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The Sacral Hiatus: An Anatomic Study on Both Cadaveric and Dry Bones

Ashraf Y Nasr[1], Youssef H Ali[1], Naser A ElSawy[1,2]*

[1]*Department of Anatomy and Embryology Faculty of Medicine Zagazig University, Egypt.*
[2]*laboratory medicine, Faculty of Applied Medical Sciences, Umm al Qura University, Makkah, Saudi Arabia.*

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Abstract

The sacral hiatus is the gap on the lower part of dorsal surface of sacrum. It is formed due to the failure of fusion of the laminae of the 5th sacral segment. The sacral hiatus provides the main route of the caudal epidural nerve block. The success rate of the caudal nerve block showed an important correlation to the variations of the sacral hiatus dimensions. 150 dry Egyptian sacra and five cadavers were used in the present study. Different anatomical measurements were made with a Vernier caliper accurate to 0.1 mm to know the anatomical variations of the sacral hiatus. Complete agenesis of the sacral hiatus was seen in four (2.66%) sacra. The mean length of sacral hiatus was 27.16 mm and it showed a wide range (7-110 mm). The mean transverse diameter (width) of sacral hiatus was 11.5 mm. The mean anteroposterior diameter of the sacral canal at the apex of sacral hiatus was 4.78 mm. Narrowing of the sacral canal at the apex of sacral hiatus, diameter less than 3 mm was seen in 10 (6.66%) sacra. The apex of sacral hiatus was commonly found at the level of the 4th sacral vertebra in 54%. Various shapes of sacral hiatus were observed which included inverted V (38.66%), inverted U (31.33%), irregular (15.33%), dumbbell (12%) and bifid (2.66%). The base of sacral hiatus was seen at the level of S5 vertebra in 70%. The fusion between coccyx and sacrum was observed in 18% of sacra while the sacralisation of the 5th lumber vertebra was noticed in 14 (9.33%) sacra. The knowledge of the anatomical variations of sacral hiatus is important during administration of the caudal epidural anaesthesia. Moreover, it may help in improving the success rate of the caudal anaesthesia.

Keywords: *Sacral hiatus, caudal anaesthesia*

Introduction

The human sacrum is a large triangular bone. It consists of five fused sacral vertebrae. The fusion of the sacral vertebrae starts at puberty from below upward. The primary cartilaginous joints between the vertebrae involute in the adulthood, leaving only transverse lines on the ventral aspect of the sacrum. The complete fusion has been reported to occur between years 23-33 of life and is related to the load- bearing aspects of this region. The sacrum articulates with the fifth lumber vertebra above and the coccyx below [1-3].

The sacrum has convex posterior surface. The posterior elements of the initial vertebral segments fuse into a bone plate marked by several longitudinal crests coursing in the rostrocaudal direction. The prominent median sacral crest is primarily formed from the rudimentary spinous processes of the upper three or four sacral vertebrae, with the laminae on either side forming the sacral grooves [4].

The sacral hiatus is a gap on the posterior aspect of the lower end of the sacrum. It is formed by failure of fusion of the laminae of 5th sacral segment. The defect may be greater than this in many cases producing the sacral segmenta spina bifida occulta. The remnants of the inferior articular process of the 5th sacral segment elongate downwards on both sides of the sacral hiatus. These two bony processes are called the sacral cornu (horns). The lateral margins of the hiatus are formed by these two sacral cornua. The body of the 5th sacral segment lies anterior to the sacral hiatus. The posterior sacro-coccygeal membrane (ligament) forms the roof of the sacral hiatus that passes from the sacral cornua to the coccyx. The

*Corresponding Author
Naser A ElSawy, MD
Department of Laboratory Medicine, Faculty of Applied Medical Sciences, Umm Al-Qura University, PO Box: 715, Makkah, KSA.
Email: naser_elsawy@ymail.com

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posterior sacro-coccygeal membrane is about 1-3 mm thick and is covered by subcutaneous fat and skin only. The location of the sacral hiatus can be easily identified by its cornua as a two knobs about 5 cm above the tip of the coccyx at the upper end of the natal cleft [5-7].

The sacral hiatus leads to the sacral canal. This sacral canal is the continuation of the lumber spinous canal. The depth of the sacral hiatus varies, depending on how much the lamina and spinous processes of the 4th sacral segment are present. The dural sac terminates at the level of S1-S3. The sacral canal below this level contains vertebral venous plexus, lower sacral nerve roots (cauda equina), the filum terminale and the extradural fat [5, 8].

Due to the proximity of the arachnoid sac and the sacral hiatus, the caudal block can be performed by introducing a catheter or needle into the sacral canal via the sacral hiatus. The trans-sacral approach through the sacral hiatus has been widely used for administration of epidural anaesthesia in obstetrics, orthopedic practice, general and pediatric surgery. The local anaesthesia, injecting into the extradural space via the sacral hiatus, will primarily affect the sacral nerve roots and will provide anaesthesia for surgery below the level of the umbilicus and the perineum [9, 10].

Moreover, the sacral hiatus provides an alternative approach during myelography, oxygen myelography and pneumo-enecephalography when the more standard approaches are unavailable [11].

The anatomical variations of the sacral hiatus have been studied by different authors [9-13]. Dalen and Hasnaoui [9] reported that, although considerable variation exists in the anatomy of the sacral hiatus, a trans-sacral approach becomes impossible only when the hiatus is absent. Crighton *et al.* [14] stated that, successful performance of a caudal block requires identification of the sacral hiatus, passage of a needle through the sacrococcygeal membrane and placement of the needle along the axis of the sacral canal without entering the dural sac or other structures. This can be difficult or impossible at times because of wide anatomical variation in this region.

Jang *et al.* [15] reported that, the experience physician has a failure rate of the caudal block up to 25% due to improper needle placement. The ultrasound guidance can increase the success rate of the needle insertion into the sacral canal. Moreover, Nagar [13] added that, there are five types of sacral hiatus with different percentages and the apex of the sacral hiatus is commonly found at the level of the S4 vertebra, the mean length of the sacral hiatus is 22.8 mm and its antero-posterior diameter at the level of its apex is 4.8 mm.

A detailed understanding of the anatomy, dimensions and variations of this region are therefore desirable for clinicians to increase the reliability and safety of using of the caudal epidural nerve block.

The present study was carried out to identify the different shapes, dimensions and variations of the sacral hiatus in the dry Egyptian sacra and confirmed with cadaveric specimens. The application of these findings will increase the reliability and the success rate of the caudal epidural anaesthesia by the clinicians.

Materials and Methods

The study was carried out at the anatomy department, faculty of medicine, Zagazig University. 150 dry adult Egyptian sacra and five cadavers were used in this study. The specimens were obtained from the anatomy department of faculty of medicine, Zagazig University. These sacra were selected after rejecting the bone having any fracture. The sacra were undetermined sex and age. The anatomical measurements were performed on these sacra by using a Vernier caliper accurate to 0.1 mm. Each sacrum was studied for different dimensions of its sacral hiatus with regards to:

1: Length (from its apex to the midpoint of its base).
2: Transverse diameter at the base (intercornual distance).
3: Antero-posterior diameter of the sacral canal at the apex of sacral hiatus.
4: Level of the sacral hiatus apex in relation to the sacral segments.
5: Number of sacral vertebrae related to the sacral hiatus.
6: Level of the base of the sacral hiatus in relation to sacral or coccygeal segment.
7: Different shapes of the sacral hiatus and the percentage of each.
8: Number and percentage of the fused coccyx and 5th lumber vertebra.
9: Confirmation the above dimensions were carried on the five cadavers.

Results

The mean length of sacral hiatus, extending from its apex to the mid-point of its base (Figure 1), was 27.16 (±1.2933 SE) mm ± 5.8394 (SD). However, it showed a wide range of variations as its minimum value was 7 mm and its maximum value was 110 mm (Table 1). So, this range was subdivided into six groups (10 mm each) to determine the number and the percentage of each group. The range of the first group was 1–10 mm. Its number was 12 sacra representing 8%. The second group range was 11-20 mm and was seen in 55 sacra representing 36.66%. The third group range was 21-30 mm and its number was 45 representing 30%. The fourth one range was 31-40 mm and was present in 25 sacra representing 16.66%. The range of the 5th group was 41-50 mm and was noticed in 8 sacra representing 5.33%. The length of the sixth group was >50 mm and was found in 6 sacra (3.33%). Agenesis of the hiatus was seen in four sacra representing 2.66% (Table 2).

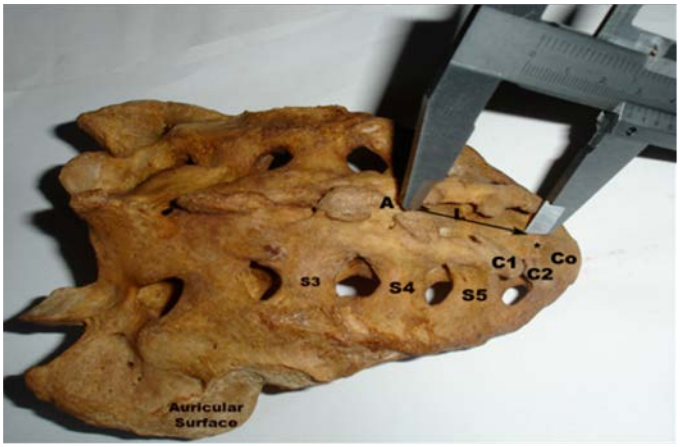


Figure 1: Light photomicrograph of the dorsal surface of a human sacrum showing dumbbell-shaped sacral hiatus (H) at its lower part. The Apex of the hiatus (A) is located at level of S4 vertebra and its base (*) is present at the sacrococcygeal junction. The black arrow is the measure of the length of the hiatus. Notice, (C1) is the sacral cornu, (C2) is the coccygeal cornu and the (Co) is the coccyx.

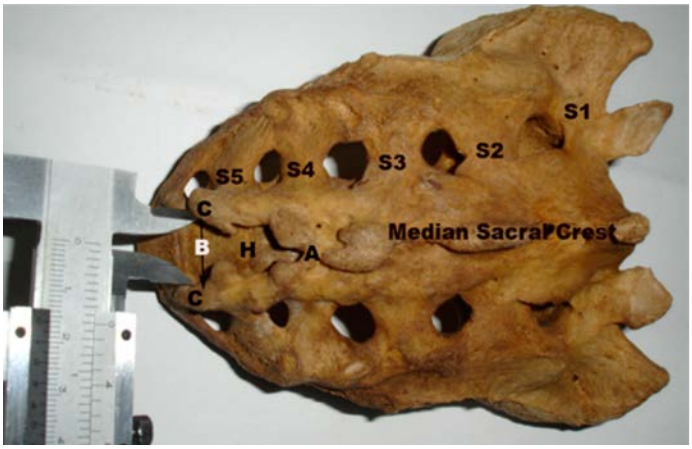


Figure 2: Light photomicrograph of human sacrum showing dumbbell-shaped sacral hiatus (H). The measure of its base (B) is distance between the two sacral cornuae (C). The apex (A) of the hiatus is present at the level of the middle of the 4th sacral vertebra (S4).

Figure 3: light Photomicrograph of the previous human sacrum showing the A-P diameter measurement of the sacral canal at the apex (A) of the sacral hiatus (H). Notice; the fusion (*) between the sacrum and the coccyx (Co) at the sacrococcygeal junction.

The transverse diameter {intercornual distance (Figure 2)} of the sacral hiatus ranged from 4 to 17 mm and its mean was 11.50 (± .2552 SE) mm ± 3.1255 (SD) (Table 1). The transverse diameter was subdivided into four groups, 5 mm for each. In the range of the transverse diameter of the first group was 1-5 mm. This group was seen in nine sacra (6%). The transverse diameter of the second group ranged from 6-10 mm. The diameter of this group was noticed in 50 (33.33%) sacra. The third group transverse diameter ranged from 11-15 mm and was found in 80 (53. 33%) sacra. The transverse diameter of the last group was > 16 mm and was seen in 11 (7.33%) sacra (Table 3).

The A-P diameter of the sacral canal at the apex of the sacral hiatus (**Fig.3**) ranged from one to nine mm and its mean was 4.780 (SE .1370) ± 1.6784 (SD) (Table 1). The A-P diameter of the sacral canal was classified into three subgroups, 3 mm for each. The range of the A-P diameter of the first group was 1-3 mm. This subgroup was seen in 28 (18.66%) sacra. The A-P diameter of the second subgroup ranged from 4 mm to 6 mm. It was found in 91 (60.66%) sacra. The range of the A-P diameter of the third subgroup was 7-9 mm. This subgroup was present in 31 (20.66 %) sacra. The A-P diameter of the sacral canal at the apex of the hiatus did not exceed 9 mm in this study (Table, 4).

Regarding the level of the sacral hiatus apex, more than 80% of the sacra showed the level of sacral hiatus apex at S4 and S5 vertebrae. The level of the apex of sacral hiatus of 54% (81 out of 150) of the sacra was opposite S4 vertebra and the level of 27.33% (41 out 150) was at S5 vertebra (Figure 4). The apex of the sacral hiatus was seen at the level of S3 in 22 (14.66%) sacra. The level of the sacral hiatus apex was seen at S2 vertebra in two sacra (1.33%) only. The agenesis of the sacral hiatus was seen in four (2.66%) sacra (Table 5).

Regarding the shape of the sacral hiatus, there were five types of the sacral hiatus; the inverted V-shaped hiatus represented the most common type of the sacra (Figure 4). This shape was seen in 58 out of 150 (38.66%) sacra. The second common shape of the sacral hiatus was the inverted U-shaped (Figure 5). This type was observed in 47 (31.33%) of the sacra. The third form of the sacral hiatus was the irregular one (Figure 6). This shape was seen in 23 (15.33%) sacra. The 4th shape of the sacral hiatus was the dumbbell-shaped (Figure 2) and was seen in 18 (12%) sacra. The bifid-shaped sacral hiatus was the least one and was observed in 4 (2.66%) sacra (Table 6). The base of the sacral hiatus was seen in 70 % of the sacra at the level of the S5 vertebra, in 12 % at the level of the S4 and in 18 % at the level of the coccyx (Table 7).

Regarding the fusion between the sacrum and the coccyx, there were 27 (18%) sacra showed fusion with the coccyx. However, the fusion between the fifth lumber (L5) vertebrae and the sacrum (**Fig.7**) was seen in 14 (9.33%) sacra (Table, 8).

In the cadaveric study, the distance between the posterior superior iliac spines of both sides was compared with the

Table 1: Shows the different statistical parameters of the sacra examined.

	Sacral Hiatus Length	Transverse Diameter of Sacral Hiatus	A-P Diameter of sacral canal at the apex
N	150	150	150
Minimum	7.00	4.00	1.00
Maximum	110.00	17.00	9.00
Range	103.00	13.00	8.00
Mean	27.1600	11.5000	4.7800
SE of mean	1.2933	.2552	.1370
Median	25.0000	12.0000	4.0000
Mode	20.00	10.00	4.00
Std. Deviation	15.8394	3.1255	1.6784
Variance	250.8870	9.7685	2.8170
Skewness	2.654	-.396	.448
SE of Skewness	.198	.198	.198
Kurtosis	10.144	-.383	-.322
SE of Kurtosis	.394	.394	.394

Table 2: Shows the length of sacral hiatus.

Sacral hiatus Length	1- 10 mm	11- 20 mm	21- 30 mm	31 – 40 mm	41 – 50 mm	> 50	Agenesis
Number	12	55	45	25	8	6	4
Percentage	8 %	36.66%	30 %	16.66 %	5.33 %	3.33%	2.66 %

Table 3: Shows the transverse diameter (width) of the sacral hiatus.

Tr. Diameter	1 – 5 mm	6 – 10 mm	11 – 15 mm	> 16 mm
Number	9	50	80	11
Percentage	6 %	33.33 %	53.33 %	7.33 %

Table 4: Shows the A-P diameter of sacral canal at the level of the apex of sacral hiatus.

A-P Diameter	1 – 3 mm	4 – 6 mm	7 – 9 mm	> 9 mm
Number	28	91	31	00
Percentage (%)	18. 66 %	60.66 %	20.66 %	00

Table 5: Shows the level of the apex of sacral hiatus.

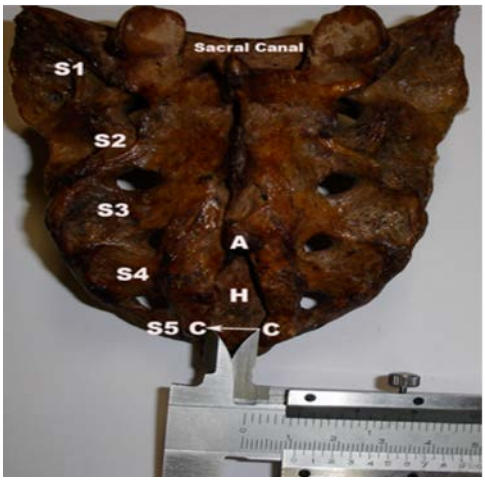
Level of the apex	Number	Percentage (%)
S1	4	2.66 %
S2	2	1.33 %
S3	22	14.66 %
S4	81	54 %
S5	41	27.33 %

Table 6: Shows the different shapes of the sacral hiatus.

Shape of the Hiatus	Number	Percentage (%)
Inverted V – Shape	58	38.66 %
Inverted U-Shape	47	31.33 %
Irregular shape	23	15.33 %
Dumbbell	18	12 %
Bifid	4	2.66 %

List of Abbreviations

H: The sacral hiatus
F4: Fourth dorsal sacral foramen
C or C1: Sacral Cornu
F3: Third dorsal sacral foramen
A: Apex of the hiatus
FT: The Filum Terminale
B: The base of the hiatus
P.S.I.S.: Posterior superior iliac spine
L: The length of the hiatus
L5: The 5th lumber vertebra
Co: The coccyx
S1: First sacral vertebra
S2: Second sacral vertebra
S3: Third sacral vertebra
S4: Fourth sacral vertebra
S5: Fifth sacral vertebra



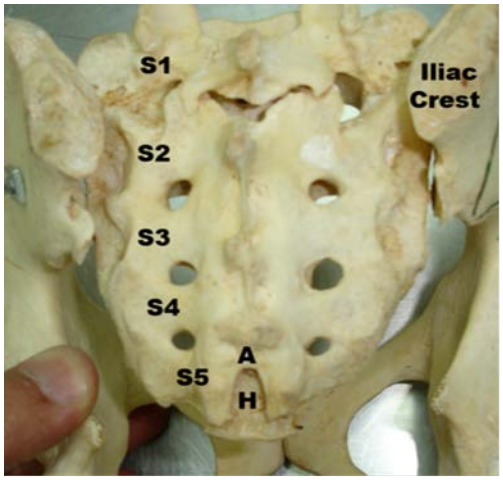
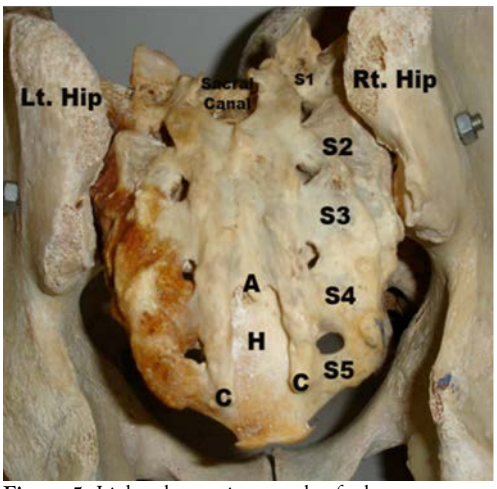


Figure 4: Light photomicrograph of a human sacrum showing an inverted V-shaped sacral hiatus (H) at its lower dorsal surface. The hiatus has variable lengths and its apex (A) is present opposite different sacral segments (S5, S4). The base (B) has fixed position between the two sacral cornuae (C). Notice; the number of sacral vertebrae (S1, S2, S3, S4 &S5) and the defect between S1 & S2.



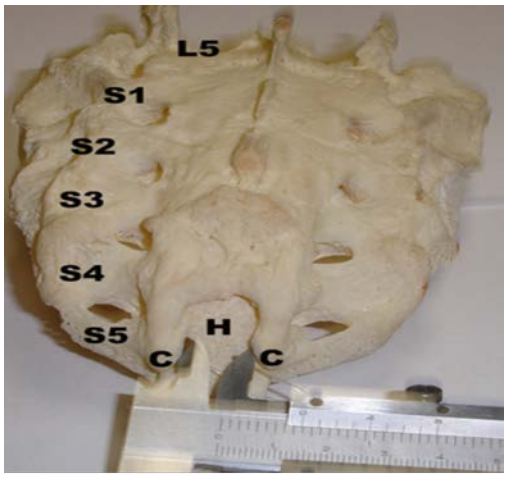


Figure 5: Light photomicrograph of a human sacrum showing an

distance between them and the apex of sacral hiatus. From these measures, an equilateral triangle between the posterior superior iliac spines and the apex of the sacral hiatus was noticed. These main landmarks were firstly determined on the skin of the cadaver before the dissection **(Fig.8)**. These landmarks were assured after removal the skin and fascia **(Figs. 9, 10)**. The sacro-coccygeal membrane was removed to expose the sacral hiatus. All the parameters of the sacral hiatus were measured on the cadavers, particularly its length and transverse diameter **(Fig.11)**. Moreover, the contents of the sacral hiatus were clearly seen, especially the filum terminale **(Fig. 12)**. A needle was introduced through the sacral hiatus from its base to its apex to clarify the exact passage of the caudal epidural block**.** The level of the dome of the coccygeal convexity was seen at the same horizontal level of the sacral hiatus **(Fig. 12)**.

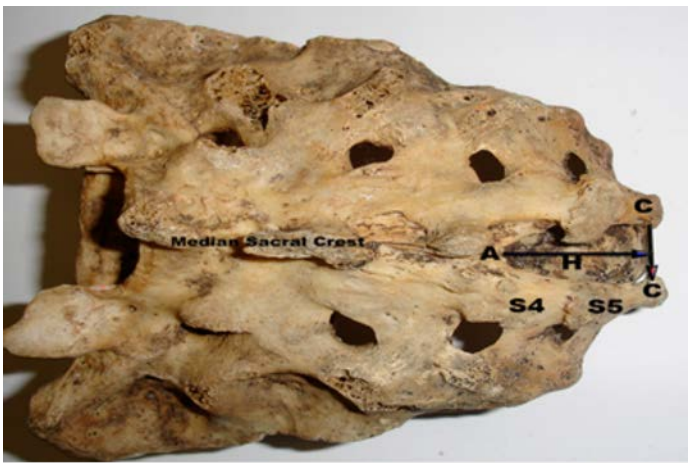


Figure 6: Light photomicrograph of a human sacrum showing an irregular shaped sacral hiatus (H) at its lower dorsal aspect. The short vertical black arrow between the two sacral cornuae (C) represents the base of the hiatus and the horizontal arrow extending from the apex (A) to the base represents the length of the hiatus. The base is present at the level of the lower border of 5th sacral vertebra (S5) and the apex is present at the 4th sacral vertebra (S4).

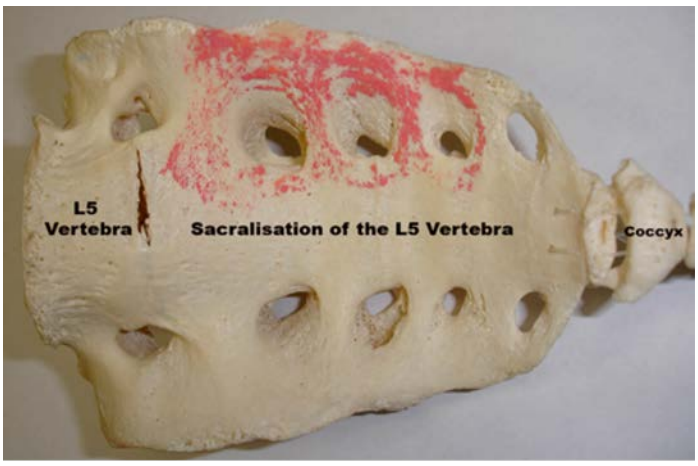


Figure 7: Light photomicrograph of a human sacrum showing the sacralisation of the 5th lumber vertebra (L5).

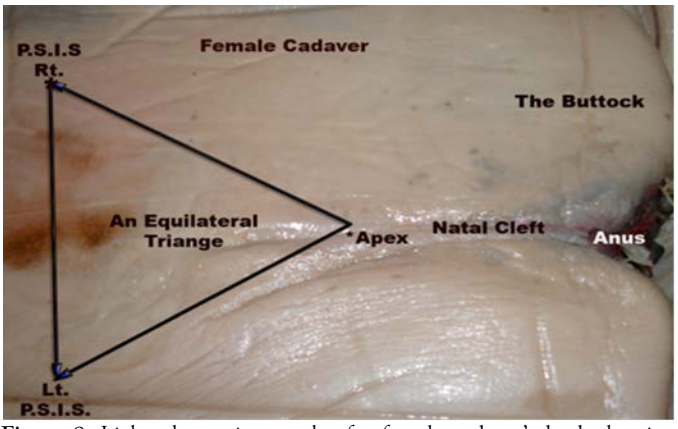


Figure 8: Light photomicrograph of a female cadaver's back showing the three main landmarks of the sacral hiatus and the equilateral triangle, which are the apex of the hiatus and the posterior superior iliac spines of both sides on the skin before.

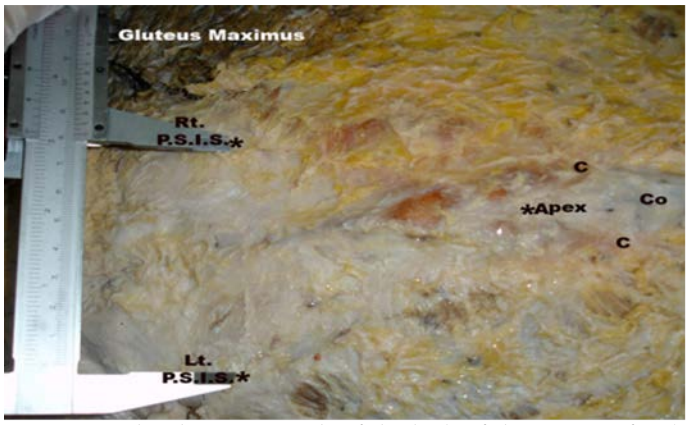


Figure 9: Light photomicrograph of the back of the previous female cadaver (after dissection the skin and fascia) showing the three main landmarks of the sacral hiatus and the equilateral triangle. These landmarks are the two posterior superior iliac spines (P.S.I.S.) and the apex of the sacral hiatus (*). Notice; The coccyx (Co) and the sacral cornuae (C).

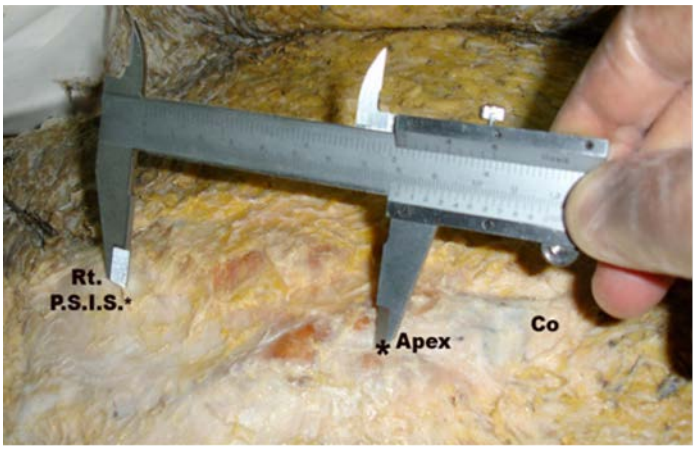


Figure 10: Light photomicrograph of the female cadaver showing the dimension between the apex (*) of the sacral hiatus and the right posterior superior iliac spine (P.S.I.S.). Notice; the coccyx (Co).

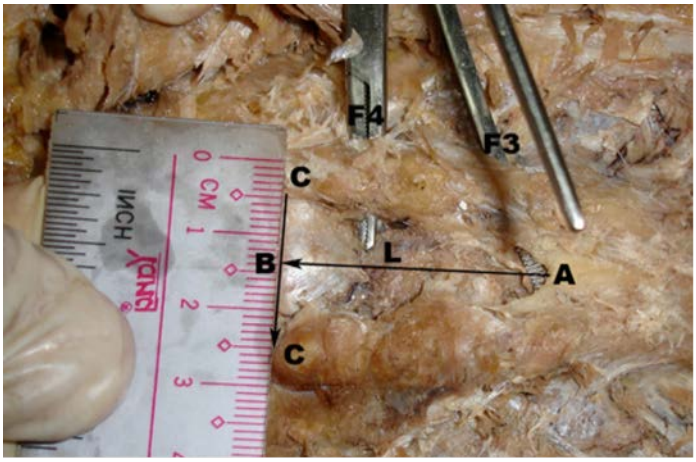


Figure 11: Light photomicrograph of a male cadaver showing the boundaries and dimensions of the sacral hiatus after removal the sacrococcygeal membrane. The base or width (B) of the sacral hiatus is the distance between the two sacral cornuae (C) and the length (L) is the distance from the base to the apex (A). Notice; The passage of the forceps from the 4th (F4) and 3rd (F3) dorsal sacral foramina to the cavity of the sacral hiatus.

Discussion

The sacral hiatus is the most important route for the caudal epidural anaesthesia. So, the full understanding of the anatomical dimensions and variations of it leads to high success rate of the caudal epidural block. In the present study, different parameters of the sacral hiatus were measured on the dry sacra and the cadavers.

In the present study, the sacral hiatus length varied from 7–110 mm and its mean was 27.16 ±15.8 mm. In two-thirds (66.66%) of the sacra, the length of the hiatus was 11-30 mm. Similar observations were recorded by Nagar [13], who 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 disagreement with the results of the present study, Senoglu *et al.* [6] stated that, the average length of the sacral hiatus was 32.1 ± 9.9 mm, its range was 12-53 mm and 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, Kumer *et al.* [12] observed the mean length of the sacral hiatus as 20 mm in Indian males and 18.9 mm in Indian females. However, Trotter and Lanie [16] 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. However, No sex determination was done in the sacra of the present study.

In the present study, the mean of the transverse diameter (width) of the sacral hiatus was 11.5 ± 3.1 mm and it ranged from 4 -17 mm. In more than half of the sacra (53.3%), the transverse diameter of the hiatus at the base ranged from 11 to 15 mm and it measured 6-10 mm in one third of the sacra (33.3%). Thus, it ranged from 6 to 15 mm in 86.6% of the

Table 7: Shows the level of the base of sacral hiatus.

Level	number	Percentage (%)
S4	18	12%
S5	105	70%
Coccyx	27	18 %

Table 8: Shows number and percentage of the fused coccyx or L5 vertebra.

Item	Number	Percentage (%)
Fused Coccyx	27	18 %
Fused L5 Vertebra	14	9.33 %

sacra. This was almost similar to Nagar [13] study on Indian sacra who noted the width of the sacral hiatus at the base varied from 0.3 to 19 mm, in more than half (54%) cases it was 10-15 mm and in 84% cases it was 6-15 mm. Similar observations were recorded in the earlier studies as Trotter and Letterman [17] who noted the width of the hiatus at the base varying from 7–26 mm with mean of 17 mm; Lanier *et al.* [18] who reported that, the mean of the width of sacral hiatus at the base was 19.3 ± 0.3 mm; Kumer *et al.* [14] 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. In agreement with the results of the present study, Sekiguchi *et al.* [10] stated that, the mean of the distance between the sacral cornua of the Japanese was 10.2 ± 0.35 mm and ranged from 2.2 to 18.4 mm. The authors added that, in 5% of sacra, the distance between the two cornuae was less than 5 mm. However, Sinoglu *et al.* [6] reported that the mean of the distance between the two cornuae of the Turkish sacra was 17.5 ± 3.2 mm and it ranged from 7 to 28 mm. Park *et al.* [19] reported that, the intercornual distance in children was 17 mm and ranged from 9.6 to 24 mm by using ultrasound imaging. These results might be attributed to racial diversity.

The A-P diameter of the sacral canal at the apex of the sacral hiatus is important as it should be sufficiently large to admit a needle. In the present study, the A-P diameter of the sacral canal at the apex of the sacral hiatus ranged from 1 to 9 mm and with a mean of 4.78 ± 1.87 mm. Similar observations were noticed by Nagar [13] and Sinoglu *et al.* [6] who reported that the anteroposterior diameter of the sacral canal at the apex of the sacral hiatus ranged from 2 mm to 14 mm and from 1 mm to 7 mm with a mean of 4.88 and 4.46 ± 1.33 mm respectively. Moreover, Trotter and Letterman [17] and Lanier *et al.* [18] who reported that, the mean of the A-P diameter of the sacral canal at the apex of sacral hiatus was 4.6 ± 1.7 mm and its range was 1 -10 mm in white females; its mean was 4.9 ± 1.5 mm and ranged from1 to 12 mm in white males. Moreover, Crighton *et al.* [14] found similar results by measuring the A-P diameter at an angle 90° to the sacrococcygeal membrane by using MRI. However, Park *et al.* [19] reported A-P diameter of the sacral canal at the apex of the hiatus by using the ultrasound imaging in children was 3.5 mm and ranged from 1-8 mm. Moreover, Sekiguchi *et al.* **[10]** stated that, in Japanese sacra, the range of the A-P diameter of the sacral canal at the apex of the sacral hiatus was 1.9-11.4 mm and its mean was 6 ± 1.9 mm. The authors added that the diameter of the sacral canal was less than 2 mm in 1% of the sacra, hence impeding the use of a 22 G needle for caudal epidural block.

In the present study, the A-P diameter of the sacral canal at the apex of the sacral hiatus measured 4-6 mm in more than 60% of the sacra; 1- 3 mm in 18.6 % of the sacra and it measured 7-9 mm in 20.6% of the sacra. Similar observations were recorded by Nagar [13] who stated that the A-P diameter of the sacral canal at the apex of the sacral hiatus measured 0-3 in 15.6%, 4-6 mm in 64.2%, 7-9 mm in 19.8% and above 9 mm in 0.4%.

In the present study, 10 out 150 (6.66%) of sacra showed the anteroposterior diameter of the sacral canal at the apex of the sacral hiatus measured 1-2 mm. This was in agreement with Sinoglu *et al.* [6] who stated that, in Turkish sacra, the A-P diameter of the sacral canal at the apex of the sacral hiatus was 2 mm or less in six out of 96 (6.25%) sacra. This small diameter might contribute to the anatomical difficulties encountered during the caudal epidural block and should be added to the other causes of the failure rate of the caudal epidural block. Trotter and Letterman[17] and Waldman [5]found the A-P diameter of the sacral canal at the apex of the hiatus less than 2 mm in 5% of the sacra. However, Crighton *et al.* [14] reported only one patient with A-P diameter at the apex of sacral hiatus less than 2 mm. The authors added that, the A-p diameter of the sacral canal of the female patients was larger than those of the male patients. This latter observation might suggest that the caudal techniques might be performed with less difficulty in female patients. In disagreement with the results of the previous researches, Lanier *et al.* [18] did not note any sacra with the A-P diameter of its canal at the apex of the hiatus less than 3mm.

In the present study, the apex of the hiatus extended between S2 and S5 and the coccygeal fusion was seen in 27 out 150 (18%) sacra. Similar observations were reported by Kumer *et al.* [12] who added that the apex of the sacral hiatus extended to the coccygeal level in 14.4% of the sacra where the ankylosis was observed. In the present study, the apex of the sacral hiatus was seen most commonly at the level of the 4th sacral vertebra; more than 80% of the sacra showed the level of sacral hiatus apex at S4 and S5 vertebrae. The apex of sacral hiatus was seen at the level of S4 vertebra in 54% of sacra. Similar observations were recorded by Trotter [20]; Lanier *et al.* [18]; Sekiguchi *et al.* [10]; Sinoglu *et al.* [6]; Nagar [13] and Standring **[3]**. Trotter [20] and Lanier *et al.* [18] who reported that, the mean level of the apex of the sacral hiatus was at the lower third of the 4th sacral vertebra. Sekiguchi *et al.* [10] noted that, the apex of the sacral hiatus was at S4 level in 64% of sacra. Nagar [13] reported that, the apex of the sacral hiatus was seen at the level of S4 vertebra in 55.9% of

sacra. Kumer *et al.* [12] and Shinohara [21] stated that, the apex of the sacral hiatus was seen in 76.23% and 75% respectively at the level of the 4th sacral vertebra. Sinoglu *et al.* [6] stated that, the level of the apex of the sacral hiatus was commonly above the distal third of S4 and distance between S2 foramen and the apex of the hiatus was 35.4 ± 10.4 mm on average range 11 – 62 mm. Waldman [5] reported that, the distance between the tip of the dural sac and the apex of the sacral hiatus around 4.5 cm. In all these studies including the present one, the location of the apex of sacral hiatus differed from the upper end of S2 to the lower part of the S5.

In the present study, the level of the sacral hiatus apex was seen at the level of S3 in 22 (14.66%) and was seen at S2 vertebra in two sacra (1.33%) only. There was complete agenesis of dorsal bony wall of sacral canal in four (2.66%) sacra. Similar observations were reported by the previous studies namely, Trotter and Letterman [17] 1.8%; Kumer *et al.* [12] 1.49% and Nagar [13] 1.5% sacra. However, Nagar [13] added that, in 0.7% of sacra the sacral hiatus was absent due to bony overgrowth which was similar to that reported by Kumer *et al.* [12] in 0.99% where as in a study by Sekiguchi *et al.* [10] it was absent in 3% of sacra. In disagreement with the results of the previous researches, no sacra showed absent hiatus in the present study.

In the present study, the sacral hiatus showed five different forms. The inverted V-shaped hiatus was the most prevalent type and was present in 38.66% of the specimens. The U-shaped hiatus was the second type and was seen in 31.33% of the specimens. The irregular sacral hiatus was seen in 15.33 of the sacra. The dumbbell-shaped sacral hiatus was noticed in 12% of the sacra and the least form of the sacral hiatus was the bifid one and it was observed in 2.66% only of the sacra. Similar observation were noticed by Kumer *et al.* [12] who noticed different shape of the sacral hiatus, the most common form was the inverted V (46.53%) and inverted U (29.70) of the sacra, the elongated shape was observed in 13.86% and the dumbbell-shaped hiatus was seen in 7.43% of the sacra. Moreover, Nagar [13] noticed various shapes of the sacral hiatus but, the most common type was the inverted U (41.5%) and inverted V (27%). The later added that, in 13.3% its outline was like a dumbbell while in 14.1% it was irregular and the bifid hiatus was seen in 1.5 %. The difference of the prevalence of the sacral hiatus might be due to racial factor.

In the present study, the equilateral triangle was confirmed on the cadavers. The distance between the right and left posterior superior iliac spines was approximately equal to the distance between the posterior superior iliac spine of both sides and the apex of the sacral hiatus. Similar observation was recorded by Senoglu *et al.* [6] on the Turkish dry sacra who added that the average distance between the superolateral sacral crest was 66.5 mm (range 51-79.5 mm). The distance between the right superolateral sacral crest and the sacral apex was 67.1 mm (range 42.1-89 mm). The distance between the left superolateral sacral crest and the sacral hiatus apex was 67.5 mm (range 46- 88.1). The equilateral nature of the triangle formed between the two posterior superior iliac spines and the apex of the sacral hiatus would be helpful in ascertaining the location of sacral hiatus and would contribute to the success of the caudal epidural anesthesia.

In the present study, the fusion of 5th lumber vertebra (sacralisation) with the sacrum was seen in 14 (9.33%) sacra. However, Kumer *et al.* [12] recorded that the sacralisation of the L5 vertebra was seen in 15 out 202 sacra (7.43%) on Indian population. This difference might be due to genetic or racial factor. In the present study, the fusion of the coccyx with the sacrum was observed in 27 (18%) sacra. Similar observation was noticed by Kumer *et al.* [12] who stated that the ankylosis of coccyx was seen in 43 out 202 sacra (14.35%). The ankylosis of coccyx was related to the aging state of the sacra.

Conclusion

There were anatomic variations of the sacral hiatus, which might be responsible for the failure of the caudal epidural block. The present study showed that the caudal epidural block (CEB) failure might occur in 2.66% to 9.32% of the patients because of the anatomic variations or abnormalities of the sacral hiatus. The rate of the impossible caudal epidural block was 6.66% since the diameter of sacral canal at the apex of the hiatus was 2 mm or less. Moreover, there was a complete agenesis of the sacral hiatus in 2.66% of sacra. Thus, these causes should be kept in mind while giving the caudal epidural anaesthesia in Egyptian population. Understanding of these variations might improve the success rate of the caudal epidural anaesthesia. Moreover, when the clinician noticed an abnormality of the hiatus, he should choose lumber epidural block or other route of anaesthesia to avoid the risk of the soft tissue injury and the toxicity of the local anesthetics.

Further clinical studies are required to compare the existing technique and anatomical description of the present study to provide more data to support the results of this study.

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