Anatomical Variations and Clinical Correlations of Sacral Hiatus and Sacral Canal

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ABSTRACT

Background: Sacral hiatus is nonfusion of the lamina of a fifth sacral vertebra in midline on the dorsal surface. The caudal epidural block is a common technique to introduce a needle into epidural space through sacral hiatus for surgical anesthesia and analgesia.

Aim: The objective was to study the morphological and morphometric variations of sacral hiatus and sacral canal in human sacra and to provide bony parameters for localization of sacral hiatus as an important landmark to access the epidural space for various clinical procedures successfully.

Materials and methods: The study was executed on 88 dry adult human sacra to scrutinize certain parameters of sacral hiatus and sacral canal including the shape of sacral hiatus, level of apex and base of sacral hiatus, length of sacral hiatus, anteroposterior distance at apex of sacral hiatus and intercortnual distance at the base of hiatus.

Results: Inverted ‘U’ shape was most frequent (35.22%) followed by inverted ‘V’ shape (29.24%). The apex and base of sacral hiatus were commonly found at fourth (57.54%) and fifth (92.04%) sacral vertebral level respectively. The mean length of sacral hiatus was 28.17 ± 16.62 mm, the anteroposterior diameter at the apex of sacral hiatus was 6.66 ± 2.71 mm, and the intercortnual distance at the base was 16.39 ± 3.44 mm.

Conclusion: Thorough knowledge of relevant anatomy and anatomical variations of sacral hiatus are imperative for clinicians for successful caudal epidural anesthesia.

Clinical significance: During caudal epidural anesthesia, incorrect needle placement in sacral hiatus may result in intraosseous drug toxicity and aspiration. Awareness about sacral hiatus and its variations may improve the understanding of disorders related to sacral nerve injuries.

Keywords: Caudal epidural block, Caudal epidural anesthesia, Sacrum, Sacral hiatus, Sacral canal.

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INTRODUCTION

The sacrum is present between the two hip bones and forms the posterosuperior limit of the pelvic cavity. This large triangular bone is formed by the union of five sacral vertebrae and its transverse processes including their costal elements (SI–S5). Fusion of these primary cartilaginous joints starts at puberty from below upwards to form sacrum. The complete fusion of sacrum occurs between 23 years and 33 years of life. Sacrum articulates caudally with coccyx (sacroccygeal joint) and cranially with fifth lumbar vertebra (lumbosacral joint). Vertebral foramina of five sacral vertebrae fuse posteriorly to form a sacral canal. It contains spinal meninges, epidural venous plexus, sacral and coccygeal nerve roots, filum terminale externum, cauda equina, and the fibrofatty tissue. The opening at the lower end of the sacral canal is called sacral hiatus, which is produced by the nonfusion of the lamina of the fifth sacral vertebra (S5). The developmental defect of nonfusion of the lamina of vertebral column or sacrum in the midline is known as spina bifida. Lumbar and sacral regions are the most common sites for complete agenesis of the sacrum. The filum terminale is present in sacral hiatus along with the fifth pair of sacral nerve and coccygeal nerve. The hiatus is enclosed posteriorly by skin, superficial fatty layer and sacrococcygeal membrane. The inferior articular processes of the fifth sacral vertebra project downwards to form the sacral cornu on both the sides of sacral hiatus. Sacral cornu is a chief landmark to move towards sacral hiatus during caudal epidural anesthesia as it lies about 0.5 cm above the tip of coccyx at the superior end of natal cleft.

Caudal epidural anesthesia (CEA) is a common regional anesthesia to block sacral nerves through epidural space of sacral hiatus. Edward used the sacral hiatus to give caudal analgesia in labor pain for the first time. Knowledge of anatomical position, size, and shape of sacral hiatus have an important role in successful needle placement during caudal epidural block (CEB) in painless deliveries, orthopedic and perineal surgeries. Corticosteroid injections are also given through this route in sciatica. Contrast dyes are injected through sacral hiatus in epidural space in epidurography and spinal endoscopy.

The sacral hiatus shows many variations in their shape and extent as per the literature review. Variation
in the anatomical structure of sacral hiatus is a foremost cause of complications during the caudal epidural anesthesia such as a dural puncture.\textsuperscript{10,11} In 25% of cases, incorrect needle placement has been reported even with the experienced hand.\textsuperscript{12} Ultrasonography, fluoroscopy and other imaging technologies have been increasingly used to guide caudal epidural block with recent advancement. The objective of the current study was to find out the morphological variations of the sacral canal and sacral hiatus with its clinical correlations for successful anesthetic procedures and surgeries in various clinical settings.

**MATERIALS AND METHODS**

Eighty-eight completely ossified and undamaged, undetermined age and sex, dry sacral bones were obtained from Department of Anatomy, Army College of Medical Sciences, New Delhi, India. Anatomical measurements for these specimens of sacrum were taken by using aerospace digimatic vernier caliper (range 0–150 mm) accurate up to 0.01 mm. We were inquisitive to verify the significance of anatomical variations of sacrum related to their shape and extent of sacral hiatus and sacral canal. Each sacrum was studied to evaluate the shape of sacral hiatus, level of apex and base of sacral hiatus, length of sacral hiatus from apex to midpoint of the base, anteroposterior diameter at the apex of sacral hiatus and intercornual distance at the base of sacral hiatus. Observations were noted and analyzed by using Microsoft Excel and Statistical Package for Social Sciences (SPSS), version 22 (SPSS-22, IBM, Chicago, IL, USA). Mean, standard deviation and range of collected data were then calculated.

**RESULTS**

Morphological and morphometric measurements of sacrum were observed for sacral hiatus, and the sacral canal is given in Tables 1 to 6. Out of 88 sacra, three cases were showing complete agenesis (3.4%) (Fig. 1), and seven sacra were showing partial agenesis (7.95%) (Fig. 2) of dorsal wall of the sacral canal. Sacral hiatus was absent in eight sacra because of the merging of the laminae of fifth sacral vertebrae (length of sacral hiatus ≤6 mm) (Fig. 3).

| Shape of sacral hiatus | Number of sacra (n = 88) | Percentage |
|------------------------|--------------------------|------------|
| Inverted ‘U’ shaped     | 31                       | 35.22      |
| Inverted ‘V’ shaped     | 26                       | 29.54      |
| Irregular shaped        | 13                       | 14.77      |
| Absent sacral hiatus    | 8                        | 9.09       |
| Partial dorsal wall agenesis | 7                | 7.95       |
| Complete dorsal wall agenesis | 3                    | 3.4        |

Sacral hiatus of inverted ‘U’ shape (Fig. 4) was the most frequent shape seen in 35.22% cases followed by Inverted ‘V’ shape (29.54%) (Fig. 5). 14.77% of cases were found with the irregular shape of sacral hiatus (Fig. 6).
and Table 1). The most usual position for the apex of sacral hiatus was fourth sacral vertebra (57.45%) (Table 2), while the base was at fifth sacral vertebra (92.04%) (Table 3). The mean length of the sacral hiatus was 28.17 ± 16.62 mm (range 2–88 mm) (Table 4). The mean ± SD for intercornual transverse diameter at fifth sacral vertebra was calculated 16.39 ± 3.44 mm (range 8–25 mm) (Table 5). The mean ± SD for anteroposterior diameter was 6.66 ± 2.71 mm (range 1.5–15 mm) at the apex of sacral hiatus (Table 6).
DISCUSSION

Sacral hiatus is a significant bony landmark for the successful caudal epidural block. Detection of caudal epidural space is not achievable always for even experienced clinicians because of the influence of anatomical variations of the sacrum. Our measurements will lead to an increase in the success rate of the caudal epidural block by easy detection of sacral hiatus.

Shape of Sacral Hiatus

According to standring S², the sacral hiatus is usually triangular, or inverted ‘U’ shaped structure. Following studies by Nagar,¹³ Seema,¹⁴ Sinha,¹⁵ Nadeem,¹⁶ Ukoha,¹⁷ Akhtar¹⁸ observed that inverted ‘U’ shape is the most frequent shape of sacral hiatus followed by inverted ‘V’ shape as observed in the current study. Whereas, Kumar¹⁹ and Nasr¹ observed that inverted ‘V’ shape is more common than inverted ‘U’ shape. In our study, the sacral hiatus was absent in 9.09% cases probably because of bony overgrowth or fused lamina of the sacrum (Table 7). The absent sacral hiatus may cause needle breakage or obstruction during needle insertion for caudal epidural anesthesia. The precise knowledge of sacral hiatus will increase the success rate of caudal epidural block. Tsui²⁰ observed a 25% failure rate in the caudal epidural block and reported anatomical variations in sacral hiatus as the commonest cause of failure.

Apex of Sacral Hiatus

Awareness about the position of the apex of sacral hiatus is imperative as it lies near to the lower edge of the dural sac. Higher apex leads to additional chances of dural sac puncture at the time of caudal epidural anesthesia. Thus, in cases of the higher apex, more precautions are required while deciding the length of the spinal needle for CEA procedure. Previous studies by Nagar,¹³ Seema,¹⁴ Sinha,¹⁵ Ukoha,¹⁷ Chhabra,²¹ and Akhtar¹⁸ reported maximum cases of the apex of sacral hiatus at fourth sacral vertebra (S4). Nadeem¹⁶ reported the most common site for the apex of sacral hiatus at the level of coccyx (Table 8). The current study shows that intercornual distance at the base of sacral hiatus ranged from 8 to 25 mm with a mean of 16.39 ± 3.44 mm. In 54.54% cases, the transverse width of sacral hiatus was calculated between 15.1 mm and 20 mm followed by 30.68% between 10.1 mm and 15 mm. Kumar,¹⁹ Nagar,¹³ Sinha,¹⁵ and Akhtar¹⁸ found intercornual distance at the base of sacral hiatus between 10.1 mm and 15 mm in 52%, 54%, 41.93%, and 48.39% cases respectively, whereas, we found maximum cases (54.54%) in 15.1–20 mm range. Nadeem¹⁶ also

| Shape of sacral hiatus | Kumar V | Seema | Sinha MB | Nadeem G | Ukoha U | Akhtar J | Nagar SK | Nasr AY | Present study |
|------------------------|---------|-------|---------|----------|---------|---------|---------|--------|--------------|
| inverted ‘U’ shape     | 29.70%  | 42.95%| 35.93%  | 56%      | 48.2%   | 44.36%  | 41.50%  | 31.33% | 35.22%       |
| inverted ‘V’ shape     | 46.53%  | 27.51%| 17.18%  | 14%      | 34.9%   | 35.48%  | 27%     | 38.66% | 29.54%       |
| Irregular              | –       | 16.10%| 15.62%  | 16%      | 4.8%    | 8.87%   | 14.10%  | 15.33% | 14.77%       |
| Absent                 | 0.99%   | 2.51% | 3.12%   | –        | 1.20%   | 2.42%   | 0.70%   | –      | 9.09%        |
observed 52% of cases with more than 15 mm width. Mustafa reported the mean transverse width of the base of sacral hiatus was 1.7 ± 0.26 cm in Egyptian sacra which is comparable to our study.

### Anteroposterior Diameter of Sacral Hiatus at its Apex

Anteroposterior diameter of the sacral canal is imperative for CEB procedures because it gives adequate space to enter the needle in the epidural space of sacrum. The discrepancy in the diameter of the sacral canal would result in deposition of anesthetic drugs subcutaneously. The observations of our work reveal the anteroposterior diameter of the apex of sacral hiatus varied from 1.5 to 15 mm with a mean of 6.66 ± 2.71 mm. Nagar, Seema, Sinha M B, Ukoha U, Chhabra N, Nadeem G, Akhtar J, and Present study reported the mean transverse width of the base of sacral hiatus was 4.88 mm, 88% ± 7.2%. Our result is close to the observation of Chhabra for the anteroposterior diameter of the apex of sacral hiatus.

### CONCLUSION

Ultrasound-guided needle placement for the caudal epidural block is recommended for overall success. Fluoroscopy is considered as a gold standard technique for placing needles correctly in the sacral hiatus still it is not always possible due to personal availability, time and cost consent. Therefore, an acquaintance of anatomical variations of the sacral canal and sacral hiatus is an essential landmark for clinicians to facilitate the procedure of caudal epidural anesthesia to improve its success rate.

### Clinical Significance

Incomplete development of dorsal neural arches of sacrum may result as incomplete neurogenesis of sacral nerves. This could lead to partial or complete incontinence of urinary bladder and bowel disorders. Usually, patients with dorsal wall agenesis of the sacrum are linked with such conditions like posterior disk herniation, backache, enuresis, bowel disorders and weakness of lower limbs. Variations in the development of sacral hiatus can decrease the region for attachment of extensor muscles at the dorsal surface of sacrum resulting in painful condition. Anatomical and developmental variations of the sacral canal and sacral hiatus make sacrum more liable to fracture, difficulty while performing internal screw fixation and other clinical complications.

Incorrect needle placement during caudal anesthesia has been linked with intraosseous drug toxicity, and aspiration. Knowledge of anatomical variations might increase the success rate of caudal epidural anesthesia. Moreover, when the clinicians notice an abnormal sacral hiatus, he/she should opt for a lumbar epidural block or an alternative route for anesthesia to avoid the soft tissue injury and the toxicity of local anesthetics.

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