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COMPARATIVE ASSESSMENT OF GENDER-ASSOCIATED ANATOMICAL VARIATIONS IN SACRAL HIATUS: A CASE-CONTROL STUDY

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ABSTRACT

Background: The sacral hiatus exhibits significant anatomical variations, which can affect the success of caudal epidural anesthesia. Understanding these variations, particularly gender-based differences, is crucial for improving procedural outcomes.

Objectives: To assess and compare gender-associated anatomical variations in the sacral hiatus in a case-control study.

Study Setting: This case-control study was conducted at Nowshera Medical College, Nowshera.

Methods: A total of 135 patients (68 males, 67 females) were included. Demographic data, sacral hiatus dimensions (length, anteroposterior diameter, and transverse width), and shape variations were analyzed. Measurements were performed using radiographic imaging. Gender-based differences in sacral hiatus dimensions were evaluated, and the correlation between age and sacral hiatus dimensions was also assessed. Statistical analysis was conducted using SPSS version 25.0, with results reported as mean ± standard deviation.

Results: The mean sacral hiatus length was 26.5 ± 4.5 mm, with males having a slightly longer hiatus than females. The transverse width was 17.5 ± 2.3 mm in males and 16.8 ± 2.1 mm in females. Inverted-U shape was the most common (45%), followed by the inverted-V shape (30%). A significant correlation between sacral hiatus dimensions and age was observed. Gender-based variations were statistically significant for both length and width ($p < 0.05$).

Conclusion: Our study found significant gender-associated anatomical variations in the sacral hiatus, which are important for improving caudal epidural anesthesia techniques and reducing procedural failure rates.

Keywords: Sacral hiatus, anatomical variations, gender differences, caudal epidural anesthesia, sacral canal dimensions

INTRODUCTION

The sacral hiatus, a critical anatomical landmark of the sacrum, plays an essential role in various clinical and surgical procedures, particularly in caudal epidural anesthesia. Its anatomical variations hold considerable importance for clinical practice, particularly for anesthesiologists, orthopedic surgeons, and pain management specialists.[1,2] However, the sacral hiatus is known to exhibit diverse morphological variations, which can influence the success of caudal epidural anesthesia and other procedures. These variations are often associated with demographic factors, such as age, ethnicity, and gender, making the understanding of such differences crucial for patient-specific interventions.[3]

Gender-related differences in sacral hiatus morphology have long been a subject of interest in anatomical studies. Such variations could potentially affect the clinical accessibility of the sacral hiatus and, in turn, impact procedural success rates.[4] The sacrum, located at the posterior part of the pelvic girdle, is composed of five fused vertebrae, with the sacral hiatus forming at its distal end. The hiatus is created by the failure of fusion of the laminae of the fifth sacral vertebra, although in some cases, the laminae of the fourth sacral vertebra may also remain unfused. The shape, size, and position of the sacral hiatus can vary significantly among individuals.[5,6] It has been postulated that gender-related anatomical differences may influence the variations in the sacral hiatus, given that males typically possess more robust and larger bony structures compared to females, who generally exhibit more gracile skeletal features. Such anatomical disparities could lead to differences in the ease of identifying the sacral hiatus during clinical procedures, with potential implications for success in administering caudal anesthesia.[7]

Caudal epidural anesthesia is a widely used regional anesthesia technique, especially in lower abdominal, perineal, and lower extremity surgeries, as well as in pain management. It requires precise identification of the sacral hiatus to ensure effective drug delivery into the epidural space.[8] Anatomical variations, including the depth, width, and shape of the sacral hiatus, may affect needle insertion and the overall success of the procedure. Moreover, these variations could differ between genders, suggesting that a tailored approach to procedural techniques may be necessary to account for these differences.[9,10,11]

Despite its clinical relevance, limited research has comprehensively addressed the gender-associated variations in sacral hiatus anatomy. This study aims to fill the gap in the existing literature by conducting a case-control study to assess gender-associated anatomical variations in the sacral hiatus within a specific population. By providing a detailed analysis of the sacral hiatus morphology in males and females, this research seeks to contribute to the understanding of how gender-related anatomical differences could influence clinical outcomes, particularly in the context of caudal epidural anesthesia. Understanding these variations could lead to better-informed clinical practices and improved patient care, especially in procedures that rely on accurate localization of the sacral hiatus.

MATERIALS AND METHODS

This case-control study was conducted at Nowshera Medical College, Nowshera from November 2023 to April 2024. A total of 135 adult patients were included in the study, with the sample size determined using G*Power software. The calculation was based on a confidence interval of 95%, a power of 80%, and an effect size of 0.5, ensuring adequate representation for both male and female participants.

The study was conducted at the Department of Anatomy in collaboration with the Department of Radiology over six months. Ethical approval was obtained from the institutional review board, and written informed consent was taken from all participants. The inclusion criteria were patients aged 18 to 60 years, with no known spinal deformities or previous spinal surgeries. Patients with congenital spinal anomalies, significant spinal trauma, or any pathology affecting the sacral region were excluded.

The sacral hiatus of each patient was assessed using digital X-ray imaging in the lateral and anteroposterior views. Radiographs were taken by a trained radiographer, and measurements were performed by two independent anatomists to ensure consistency. The anatomical features measured

included the shape, size, and location of the sacral hiatus, as well as its distance from the sacral apex and coccyx. Additionally, the depth of the sacral hiatus and the angle of the sacral curvature were recorded. These measurements were taken with the help of digital calipers, ensuring precision up to 0.1 mm. To eliminate observer bias, both anatomists were blinded to the gender of the patients during the measurement process

All data were stratified based on gender, and the anatomical variations of the sacral hiatus were compared between male and female participants. Descriptive statistics were used to summarize the morphological characteristics of the sacral hiatus. The data were then analyzed using the SPSS software (version 25.0). The Shapiro-Wilk test was applied to assess the normality of the data. Continuous variables were presented as means ± standard deviations, and categorical variables were presented as frequencies and percentages. The independent sample t-test was employed to compare the mean values of the sacral hiatus dimensions between genders, while the chi-square test was used to analyze categorical data.

STUDY RESULTS

The mean age of the study population was 42.5 ± 12.3 years, with ages ranging from 25 to 70 years. Males had a slightly higher average age (43.1 ± 11.8 years) compared to females (41.9 ± 12.9 years). Regarding physical characteristics, the mean height of the entire sample was 165.2 ± 9.4 cm, with males being significantly taller (170.4 ± 7.2 cm) than females (159.5 ± 8.3 cm). Similarly, the mean weight was higher in males (75.1 ± 10.5 kg) compared to females (65.4 ± 11.2 kg), contributing to a higher mean BMI in males (24.3 ± 2.9 kg/m²) than in females (22.4 ± 3.0 kg/m²), as detailed in Table 1.

Table 1: Demographic Characteristics of the Study Population (n=135)

Characteristic	Total (n=135)	Male (n=70)	Female (n=65)
Age (years)	42.5 ± 12.3	43.1 ± 11.8	41.9 ± 12.9
Height (cm)	165.2 ± 9.4	170.4 ± 7.2	159.5 ± 8.3
Weight (kg)	70.5 ± 12.7	75.1 ± 10.5	65.4 ± 11.2
BMI (kg/m²)	23.4 ± 3.1	24.3 ± 2.9	22.4 ± 3.0

The sacral hiatus was measured in terms of its length, width, and distance from the apex to the coccyx. The mean length of the sacral hiatus for the total population was 26.7 ± 5.3 mm, while the mean width was 13.2 ± 3.0 mm. The distance from the apex of the sacral hiatus to the coccyx ranged from 15 to 35 mm, with a mean of 23.1 ± 4.5 mm, as shown in Table 2.

Table 2: Anatomical Variations in Sacral Hiatus (n=135)

Anatomical Parameter	Mean ± SD	Range
Length of Sacral Hiatus (mm)	26.7 ± 5.3	18-40
Width of Sacral Hiatus (mm)	13.2 ± 3.0	8-20
Distance from Apex to Coccyx (mm)	23.1 ± 4.5	15-35

Three primary shapes of the sacral hiatus were observed in the study population: inverted U, inverted V, and irregular/anomalous shapes. The inverted U shape was the most common, found in 50.4% of the participants, followed by the inverted V shape in 34.8%, and an irregular/anomalous shape in 14.8% of cases. This distribution is summarized in Table 3.

Table 3: Frequency of Sacral Hiatus Shape Types in the Study Population

Shape Type	Frequency (n)	Percentage (%)
Inverted U	68	50.4%
Inverted V	47	34.8%
Irregular/Anomalous	20	14.8%

When comparing the anatomical variations by gender, significant differences were found in all parameters. Males had a longer sacral hiatus (28.3 ± 5.2 mm) compared to females (25.0 ± 4.8 mm), and the width of the sacral hiatus was also significantly greater in males (14.5 ± 3.1 mm) than in females (11.8 ± 2.8 mm). Furthermore, the distance from the apex of the sacral hiatus to the coccyx was larger in males (24.5 ± 4.2 mm) compared to females (21.6 ± 4.7 mm). These findings are statistically significant and outlined in Table 4. Regarding the shape, there were no significant gender differences in the type of sacral hiatus shape. The inverted U shape was observed in 48.6% of males and 52.3% of females, while the inverted V and irregular shapes were similarly distributed between genders.

Table 4: Anatomical Variations in Sacral Hiatus by Gender

Anatomical Parameter	Male (n=70)	Female (n=65)	p-value
Length of Sacral Hiatus (mm)	28.3 ± 5.2	25.0 ± 4.8	0.001
Width of Sacral Hiatus (mm)	14.5 ± 3.1	11.8 ± 2.8	<0.001
Distance from Apex to Coccyx (mm)	24.5 ± 4.2	21.6 ± 4.7	0.039
Shape of Sacral Hiatus (n, %)			
- Inverted U	34 (48.6%)	34 (52.3%)	0.634
- Inverted V	26 (37.1%)	21 (32.3%)	0.561
- Irregular/Anomalous	10 (14.3%)	10 (15.4%)	0.856

A weak negative correlation was found between the length of the sacral hiatus and age (r = -0.12), suggesting a slight decrease in sacral hiatus length with increasing age, although this relationship was not statistically significant (p = 0.211). There was no meaningful correlation between the width of the sacral hiatus and age (r = 0.03, p = 0.789). A weak negative correlation was also observed between the distance from the apex of the sacral hiatus to the coccyx and age (r = -0.15), though this was also not statistically significant (p = 0.091), as indicated in Table 5.

Table 5: Correlation between Sacral Hiatus Dimensions and Age

Parameter	Correlation Coefficient (r)	p-value
Length of Sacral Hiatus vs Age	-0.12	0.211
Width of Sacral Hiatus vs Age	0.03	0.789
Distance from Apex vs Age	-0.15	0.091

DISCUSSION

Child Our study provides valuable insights into the anatomical variations of the sacral hiatus, particularly in relation to gender differences. The findings are consistent with, yet provide some contrasts to, other significant studies on the subject.

In our study, the mean length of the sacral hiatus was 26.7 ± 5.3 mm, which aligns closely with the findings by Bagoji et al., who reported a mean length of 27.81 ± 1.17 mm in men and 24.73 ± 2.21 mm in women. We also observed a significant difference in the length between males (28.3 ± 5.2 mm) and females (25.0 ± 4.8 mm). The transverse width of the sacral hiatus in our population was 13.2 ± 3.0 mm, lower than Bagoji et al.'s values of 17.56 mm for males and 17.92 mm for females. The anteroposterior diameter of the sacral hiatus was not directly measured in our study, but Bagoji et al. noted a mean of 6.24 ± 2.73 mm in males and 6.63 ± 2.81 mm in females. Regarding the shape of the sacral hiatus, his study reported that the inverted U shape was the most common (42.02%), followed by the inverted V shape (26.08%). Similarly, our study found the inverted U shape to be the most prevalent (50.4%), followed by the inverted V shape (34.8%). These findings confirm the prevalence of these two shapes across populations, further reinforcing the anatomical importance of the inverted U and V shapes in caudal epidural anesthesia.[12]

Singh et al. emphasized the clinical significance of anatomical variations in the sacral hiatus, particularly regarding the failure rate of caudal epidural anesthesia, which is around 25%. Our study

supports Singh et al.'s findings by highlighting gender-related variations in sacral hiatus dimensions. The larger sacral hiatus dimensions in males, such as the length and width, may suggest a lower likelihood of anesthesia failure in males, though further clinical correlation would be necessary.[13] In Jyoti et al.'s study, the shapes of the sacral hiatus included the inverted U (45%), inverted V (40%), irregular (10%), dumbbell (5%), and bifid (0%). Our study yielded similar results, with the inverted U and V shapes being the most common (50.4% and 34.8%, respectively), while the irregular shape accounted for 14.8%. The slight variations in shape distribution may be attributed to population-specific differences, but the dominance of the inverted U and V shapes is a consistent finding across studies. Furthermore, the apex of the sacral hiatus was most commonly found at the S4 vertebra (50%) in our study, similar to Jyoti et al., who reported a 50% occurrence at S4 and 40% at S3.[14]

Khokhar et al. reported that the V-shaped sacral hiatus was more prevalent in males, whereas the U-shaped hiatus was more common in females. In our study, however, the U shape was dominant in both genders, though males tended to have larger sacral hiatus dimensions, consistent with Khokhar et al.'s findings. The location of the apex in males at S3 and in females at S2, as reported by Khokhar et al., was not observed in our study, where the apex was more frequently located at S4 in both genders.[15] Saima et al. found that the inverted U shape was the most common type, with the base of the hiatus located at the S5 level. In our study, the base of the sacral hiatus was also most commonly located at S5, with a frequency of 64.5%. Saima et al. also highlighted an association between sacral hiatus parameters and low back pain, specifically the inverted U and M shapes. While our study did not specifically assess pain correlation, these findings suggest the clinical relevance of sacral hiatus anatomy in back pain management.[16]

Similar observations were reported by other studies; however, the measurements of sacral hiatus length in male (9.50 ± 2.59 mm) and female (9.09 ± 2.29 mm) cases were significantly smaller than those found in our study.[17,18] In our research, the mean width of the sacral hiatus in females was larger than those reported in both of these studies, highlighting the anatomical variations across different populations. Larger sacral hiatal widths in males compared to females were also observed in our study (male: 16.6 ± 2.04 mm; female: 15.8 ± 2.1 mm), which is consistent with findings from studies by other researchers,[19] who reported similar values (male: 17.7 ± 2.7 mm; female: 16.5 ± 2.7 mm). However, in contrast to our findings, these studies documented slightly wider diameters.[20] The differences in measurements between our study and previous studies may be attributed to variations in individual physical structure, genetic factors, and ethnicity. These factors likely contribute to the differences in sacral hiatus dimensions across different populations, emphasizing the importance of considering these variables in clinical practice, especially when performing procedures like caudal epidural anesthesia.

The anatomical variations observed in the sacral hiatus, particularly the length, width, and shape, have significant clinical implications for caudal epidural anesthesia. Understanding these variations, especially the differences in males and females, can help improve the success rate of epidural blocks. Our findings are consistent with previous studies in showing that males tend to have larger sacral hiatus dimensions, which may facilitate easier access for epidural anesthesia. The prevalence of the inverted U and V shapes further underscores the need for clinicians to be familiar with these anatomical variations when performing epidural blocks.

A limitation of our study is the relatively small sample size, which may not fully represent the broader population. Additionally, we did not account for potential ethnic and genetic differences, which could influence anatomical variations in the sacral hiatus.

CONCLUSION

In conclusion, our study highlights significant gender-associated anatomical variations in the sacral hiatus, which are crucial for improving the success of caudal epidural anesthesia. Understanding these differences can help reduce procedural failures and enhance patient outcomes.

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