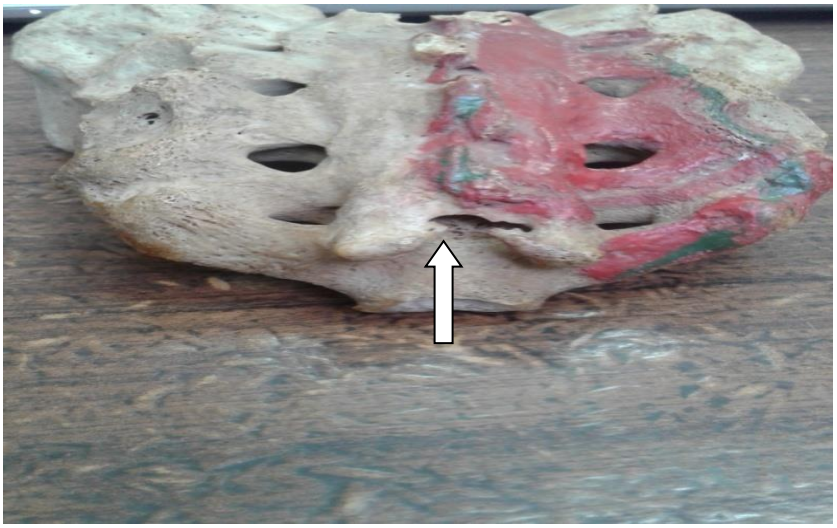

Fig 6: Showing an irregular shaped sacral hiatus.

Fig 7: Showing an Elongated U shaped sacral hiatus.

Fig 8: Showing an Elongated V shaped sacral hiatus.

Fig 9: Showing an Inverted V shaped sacral hiatus.

DISCUSSION

Because of its role in the formation of pelvic girdle and related functional sex variations, the sacrum is often used by medico-legal experts to assess the sex. Much emphasis is focused on the importance of the sacrum during the teaching of sex differences in the bones. Various factors such as race, sex, environmental factors and life style affect the morphology of bones [7].

In the present study, most of the values for parameters such as width (maximum transverse diameter) and height (maximum length) of the sacrum, transverse diameter of the wing (ala) and the base of sacrum were more in males when compared with females. While other parameters like auricular surface length, sacral and auricular indices are higher in females than in males. The mean value of sacral index (SI) was 96.34 in males and 105.62 in females. Mishra et al., [8] found that the mean sacral index (SI) in male and female sacra was 98.21% and 117.84%, respectively, in India. Patel et al., [9] stated that a mean value of (SI) was 96.25 and 113.25 respectively in their work on 32 male and 32 female sacra. Math et al., [10] in their work on 190 male and 64 female sacra noticed the mean value of (SI) to be 94.24 in males and 113.19 in females. Therefore sacral index still remains the best parameter for sex identification amongst the parameters studied. Other parameters studies showed little significance when compared with sacral index. So sacral index may be used together with other parameters to improve the accuracy of sex determination.

In the present study, the male sacra were significantly longer and more curved than female sacra as sacral height and curved length values were higher in male than in female sacra. These findings were in agreement with [8], [11], and [12]. In our study, the mean width of the male sacra is 115mm while it is (105.34mm) in the observations made by [8]. While the females in the present work showed a lesser value (108mm). A study on the Australian females, the maximum width of sacrum was 101.24mm, which is found to be higher than that of males (99.92mm) of the same race [13]. Thus there is a regional and racial difference in the length and width of the sacrum. The mean transverse diameters of body of S1 (base) in female is 52.6 mm which is nearly similar to that of male 53 mm. From the above mentioned results, the

recognition of female sacrum from the male ones by the above mentioned parameters alone is still difficult. In the present study, the mean auricular index is more in females (56.72 mm) than males (52.76mm), unlike the observations made by [8] where he had found the auricular index to be more in males (59.78mm) than in females (51.69mm).

Awareness of the anatomy of the Sacral Hiatus (SH) is of a great importance in clinical conditions requiring CEB for specific lumbosacral spine diagnostic and therapeutic procedures to avoid failure and prevent injury of the dura [14]. The SH has variable sizes and shapes. The laminae of the Sacral Vertebrae may unite in the midline leading to an absence of SH or it may fail to unite leading to incomplete formation of the dorsal wall of the sacral canal. Between these two forms a number of variations in the shape of SH have been found [15]. The sacral hiatus is the most important way to do the caudal epidural anaesthesia. So, the full understanding of the anatomical dimensions and variations of it leads to a high success rate of the caudal epidural block.

In the present work, different parameters of the sacral hiatus were measured on the dry sacra. The study on the shape of the sacral hiatus declared that the most common form is the inverted V shaped hiatus in 50% of males and 38.46% in females. Inverted U, Elongated V, U and irregular shapes were also found. Nagar [16] in his study had noted that the most common shape of sacral hiatus is inverted U (41.5%) and inverted V (27%) which is different from our results. In the present study, the most common forms of SH were the inverted V and inverted U in both males and females. These two shapes provide enough space for needle access during CEB. The other shaped SH provide challenge during CEB. [17] had also observed various shapes of sacral hiatus, most common being inverted V and inverted U in 76.23% of sacra, 7.43% were dumb bell shaped. In the present study, the sacral hiatus length varied from 21-40 mm and its mean was 34.4 mm in males and 28.8 mm in females. [16] stated that, in about 2/3 of sacra (65.8%), the length of sacral hiatus was 11-30 mm but its range was 5-69 mm. In agreement with the results of the present study, Senoglu et al., [18] stated that, the average length of the sacral hiatus was 32.1 ± 9.9 mm, its range was 12-53 mm and in more than two-thirds of the sacra (72.3%), the length of sacral hiatus was 20 – 40 mm. Regarding the sex difference of the length of the sacral hiatus, [19] observed the mean length of the sacral hiatus as 20 mm in Indian males and 18.9 mm in Indian females. However, [20] had reported the sacral hiatus length was 24.8 mm in American males and 19.8 mm in American females and its length varied from 0-60 mm with a mean of 22.5 mm.

The differences between the results of the previous researches might be due to racial difference of the sacral hiatus parameters. In the present study, the mean of the transverse diameter (width) of the sacral hiatus was 14.6 mm in males and 13.4 mm in females. This was almost similar to [19] who reported the transverse diameter of the sacral hiatus at the base ranged from 5- 20 mm in male and was varied from 8-18 mm in female sacra. SH may be difficult to be palpated, especially in overweight patients. So using other prominent anatomical landmarks is required, such as the triangle made between the posterior superior iliac spines and the apex of sacral hiatus this equilateral triangle is a practical guide for determining the site of sacral hiatus easily and increasing the success rate of CEB [21]. Five pairs of sacral foraminae were seen in three male sacra of the present work.

(Sadler, 2000) mentioned that HOX gene is responsible for determining the shapes of vertebrae. Sacralization of the 5th lumbar vertebra or lumbarization of the first sacral vertebra as mentioned in the present work could be due to mutation of HOX gene. Other less common causes as arthritic changes, traumatic injury and intentional spinal fusion surgery may play a role [22]. In the present study, the dimensions (vertical and transverse) distances between the different anterior and posterior sacral foramina were found to be nearly similar to [23] (Turkish population). In addition, these dimensions are crucial during electric stimulation of sacral nerve roots for modulating the lower urinary tract neural reflexes in patients refractory to the conventional treatment. These dimensions assist in many clinical applications such as posterior sacral screw placement during internal fixation.

CONCLUSION

From our findings, we conclude that the sacral index and the maximal sacral length and width are the most significant parameters for sex identification in a positive way. However a single parameter may be of no value in identifying sex of sacrum correctly. Therefore, we can conclude that many parameters should be obtained for better sex determination. In addition to sex differences, knowing the anatomical variations of the sacral hiatus may be helpful in increasing the success rate of caudal epidural anaesthesia.

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