Anatomical study of sacral hiatus in South Indian population and its clinical significance in caudal epidural anaesthesia

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Abstract

Background: Caudal anaesthesia is administered into the epidural space through Sacral Hiatus(SH). Hence reliability and success of caudal epidural anaesthesia depends upon the anatomical knowledge of sacral hiatus. Aim: The aim is to study the morphological measurements and variations of structures around the sacral hiatus and to identify possible anatomical reasons for failure of caudal epidural anaesthesia (CEA).

Materials and methods: Fifty three dry adult sacral bones of both sexes were measured using Vernier Caliper, scale and divider. The shape of sacral hiatus (SH) was observed and its length and breadth were measured. The measurements were focused on sacral hiatus and its relation with surrounding bony projections. Results: The shape of the sacral hiatus showed a maximum occurrence of inverted 'V' and 'U' shapes with 35.85% and 26.42% respectively. The level of apex of SH was maximum at S4 foramen level in 68.63% cases followed by S5 and S3 level. In 62.26%, the level of base was observed at S5 level .The average length of the sacral hiatus was 23.02±8.95mm), AP diameter was 5.49±1.44mm) and base of SH was 14.6±3.99mm). The distance from apex and base of SH to S2 foramen level was 31.07mm and 52.86mm respectively. Conclusion: The anatomical knowledge of SH is very much necessary to increase the reliability and success of CEA. Surrounding bony irregularity, different shapes of hiatus and defect in dorsal wall of sacral canal should be taken into consideration before undertaking CEA so as to avoid its failure.

Key words: caudal epidural block, sacral composition, supero-lateral sacral crest, sacral hiatus apex

Introduction

Caudal epidural block (CEB) has been widely used for analgesia and anaesthesia in various clinical settings like caudal anaesthesia in perineal surgery, diagnosis and treatment of lumbar spinal disorders and analgesia during labour and delivery. Caudal epidural block involves injection of a drug into the epidural space through the sacral hiatus.

Below the fourth or sometimes the third sacral foramen, there is an inverted ‘U’ shaped gap in the posterior wall of the sacral canal called the sacral hiatus. This is due to the failure of the laminae of the fifth sacral vertebra to meet in the median plane. The hiatus is covered only by skin, a subcutaneous fatty layer and sacroccocygeal membrane. The superficial dorsal sacrococcygeal ligament is attached to the margins of the sacral hiatus and completes the lower part of sacral canal. Sacral hiatus contains part of lower sacral and coccygeal nerve roots, filum terminale externum and fibro fatty tissue. The dural space ends against S2 vertebra.

In clinical studies, the success rate of CEB has been reported to be about 70 -80%43. It has been reported that one of the anatomical reasons of CEB failure was caused by absence of hiatus (7.7%) and discrepancies in the size and shape of sacral hiatus. The sacral hiatus is variable in its shape and size. The laminae of all the sacral vertebrae may fuse in the midline resulting in absence of sacral hiatus or may fail to fuse resulting in incomplete dorsal wall of sacral canal. Between these two extremes, a number of variations in the sacral hiatus have been observed. Hence it is sometimes hard to determine the anatomical location of sacral hiatus and caudal epidural space, especially in adults.
The determination of landmarks by the clinician enables the sacral hiatus to be ascertained and may increase success rate of CEB. Entry into the sacral hiatus should be safe to prevent dural sac puncture and protect surrounding structures. Therefore knowledge of anatomical variation associated with sacral hiatus is very much essential for successful CEB.

Fewer studies are available on the sacral hiatus. Therefore the present study was undertaken because of the scarcity of data amongst the South Indian population.

Materials and methods

Fifty three dry adult sacral bones of both sexes were measured in Sri Ramachandra Medical College & Research Institute, Chennai. Measurements were focused on sacral hiatus and its relations with surrounding bony projections. The length, shape and necessary distance were measured using Vernier caliper, scale, divider & protractor. Two sacrum showed total spinal bifida; hence they were excluded for certain parameters from the study.

Observations for different features of sacral hiatus were as follows:

1. Sacral composition: the sacrum was composed of 5 segments or 4 segments, 5th lumbar sacralisation and coccygeal ankylosis with sacrum was also observed. (Table 1).

2. Shape of the sacral hiatus: Many variations in the shape of sacral hiatus was observed as Inverted ‘V’ shape, Inverted ‘U’ shape, Irregular shape, Dumb bell shape (nodular bony growth from the lateral wall of hiatus), Sacral spina bifida, ‘M’ shape and absence of hiatus (Fig 1) (Table 2).

3. Level of Apex of sacral hiatus: The level of apex in relation to sacral vertebrae was seen at level of S3, S4 and S5 foramina. (Table 3).

4. Level of Base of sacral hiatus: The base of hiatus in relation to sacral and coccygeal vertebrae was observed at the level of S4, S5 and coccyx (Table 3).

5. Level of maximum curvature of sacrum: In relation to sacral vertebra was observed at S3, S4 and S5 level.

The measurements were made as follows (Fig.2):

1. Length of the sacral hiatus: Measured from the apex of SH to midpoint of base of SH.

2. Anteroposterior diameter at the sacral hiatus

3. Intercornual distance/ base of sacral hiatus: Distance between the inner surface of sacral cornu.

4. Median distance between the level of lower margin of second sacral foramen and apex of sacral hiatus.

5. Distance from midpoint of base of sacral hiatus to second sacral foramen.

6. Transverse distance between right & left lateral sacral crest at the level of first sacral foramen.

7. Distance between right lateral sacral crest at the level of first sacral foramen (supero lateral sacral crest- SLSC) & apex of hiatus.

8. Distance between left lateral sacral crest at the level of first sacral foramen (supero lateral sacral crest- SLSC) & apex of hiatus.

9. The following angles were measured:
   a) Angles between the lines formed by 6 & 7 parameters on the right side.
   b) Angles between the lines formed by 6 & 8 parameters on the left side.

All data were expressed as Mean, Standard Deviation and Range. Correlation coefficient(r) test was performed between the base, right and left margins of the triangle and also between the angles on rt. and Lt. side.

The distances measured in relation to sacral hiatus (Fig. 2):

A - Length of sacral hiatus

B - Intercornual distance / base of sacral hiatus

C - Distance from sacral hiatus apex (SA) to S2 foramen

A+C- Distance from sacral hiatus base to S2 foramen
Fig. 1 Shapes of sacral hiatus

Fig. 2: Distances measured in relation to sacral hiatus

D - Distances between the right [Rt] and left [Lt] superolateral sacral crest [SLSC]
E - Distances between the right [Rt] superolateral sacral crest [SLSC] and sacral hiatus apex

F - Distances between the left [Lt] superolateral sacral crest [SLSC] and sacral hiatus apex

G - Angle between the base and left side of triangle

H - Angle between the base and right side of triangle

Results

Fifty three dry sacral bones of which two had total spinal bifida were observed.

Sacral composition was observed and tabulated in Table 1. Variations in shapes of SH in the present study were tabulated in Table 2 (Fig. 1). Except for inverted ‘V’ and ‘U’ shapes all the shapes cause hindrance to needle insertion.

Levels of Apex and Base of SH in relation to sacral foramen were observed and results were tabulated in...
### Table 1: Sacral composition

<table>
<thead>
<tr>
<th>S.No</th>
<th>SACRAL COMPOSITION</th>
<th>No. observed</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 Segments</td>
<td>35</td>
<td>66.04</td>
</tr>
<tr>
<td>2</td>
<td>4 Segments</td>
<td>7</td>
<td>13.21</td>
</tr>
<tr>
<td>3</td>
<td>5th lumbar sacralisation</td>
<td>3</td>
<td>5.66</td>
</tr>
<tr>
<td>4</td>
<td>Coccygeal ankylosis</td>
<td>8</td>
<td>15.1</td>
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</table>

### Table 2: Shape of sacral hiatus

<table>
<thead>
<tr>
<th>S.NO</th>
<th>SHAPE OF SACRAL HIATUS</th>
<th>No. observed</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inverted ‘V’</td>
<td>19</td>
<td>35.85</td>
</tr>
<tr>
<td>2</td>
<td>Inverted ‘U’</td>
<td>14</td>
<td>26.42</td>
</tr>
<tr>
<td>3</td>
<td>Irregular</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>Dumb bell</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Spina bifida</td>
<td>2</td>
<td>3.8</td>
</tr>
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### Table 3: Level of apex & base of sacral hiatus

<table>
<thead>
<tr>
<th>S.NO</th>
<th>SACRAL FORAMEN LEVEL</th>
<th>LEVEL OF APEX (n = 51)</th>
<th>LEVEL OF BASE (n = 53)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S3</td>
<td>5 (9.8%)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>S4</td>
<td>35 (68.63%)</td>
<td>7 (13.21%)</td>
</tr>
<tr>
<td>3</td>
<td>S5</td>
<td>11 (21.57%)</td>
<td>33 (62.26%)</td>
</tr>
<tr>
<td>4</td>
<td>coccyx</td>
<td>-</td>
<td>13 (24.53%)</td>
</tr>
</tbody>
</table>

### Table 4: Level of maximum curvature

<table>
<thead>
<tr>
<th>S.NO</th>
<th>LEVEL OF MAXIMUM CURVATURE OF SACRUM</th>
<th>No. observed (n=53 Sacra)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S3</td>
<td>40</td>
<td>75.47</td>
</tr>
<tr>
<td>2</td>
<td>S4</td>
<td>12</td>
<td>22.64</td>
</tr>
<tr>
<td>3</td>
<td>S5</td>
<td>01</td>
<td>1.9</td>
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</tbody>
</table>

### Table 5: Measurements of Sacrum

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PARAMETERS</th>
<th>AVERAGE ± SD (RANGE) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length of sacral hiatus (SH)</td>
<td>23.02 ±8.95 (8.48)</td>
</tr>
<tr>
<td>2</td>
<td>Anteroposterior diameter of SH</td>
<td>5.49 ± 1.44 (2-9)</td>
</tr>
<tr>
<td>3</td>
<td>Base of sacral hiatus</td>
<td>14.6 ± 3.99 (4-21)</td>
</tr>
<tr>
<td>4</td>
<td>S2 to apex of SH</td>
<td>31.07 ± 8.33 (15-45)</td>
</tr>
<tr>
<td>5</td>
<td>S2 to base of SH</td>
<td>52.86 ± 8.4 (33-77)</td>
</tr>
</tbody>
</table>

Table 6: Results of statistical analysis of sides of triangle

<table>
<thead>
<tr>
<th>SIDES</th>
<th>MEAN (mm)</th>
<th>MAXIMUM (mm)</th>
<th>MINIMUM (mm)</th>
<th>STANDARD DEVIATION (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rt-Lt SLSC (BASE)</td>
<td>62.24</td>
<td>79.5</td>
<td>51</td>
<td>±7.11</td>
</tr>
<tr>
<td>Lt SLSC- SA</td>
<td>62.49</td>
<td>81</td>
<td>48</td>
<td>±7.66</td>
</tr>
<tr>
<td>Rt SLSC-SA</td>
<td>62.96</td>
<td>82</td>
<td>49</td>
<td>±7.58</td>
</tr>
</tbody>
</table>

SA - Sacral hiatus apex
SLSC - Superolateral sacral crest

Table 7: Intercornual distance / Base of the sacral hiatus

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>POPULATION RACE</th>
<th>MEAN ± STANDARD DEVIATION (mm)</th>
<th>RANGE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESENT STUDY</td>
<td>SOUTH INDIAN</td>
<td>14.62 ± 3.99</td>
<td>4-12</td>
</tr>
<tr>
<td>ANJALI² (2009)</td>
<td>NORTH INDIAN</td>
<td>11.95 ± 2.78</td>
<td>6-23.3</td>
</tr>
<tr>
<td>SENOGLU¹¹ (2005)</td>
<td>TURKISH</td>
<td>17.47 ± 3.28</td>
<td>7-28</td>
</tr>
<tr>
<td>SEKIGUCHI¹ (2004)</td>
<td>JAPANESE</td>
<td>10.2 ± 0.35</td>
<td>2.2-18.4</td>
</tr>
</tbody>
</table>

Table 8: Results of statistical analysis of sides of triangle in present and other studies

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>DISTANCES BETWEEN THE RT AND Lt SLSC (mm)</th>
<th>DISTANCES BETWEEN THE Rt SLSC AND APEX OF SH (mm)</th>
<th>DISTANCES BETWEEN THE Lt SLSC AND APEX OF SH (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESENT STUDY</td>
<td>62.24 ±7.11 (51-79.5)</td>
<td>62.96 ±7.58 (49-82)</td>
<td>62.49 ±7.66 (48-81)</td>
</tr>
<tr>
<td>ZAHRA¹² (2007)</td>
<td>62.53 ±5.8 (50-78)</td>
<td>63.72 ±7.08 (42.5-85.5)</td>
<td>63.72 ±7.08 (42.5-85.5)</td>
</tr>
<tr>
<td>SENOGLU¹¹ (2005)</td>
<td>66.5 ±5.5 (51-79.5)</td>
<td>67.1 ±10 (42.1-89)</td>
<td>67.5 ±6.5 (46.8-81)</td>
</tr>
</tbody>
</table>
Table 3: Results of statistical analysis of angles of triangle in present and other studies

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ANGLE BETWEEN THE BASE AND RIGHT SIDE (DEGREE)</th>
<th>ANGLE BETWEEN THE BASE AND LEFT SIDE (DEGREE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESENT STUDY</td>
<td>59.26 ± 4.55 (46-67)</td>
<td>59.46 ± 4.48 (47-67)</td>
</tr>
<tr>
<td>ZAHRA¹²</td>
<td>60.5 ± 4.88 (51-70)</td>
<td>60.27 ± 4.84 (51-70)</td>
</tr>
<tr>
<td>(2007)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SENOGLO¹¹</td>
<td>61.9 ± 4.8 (50-70)</td>
<td>61.2 ± 4.8 (50-70)</td>
</tr>
<tr>
<td>(2005)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. The base of SH when present at coccygeal level was little narrower than at sacral level. The foramen level at which the sacrum curves maximum was observed to estimate the angulation of needle insertion (Table 4). The maximum curvature of sacrum was at level of S3 foramen level.

The following measurements were made and tabulated (Table 5) (Fig.2):
1. Length of the sacral hiatus from apex to midpoint of base.
2. Anteroposterior diameter at the sacral hiatus, in the present study it was ≤3mm (7.84%).
3. Intercornual distance/base of sacral hiatus.
4. Median distance between the level of lower margin of second sacral foramen and apex of sacral hiatus.
5. Distance from midpoint of base of sacral hiatus to second sacral foramen.

The distance between right (Rt) and left (Lt) superolateral sacral crest (SLSC) - Base of triangle and the distance between sacral hiatus apex (SA) to Rt & Lt SLSC were measured. The angles between base and Rt & Lt sides of triangle were measured. The results of statistical analysis of sides of triangle were tabulated in Table 6.

There exists a strong positive correlation in the equivalence of length. The angles showed no statistically significant difference between them. Hence the present study reveals an equilateral triangle formed between two posterior superior iliac spine and SA. This forms an important landmark to determine SA easily and carefully to do CEB.

Discussion

Caudal epidural block is used for anorectal and perineal procedures as well as for some lower extremities surgeries. It is also used during labour. The anatomy pertinent to caudal epidural block (CEB) centres around the sacral hiatus since it is the easiest and safest approach to the epidural space. Therefore anatomical knowledge of sacral hiatus increases the reliability and success of CEB.

Sacral Composition

Sacral composition was studied by Vinod Kumar who had observed sacral composition of five segments to be maximum (69.8%), which was also almost maximum in the present study (66.04%).

The present study also confirms the incidence of coccygeal fusion (CF) to be more than sacralisation of
5th lumbar vertebra, i.e.15.1% of CF and 5.6% of 5th lumbar sacralisation. The increased incidence of four segment sacrum in the present study indicates an evolutionary change in reduction of vertical dimension of lesser pelvis, which may be useful to facilitate labour in females. 

Shapes of Sacral Hiatus 

Variations in shapes of sacral hiatus in the present study are as follows:

**Inverted 'V' And 'U' Shape:** The other studies showed 31.57% of 'V' shape and 40.35% of 'U' shape by Anjali; 46.53% ('V' shape) and 29.7% ('U' shape) by Vinodh Kumar and 27% ('V' shape) and 41.5% ('U' shape) by Nagar. The present study also showed a higher incidence of 'V' and 'U' shapes as 35.85% and 26.42% respectively. These shapes have enough space to introduce needle into the sacral canal.

**Irregular Shape [IR]:** Anjali and Nagar observed 15.78% and 14.1% respectively, whereas the present study observed a higher incidence of 17% of irregular shape. **Dumb bell Shape Hiatus [DB]:** This shape also showed a higher incidence of 17% in the present study as compared to Anjali (7.01%); Vinodh Kumar (7.43%) and Nagar (13.3%).

**Spina Bifida:** Present study reported two out of 53 sacrum of spina bifida (3.8%) which is more when compared to others' study like Nagar (1.5%) and Vinodh Kumar (1.49%). 

**Absence Of Sacral Hiatus:** In the present study, there was no absence of sacral hiatus, whereas Nagar® and Vinodh Kumar® observed 0.7% and 0.99% respectively. Except for Inverted 'V' and Inverted 'U' shapes all other shapes cause hindrance to needle insertion.

**Level of apex of scral hiatus**

The apex level is very important for the safety of dura. The level of apex was most common at the level of S4 foramen (68.63%), followed by S5 (21.57%) and S3 (9.8%) in the present study. This was similar to Anjali’s report S4 (68.42%); S5 (14.91%); S3 (14.03%) and S2 (2.63%), but Vinodh Kumar® showed still higher incidence of S4 foramen level of 76.23%. Sekiguchi® reported apex at S1 in 1%.

High apex is associated with high chances of dural puncture; on the other hand lower apex needs longer needle.

**Level of base of sacral hiatus**

The location of base varied from S4 to coccyx. In our study, the base was seen most commonly against S5 in 62.26%, whereas in the study of Nagar® it was 72.6% and in the study of Anjali® it was 61.40%. Incidence of base at S4 foramen level was 13.2% which was comparatively higher than Anjali’s® (11.4%) and Nagar's® (11%) studies. The lowest location of base was at coccyx 24.53% in the present study. However, the base when present at the coccygeal level was a little narrower than at the sacral level.

**Level of maximum curvature of sacrum**

Angulation of needle insertion may be influenced by the level of maximum curvature. In the present study, levels of maximum curvature was observed in S3 dry adult sacrum. 40 bones showed maximum curvature at S3 level (75.47%), 12 bones at S4 foramen level (22.64%) and one bone at S5 level (1.9%), whereas Anjali® reported 80% cases at S3 level.

**Length of the sacral hiatus**

The mean length of the hiatus was observed as 23.02 ± 8.95 (8-48)mm in the present study. Anjali® observed 18.81 ±7.53 (4.30-38.60) mm, Senoglu® 32.09±9.92 (12-53) mm, Vinodh Kumar® 20 ±1.017 (3-37)mm. The present and past studies shows that the increase in length of the hiatus is influenced by the defect of non union of 2nd and 3rd pair of sacral laminae and also by coccygeal ankylosis.
Anteroposterior [AP] diameter of sacral hiatus

The AP diameter of sacral hiatus at the apex needs to be sufficient enough to admit the needle into the sacral canal. The results of the various studies are as follows: present study 5.49 ±1.44 (2-9) mm, Anjali 9 5.03 ±1.57 (1.9-10.4) mm, Senoglu11 4.46 ±1.33 (1-7) mm, Nagar10 4.88 (2-14) mm, Sekiguichi6 6 ±1.9 (1.9-11.4) mm, Vinodh Kumar7 4.8 (0-12) mm.

The results were almost similar in all studies. In the present study, 7.84% showed AP diameter of <3mm which suggest that it would be difficult to insert needle.

Intercornual distance / base of sacral hiatus

Base showed variable range in various studies as follows (Table 7):

In the present study 9.43% sacral bones showed less than 10mm base. This implies that in 90.57% cases, the base was sufficient enough for the needle insertion. The difference in values as reported in different studies may be due to ethnic differences.

Distance from sacral hiatus apex to S2 foramen

Dural sac terminates at S2 level. Hence the distance between apex of hiatus and S2 level decides the length of the needle that can be safely introduced into the canal. The measured distances are as follows: Present study 31.07 ± 8.33 (15-45)mm, Anjali9 30.16 ±14.07 (2-13.5)mm, Zahra12 35.54 ± 10.63 (10.75-63)mm, Senoglu11 35.37 ± 10.36 (11-62)mm.

Distance from sacral hiatus base to S2 foramen

In the present study this distance was 52.86 ±8.4 (33-77)mm. This was little less when compared to the study of Senoglu11 which reported an average distance of 65.25 ± 9.39 (39-85)mm.

Thus the needle should be advanced only a few mm after penetrating the sacrococcygeal membrane in adults, to reduce the risk of dural puncture.

Distances between the right [R] and Left [L] Superolateral Sacral Crest [SLSC] and between SLSC and SA :

Apart from the present study, these distances were also measured by Senoglu11 and Zahra12. The results are tabulated in Table 8.

Hence, the observations in all the studies were almost similar which concluded that the distance from right and left SLSC to sacral hiatus apex is almost equal.

The angles formed on the right and left sides are almost same indicating an equilateral Triangle. Thus suggesting this as an important landmark to detect sacral hiatus for CEB (Table 9).

Conclusion

The anatomical knowledge of sacral hiatus is very much necessary to increase the reliability and success of CEB. When correctly performed, there is little danger either to spinal cord or to dura mater being damaged. It is sometimes difficult to determine the anatomical location of sacral hiatus especially in adults. Single bony landmark may not help in locating sacral hiatus, because of variations. The shape, length, depth and level of apex and base of sacral hiatus were analysed. Depth of hiatus <3 mm may be one of the cause for failure of needle insertion. Surrounding bony irregularities, different shapes of hiatus and defect in dorsal wall of sacral canal should be taken into consideration before undertaking caudal epidural block (CEB) so as to avoid failure.

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References


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