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ORIGINAL RESEARCH

Sex determination using the human sacrum – A morphometric study

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ABSTRACT

Background: The sacrum is a vital bone in the human skeleton, essential for forming the pelvic girdle and providing stability to the body. Its anatomy has significant clinical applications in Orthopedics and anesthesiology. This study investigates the dimensions and measurements of the sacrum to aid in sex determination and improve the efficacy of caudal epidural blocks, ultimately enhancing clinical practices related to this important skeletal structure. **Methods**: The present study was conducted on 110 dry human sacra within one and a half years. Sacra of unknown sex morphometric parameters data were collected from medical colleges of central India. After getting permission from the institutional ethics committee, this study was conducted by the Department of Anatomy, Index Medical College, Hospital and Research Centre, Indore, Madhya Pradesh.The dry sacral bones, which were ossified entirely without any visible variation or damage, were taken for study purposes. All the measurements were performed by using a Vernier digital calliper with an accuracy of 0.1mm. The measurements were recorded, and their mean and standard deviations were calculated. **Results**: This study found that the mean values of sacrum width and length were higher in males than in females. **Conclusion**: The sacral index, along with the maximum sacral length and width, were the most significant parameters for identifying sex. Additionally, understanding the anatomical variations of the sacral hiatus may enhance the success rate of caudal epidural anesthesia.

Keywords: Sacrum- sacral index- auricular index.

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INTRODUCTION

The sacrum is a large triangular bone that forms the posterosuperior wall of the pelvic cavity, situated between the two hip bones. It comprises the fusion of five sacral vertebrae and constitutes the caudal end of the vertebral column. In males, the sacrum is more prominent than in females, while the width of the ala is more significant in females than in males. The sacrum connects above the fifth lumbar vertebra and the coccyx below. It consists of trabecular bone surrounded by a shell of compact bone that varies in thickness. [1].

The vertebral foramen of the sacrum forms the sacral canal, which houses the cauda equina, spinal meninges, and the nerve roots of the sacral and coccygeal regions. The sacral hiatus is the opening at the caudal end of the sacral canal. This opening occurs due to the failure of fusion of the laminae of the fifth sacral vertebra and occasionally the fourth. It is located inferior to the fused spines of the fourth (or third) sacral vertebrae, which also mark the lower end of the median sacral crest. The shape of the sacral hiatus is variable, but it is generally triangular, with the apex facing upward and the base facing downward. It contains the fifth pair of sacral nerves, the coccygeal nerve, and the filum terminale. The location of the sacral hiatus can be identified by palpating the sacral cornua, which are the remnants of the inferior articular processes that extend downward on each side of the sacral hiatus.[2].

The sacral hiatus is located posteriorly and is covered by skin, a subcutaneous fatty layer, and the sacrococcygeal membrane. The dural sac ends at the level of the S2 vertebra. Below this level, the sacral canal contains extradural fat, vertebral venous plexus, lower sacral nerve roots, and the filum terminale.[1]

On the posterior aspect of the sacrum, lateral to the intermediate crest, are four dorsal sacral foramina that allow the passage of the posterior divisions of the sacral nerves. Additionally, four pairs of ventral sacral foramina permit the passage of the anterior divisions of the sacral nerves. In some cases, the first sacral vertebra may not fuse with the other four sacral vertebrae, a condition known as lumbarization of the

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first sacral vertebra, resulting in three pairs of sacral foramina. Conversely, the fifth lumbar vertebra may fuse with the first sacral vertebra, a condition known as sacralization of the fifth lumbar vertebra, leading to five pairs of dorsal sacral foramina.[3]

Understanding the variations in the number of dorsal sacral foramina is crucial, as these foramina serve as an essential anatomical landmark in spinal surgery. They can also be used for blocking sacral nerves to minimize pain and perform anesthesia during pelvic surgeries. The caudal epidural block is accomplished by inserting a needle into the epidural space via the sacral hiatus to deliver medication effectively.

METHODS & MATERIALS

The present study was conducted on 110 dry human sacra within one and a half years. Sacra of unknown sex morphometric parameters data were collected from medical colleges of central India. After getting permission from the institutional ethics committee, this study was conducted by the Department of Anatomy, Index Medical College, Hospital and Research Centre, Indore, Madhya Pradesh.The dry sacral bones, which were ossified entirely without any visible variation or damage, were taken for study purposes. The sacral hiatus's shape, apex, and base will also be noted. Sacra with pathological changes were excluded from the study.

The following equipment was used for measuring the different parameters

1. Sliding vernier caliper
2. Divider
3. Steel Measuring Scale
4. Flexible ribbon tape

STATISTICAL ANALYSIS

All measurements were tabulated and statistically analyzed for mean and standard deviation by using Statistical Package for the Social Science software (SPSS)

RESULTS

Table 1 presents detailed statistical information, including the mean and standard deviation (SD) for various measurements related to the sacrum. Specifically, these measurements encompass the length and width of the sacrum, the sacral index, and the inner curvature of the sacrum. This data provides insights into the average dimensions and variability of these anatomical features, which may be relevant for further research and analysis in the field.

Table 1: Showing the meaning and standard deviation of various parameters included in this study. (N=110)

Parameters	Mean(mm)±SD	
	Female (n=60)	Male (n=50)
The Maximum Length (mm)	103.7±6.87	118.6±6.53
The maximum Width (mm)	116.53±13.27	117.31±12.87
Sacral Index	104.5±10.87	97.54±9.34
Inner curvature of Sacrum	107.65±11.54	106.37±10.53

Table 2 illustrates the average measurements of the sacral hiatus's width and height. This data provides insight into the sacral hiatus's anatomical characteristics, contributing to a better understanding of its dimensions in the population studied. The mean values presented in these visuals highlight the sacral hiatus's typical size, which is crucial for various medical applications, including surgical procedures involving the sacral region.

Table 2: Showing the mean and standard deviation of the width and the height of the sacral hiatus

Parameters sacral hiatus	Mean(mm)±SD	
	Female	Male
Height	29.87±5.79	34.74±6.43
Width	14.78±5.67	15.65±7.51

Table 3 shows a variety of sacral hiatus shapes, as illustrated in Table 3 and Figure 3. The analysis revealed that the most prevalent shape among the sample population was the inverted U shape. This was closely followed by the inverted V shape, which also appeared frequently. Additionally, we identified a less common shape, characterized as a dumbbell. These findings contribute to understanding anatomical variations in sacral hiatus shapes within this demographic, highlighting the diversity in human anatomy.

Table 3: Morphology of sacral hiatus.

Shapes of sacral hiatus	Number (n)	Percentages (%)
Inverted U	57	51.8%
Inverted V	49	44.5%
Dumbbell	4	3.6%
Irregular	0	0
Inverted J	0	0

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Inverted W	0	0
Elongated d	0	0

Table 4: level of apex of sacral hiatus in male and female sacra

The apex of the sacral Hiatus	Female(n=60)	Male (n=50)	Total
S2	2(3.3%)	7(7%)	9(8.1%)
S3	1(1.66%)	3(6%)	4(3.6%)
S4	43(71.66%)	29(48%)	72(65.5%)
S5	14(23.33%)	11(22%)	25(22.7%)

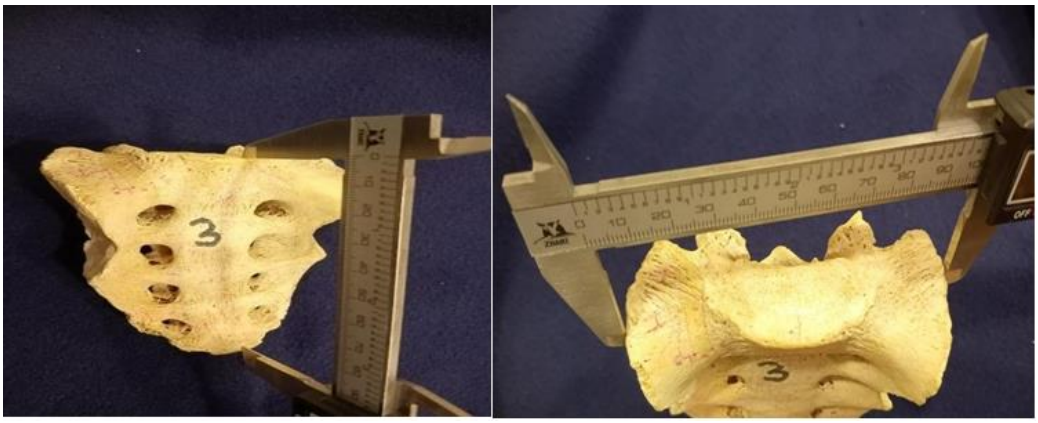

Figure 1: Showing the Maximum Length and width of theSacrum

Figure 2: Showing Inverted U Shape Sacral hiatus

Figure 3: Showing Inverted V Shape Sacral hiatus

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Figure 4: Showing sacral Dumble shape hiatus

DISCUSSION

This study examined 110 dry human sacra from central India in the Department of Anatomy. The sacrum is a bone that exhibits many variations, particularly in its sacral hiatus. The sacral hiatus is a variable space utilized for administering caudal epidural anaesthesia for various purposes. Additionally, the human sacral bone plays a significant role in gender identification.

Our study measured the mean length of the sacrum in a population from central India. Our comparison between males and females revealed that the average length of the male sacra was greater than that of the female sacra. A study conducted by Mishra SR et al. [4] in the population of Agra, India, revealed interesting findings regarding the length of the sacrum. The researchers recorded a mean sacral length of 107.53 mm in males, notably more significant than the mean length of 90.58 mm observed in females. This pattern is consistent with our research conducted in the central region, where we found the mean sacral length to be 103.7 mm in males and 118.6 mm in females. Another study by Kanika et al. focused on North India and reported approximately similar results, with mean sacral lengths of 104.1 mm for males and 91.8 mm for females. These findings underscore the significant sexual dimorphism present in sacral dimensions within these populations.

In our study, the mean length of the sacrum in males was found to be 118.6 mm, which is significantly greater than the mean length in females, measured at 103.7 mm. This contrasts with a study conducted by Jyothinath K et al. [5], which reported a greater length of the sacrum in females. In another study by Parashuram R et al. [6], the length of the sacrum in males was 120.13 mm, compared to 103.78 mm in females, which aligns more closely with our findings. Additionally, studies by other authors, such as Kataria et al. [7] from Rajasthan and Bindra GS & Mohan A [8] from Haryana, demonstrated similar results.

Whereas in a study done by Sachdeva et al. [9] Sacral Index was more compared to the present study in both the Gender, that is, in males (100.24mm) and in females (111.74mm).

Our study revealed that the average width of the sacrum among the population in central India was 117.31 mm for males and slightly less, at 116.53 mm, for females. This indicates a clear distinction, with the male sacra exhibiting a greater average width compared to their female counterparts. Interestingly, our findings contrast sharply with those reported by Kanika et al. [7], who conducted a similar analysis in North India and found average sacral widths of 103.1 mm for males and 101.7 mm for females. Additionally, a study by Mishra SR et al. [4], carried out in the Agra region, concluded that there was no significant difference in the sacral width between males and females. This variation in results highlights the importance of considering geographic and demographic factors when studying anatomical differences.

In our study, we observed that the mean value of the Sacral Index was notably higher in females, recorded at 104.5 mm, compared to 97.54 mm in males. This finding aligns closely with a similar study by Patel MM et al. [8] in Gujarat, which reported a sacral index of 96.25 mm in males and 113.25 mm in females. Furthermore, our results corroborate those of Nisha Yadav et al. [10] from Maharashtra, who determined mean sacral index values of 98.44 mm for males and 113.73 mm for females. These comparative findings highlight the consistent trend of a higher sacral index in females across different studies.

In our investigation of the inner curvature of the sacra, we observed that the measurements for males averaged 106.37 mm, while for females, the average was slightly higher at 107.65 mm. This contrasts with findings reported by Mishra SR et al. [4] in Agra, where the mean curvature indices were significantly more significant, with males measuring 119.56 mm and females at 100.95 mm. These figures suggest a

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notable divergence from our study's results. Additionally, we encountered contrasting data from Dr. S. Ranjan Bajpai [10], who reported a curvature index of 93.3 mm for males and 88.6 mm for females. These measurements were lower than those found in our research, highlighting the variability in sacral curvature across different studies.

The present study revealed that the inverted U shape was the most prevalent configuration, appearing in 58.8% of cases. This was closely followed by the inverted V shape, which accounted for 44.5%. The dumbbell shape was notably lower, observed in just 3.6% of instances. These findings align closely with the research conducted by Archana Singh et al. [11], who reported an inverted U shape in 60.7% of their study sample, while the inverted V shape was less common and found in 25% of cases. In contrast, a study carried out by MB Sinha et al. [12] in central India presented different results, with the inverted U shape reported at 35.93% and the inverted V shape at 17.18%, both figures being substantially lower than those obtained in our study.

Many studies have examined the anatomy of the sacral hiatus, revealing that the most frequently observed shape is the Inverted U, closely followed by the Inverted V. Notably, a study conducted by Vinod Kumar [13] and colleagues recorded a variety of shapes, identifying the Inverted V as the most prevalent, occurring in 46.53% of cases, while the Inverted U was found in 29.70% of instances. This variation in morphology highlights the diversity in anatomical presentations of the sacral hiatus among individuals.

CONCLUSION

Our findings suggest that the sacral index, along with the maximum sacral length and width, plays a crucial role in determining sex with a positive degree of accuracy. However, it is important to note that using a single parameter may not provide reliable identification of the sacrum's sex. To improve the accuracy of sex determination, we advocate for collecting multiple anatomical parameters in conjunction. Additionally, gaining insights into the anatomical variations of the sacral hiatus can be beneficial, as it may enhance the success rate of caudal epidural anaesthesia. This holistic approach improves diagnostic accuracy and optimizes clinical outcomes in procedures involving the sacral region.

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