

# A Morphometric and Radiological Study of Sacral Hiatus in Human Adult Sacra and Its Clinical Relevance in Caudal Epidural Anaesthesia

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## ABSTRACT

**Background:** The knowledge of sacral hiatus anatomy is crucial in clinical situations requiring caudal epidural block for various diagnostic and therapeutic procedures of the lumbosacral spine to avoid complications and failure rate. This study was undertaken to compare morphometric characteristics of sacral hiatus in human dry sacra and pelvic radiographs for placing the needle more accurately in the sacral hiatus landmarks to permit correct, painless, and uncomplicated caudal epidural accesses.

**Materials and methods:** The present study was done on 138 human adult dry sacra and 110 anteroposterior lumbosacral spine radiographs of the North Karnataka region of India. Sacral hiatus was evaluated in each sacrum based on its shape, level of its apex, and base according to sacral and coccygeal vertebrae, length, anteroposterior diameter at its apex, and transverse width at its base.

**Results:** The mean length of sacral hiatus in men and women was 27.81±1.17 mm and 24.73±2.21 mm, respectively. The mean anteroposterior diameter of the sacral hiatus at the apex was 6.24±2.73 mm in males and 6.63±2.81 mm in females. The transverse width of the sacral hiatus at the base was 17.56±1.81 mm in males and 17.92±2.59 mm in females. The location of the apex of sacral hiatus was the highest in number at

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*the level of the fourth sacral vertebra (23.63%). The location of apex in radiographs of all lumbosacral spine S3 showed 49.09% maximum. The location of the base of the sacral hiatus was observed in the dry sacra at the level of the fifth sacral vertebra (64.54%). In the present study, different shapes of the sacral hiatus were recorded. The most common shape in males and females was inverted U shape (42.02%), followed by inverted V shape (26.08%) and dumbbell shape (12.31%). The least common shape was observed in the bifid sacra (5.07%). In 2.17% of cases, sacral hiatus was absent. Percentage of absence, agenesis, irregular, and bifid shapes were found rather in female than male sacra. An anteroposterior view of spine radiograph showed sacral hiatus agenesis in both females (7.81%) and males (4.34%). The anatomical knowledge of sacral hiatus and its variations are important in caudal epidural anesthesia, and it may improve the success rate of caudal epidural anesthesia.*

**Keywords:** sacral hiatus, caudal epidural anaesthesia, anatomical variations.

## INTRODUCTION

**T**he sacrum is a triangular wedge-shaped bone that is composed of five fused sacral vertebrae. It articulates with the lumbar spine superiorly, the iliac bones laterally, and the coccyx inferiorly (1). The posterior midline crest represents the vertebral spines. Sacral and coccygeal cornua are important landmarks for the identification of the sacral hiatus (SH) and increase the success rate of the caudal epidural block (CEB) (2). These landmarks are easily palpable in infants and children, but can be very difficult in adults because of the increase in fat and tissue content in this area (3). Lack of fusion or the absence of the S4-S5 laminae gives rise to the SH. The SH contains: 1) a pair of the fifth sacral nerves, which groove the lateral parts of the fifth sacral vertebra; 2) a pair of coccygeal nerves; 3) filum terminale externa, which passes to the coccyx; and 4) fibrofatty tissue (3). Sacrococcygeal symphysis is stabilized by dense sacrococcygeal ligament as well as ligamentum flava (4, 5).

In the current study, we aimed to find out the anatomical variations of SH by morphometric and radiological measurements, as the reliability and success of caudal epidural anesthesia depend upon anatomical variations of sacral hiatus. □

## MATERIAL AND METHOD

**T**he material for the present study consists of sacra from 138 adults (86 males and 52 females), which were collected from the Bone Bank Department of Anatomy, and 110 pelvis radiographs of normal adults (46 males and 64

females), which were collected from the Department of Radiology Faculty of Medicine, Shri B.M. Patil Medical College Hospital and Research Center, BLDE (deemed to be University) Vijayapur, India. All selected sacra were normal, fully mature and ossified, and devoid of any fractures or pathological changes. Methods of measurements, index calculation and statistical methods were used. The different parameters of each sacrum studied by us include: 1) SH shape, noted by appearance; 2) level of SH apex, noted with respect to the sacral vertebra; 3) SH length, measured from the midpoint of the base to the apex; 4) the measured SH anteroposterior depth of the apex; and 5) SH transverse width at the base, measured between the inner aspects of sacral cornua using a Digital Vernier Caliper.

1) Maximum length is the distance between the middle points on the anterosuperior margin of the promontory to the middle of the anteroinferior margin of the fifth sacral vertebrae.

2) Maximum sacral width is the most distant point on the sides of the ala of the sacrum.

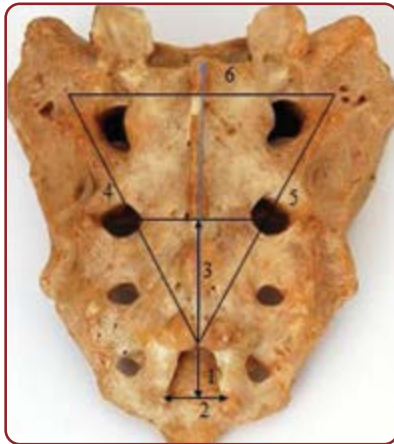
3) Mid ventral curved length measured along the midline of the pelvic surface of the sacrum from the middle of the anterosuperior margin of the promontory to the middle of the anteroinferior margin of the fifth sacra by using a flexible measuring tape.

4) Transverse diameter of the body of the first sacral vertebra [S1]: measurements were taken from the right to the left end of the body of sacral promontory.

5) The anteroposterior diameter of the body of the first sacral vertebra [S1]: midpoint anterior border of sacral promontory to the midpoint of the posterior border of the first sacral vertebral body.

$$6) \text{ Sacral index} = \frac{\text{sacral width} \times 100}{\text{sacral ventral straight length}}$$

$$7) \text{ Corporo-basal index} = \frac{\text{transverse diameter of body of S1} \times 100}{\text{width of sacrum}}$$



**FIGURE 1.** Measured parameters of the sacral hiatus. 1) height of sacral hiatus; 2) width of sacral hiatus at the level of sacral cornua; 3) distance from hiatus apex to the level of S2 foramina; 4) distance between the left superolateral sacral crest and sacral hiatus apex; 5) distance between the right superolateral sacral crest and sacral hiatus apex; and 6) distance between two superolateral sacral crests (base of the triangle)

**RESULTS**

Observations were made on 138 dry sacra and 110 anteroposterior sacral radiographs

Parameters (mm)	Males (n=86)	Females (n=52)
Length	108.60±14.21	97.69±11.9
Width	97.69±12.80	103.55±13.19
Mid ventral curved length	117.50±24.83	112.02±16.86
Anteroposterior diameter (S1)	35.47±7.80	33.46±7.57
Transverse diameter (S1)	42.73±7.99	35.77±5.72
S1 index	59.88±2.4	67.78±38.89
Sacral index	105.13±14.89	118.57±9.47
Curvature index	93.98±4.10	87.92±5.10
Corporo-basal index	43.25±7.81	47.33±5.81

**TABLE 1.** Morphometric parameters of dry sacra

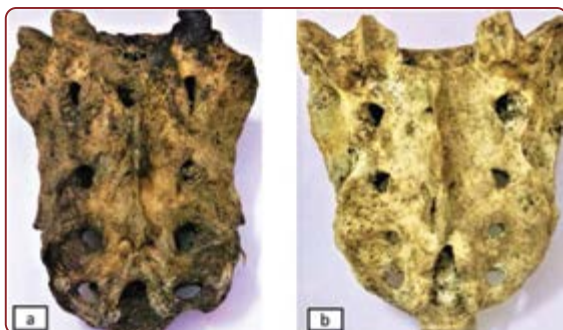
of both males and females, which showed significant morphological findings.

**Assessment of sacral hiatus**

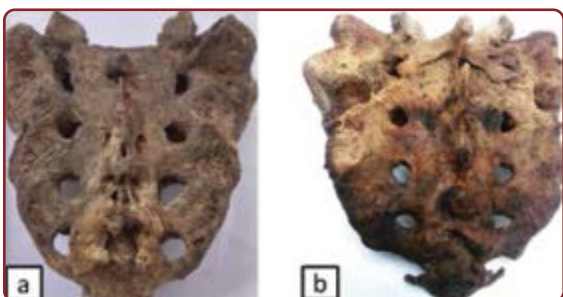
Out of the 138 dry sacra studied by us, the most common shape of SH recorded in the present study was inverted U shape (42.02%), followed by inverted V shape (26.08%), dumbbell (12.31%), irregular (7.24%) bifid (5.07%) and M shape (2.17%). The most common shapes of dry sacra were U, V and dumbbell shapes in men, and bifid and irregular shapes in women. Agenesis of sacral hiatus was detected in 2.89% of all sacra, out of which 3.84% in females. Thus, complete agenesis of the dorsal wall of sacrum is more common in females than males. In both male and female sacra, the least common shape was M (2.17%) and bifid shape (5.07%) (Table 2, Figure 4a). Absence of sacral hiatus was found in 3.84% of female sacra (Table 1).

S/n	The shape of the sacral hiatus	Males		Females		Total	Percentage
		No	%	No	%		
1	Inverted U shape	43	50.00	15	28.84	58	42.02
2	Inverted V shape	18	21.17	18	34.61	36	26.08
3	Dumbbell shape	13	15.11	4	7.69	17	12.31
4	Irregular shape	4	4.65	6	11.53	10	7.24
5	Bifid shape	3	3.48	4	7.69	7	5.07
6	M shape	2	2.32	1	1.92	3	2.17
7	Absent	1	1.16	2	3.84	3	2.17
8	Agenesis	2	2.32	2	3.84	4	2.89
<b>Total</b>		86		52		138	

**TABLE 2.** Different shapes of sacral hiatus in dry sacra



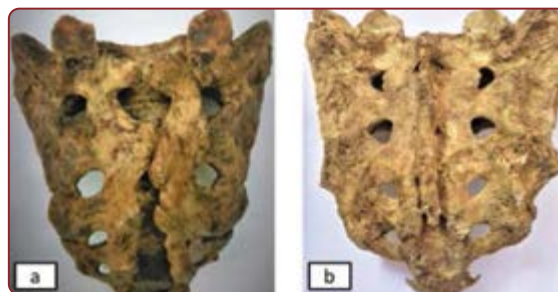
**FIGURE 2.** Posterior surface of sacra showing: (a) inverted U shaped sacral hiatus with its apex at the level of S4 and its base at S5 in Indian female adults; and (b) inverted V shaped sacral hiatus with its apex at the level of S3 and its base at S5 in Indian male adults.



**FIGURE 3.** Posterior surface of sacrum showing: (a) dumbbell shaped sacral hiatus with its apex at the level of S4 and its base at S5 in Indian male adults; and (b) irregular shaped sacral hiatus at S3 and its base at S5 in Indian female adults

Table 1 shows the mean and standard deviation (SD) of maximum height, width, and antero-posterior diameter sacral index curvature index corporo-basal index of SH in all male and female sacra.

The mean length of dry sacra in males and females was 108.60+14.21 mm and 97.69+11.9 mm, respectively. The mean anteroposterior diameter of dry S1 sacra was 35.47+7.80 mm in males and 33.46+7.57 mm in females. The transverse



**FIGURE 4.** Posterior surface of sacrum showing: (a) bifid shaped SH in Indian female adults; (b) M shaped sacral hiatus in Indian male adults



**FIGURE 5.** Posterior surface of sacrum showing: (a) absent sacral hiatus in Indian female adults; (b) complete agenesia of the sacral canal in Indian male adults.

width at the base of sacra was 97.69+12.80 mm in males and 103.55+13.19 mm in females. The maximum sacral width and sacral index were significantly increased in females comparatively with males, whereas the sacral length and mid-ventral curved length and curvature index were significantly increased in male subjects.

The mean length of SH was 26.80+2.14 mm. The mean transverse width at base was 17.70+2.14 mm and the mean anteroposterior diameter of SH 6.80+2.81 mm. The width at apex and base was 6.48+1.46 mm and 17.70+2.14 mm, respectively. The anteroposterior diameter was significantly increased in fe-

Parameters (mm)	Total sacra (n=138)	Male sacra (n=86)	Female sacra (n=52)
Length	26.80±2.14	27.81±1.17	24.73±2.21
Width at base	17.70±2.14	17.56±1.81	17.92±2.59
Width at apex	6.48±1.46	6.19±1.45	6.96±1.34
Anteroposterior diameter at apex	6.80±2.81	6.24±2.73	6.63±2.81

**TABLE 3.** Length width and anteroposterior diameter of sacral hiatus



TABLE 4. Different locations of sacral hiatus apex in adult dry sacra

Location of apex	Males (86)		Females (52)		Total No.	Percentage
	No.	%	No.	%		
2	4	4.61	0	0	4	2.89
3	23	26.74	14	26.92	37	26.81
4	49	58.33	32	61.53	81	58.69
5	7	8.13	2	3.84	9	6.52
Absent	1	1.16	2	3.84	3	2.17
Agenesis	2	2.32	2	3.84	4	2.89

TABLE 5. Different locations of sacral hiatus base in relation to sacral and coccygeal vertebrae in adult dry sacra

Location of base	Males (86)		Females (52)		Total (138)	Percentage
	No.	%	No.	%		
4	17	16.27	8	23.07	25	18.11
5	59	70.23	38	73.07	97	70.28
Coccygeal	7	6.97	2	3.84	9	6.52
Absent	1	1.16	2	3.84	3	2.17
Agenesis	2	2.32	2	3.84	4	2.89

TABLE 6. Anteroposterior diameter of sacral hiatus apex in adult dry sacra

Anteroposterior diameter at base	Males (86)		Females (52)		Total (138)	Percentage
	No.	%	No.	%		
0-3	2	2.32	4	7.69	6	4.34
3.01-6.00	48	55.81	27	60.71	75	54.34
6.01-9.00	25	29.06	10	26.78	35	25.36
>9.1	7	8.13	7	12.5	14	10.14
Absent	2	2.38	2	3.84	4	2.89
Agenesis	2	2.38	2	3.84	4	2.89

TABLE 7. Different shapes of sacral hiatus in anteroposterior lumbosacral spine radiographs of Indian adults

Shape	Males (46)		Females (64)		Total (110)	Percentage
	No.	%	No.	%		
U	16	34.78	23	42.18	39	35.93
V	10	21.73	15	23.43	25	22.72
Dumbbell	8	17.39	10	15.62	18	16.36
Irregular	5	10.86	7	10.93	12	10.90
Bifid	2	4.34	2	3.12	4	3.63
M	2	4.34	1	1.56	3	2.72
Absent	1	2.17	1	1.56	2	1.81
Agenesis	2	4.34	5	7.81	7	6.36
					Total = 110	



FIGURE 6. Anteroposterior view of male lumbosacral spine radiograph showing inverted U shaped sacral hiatus and its apex at the level of S3 and its base at S5



FIGURE 7. Anteroposterior view of male lumbosacral spine radiograph showing inverted V shaped sacral hiatus and its apex at the level of S4 and its base at the level of the coccyx



FIGURE 8. Anteroposterior view of female lumbosacral spine radiograph showing dumbbell shaped sacral hiatus and its apex located at the level of S4 and its base at the level of the coccyx



**FIGURE 9.** Anteroposterior view of female lumbosacral spine radiograph showing agnesis of sacral hiatus



**FIGURE 10.** Anteroposterior view of male lumbosacral spine radiograph showing incomplete sacral hiatus and its apex at the level of S4 and its base at S5

**TABLE 8.** Different locations of sacral hiatus apex in anteroposterior lumbosacral spine radiographs of Indian adults

Location of SH apex	Males (n=46)		Females (n=64)		Total (110)	Percentage
	No.	%	No.	%		
2	4	8.69	7	10.93	11	10
3	21	46.65	33	51.56	54	49.09
4	15	32.60	11	17.18	26	23.63
5	3	6.52	7	10.93	10	9.09
Absent	1	2.17	1	1.56	2	1.81
Agnesis	2	4.34	5	7.81	7	6.36

**TABLE 9.** Different locations of sacral hiatus base in sacral and coccygeal vertebrae in anteroposterior lumbosacral spine radiographs of Indian adults

Location of SH base	Males (n=46)		Females (n=64)		Total	Percentage
	No.	%	No.	%		
4	14	30.43	10	15.62	24	21.81
5	24	52.17	47	73.43	71	64.54
Coccygeal	5	10.86	1	1.56	6	5.45
Absent	1	2.17	1	1.56	2	1.81
Agnesis	2	4.34	5	1.56	3	2.72

male dry sacra (6.63+2.81), and the length of SH was higher in male sacra (27.81+1.17 mm) (Table 3).

The levels of the apex and base of each SH of dry sacra were determined according to the sacral and coccygeal vertebrae (Tables 4-6; Figures 2-5). Among all sacra, the most common location of SH apex was found at the level of the fourth sacral vertebra (58.69%), followed by SH

base (70.28% at the level of the fifth sacral vertebra in all sacra). The anteroposterior diameter of SH was 54.34%. All three parameters were significantly increased in female dry sacra.

Radiographic observations of the pelvis showed U shaped SH in 35.93% of cases. V shape was the second commonest shape in 23.43% of female radiographs. Agnesis of SH in pelvic radiograph was significantly increased (7.81%) in Indian women. The remaining shapes showed by pelvic sacral radiographs were almost similar in both sexes (Table 7, Figures 6-10).

Tables 8 and 9 show the level of the apex and base of SH. The apex of SH was found to be most common at the level of the third sacral vertebra in 54 (49.09%) sacra and fourth sacral vertebra in 26 sacra bones (23.63%); the apex at the level of the second sacra was seen in 11 (10%) and at the level of the fifth sacral vertebra in 10 (9.09%). While the level of the base was common at the level of the fifth sacra vertebra in 71 (64.54%) sacra and that of the fourth sacra vertebra in 24 (21.81%), base at the level of coccyx also observed in six (5.45%) Indian adults' pelvic radiographs of SH. □

**DISCUSSION**

Anatomical variations in morphology and morphometry of sacral hiatus are more clinically and surgically important, since this route is frequently utilized for caudal epidural anesthesia (CEA) in perineal surgery and caudal analgesia for a painless delivery. The sacrum is a wedge-

shaped triangular bone formed by the fusion of all sacral vertebra and completes the lower end of the skeleton of the vertebral column by protecting the meningeal part of the spinal cord. Sacral somites contribute to the development of the sacrum during the end of the first month of development. The secondary centers of ossification appear in adolescence. Any defect in the formation of primary centers may lead to incomplete formation of the sacral canal and incomplete ossification of the laminae (5). The incomplete fusion of posterior elements of the fifth or fourth sacral vertebra results in the formation of SH. Sacral hiatus is used for caudal epidural block in orthopedic therapeutic and diagnostic procedures (2). Epidural corticosteroid injections can be given into the SH to treat sciatica and chronic low back pain in clinical cases (6).

### Shape of hiatus

Unilateral incomplete development of sacra, flattened SH, reduced sacral size, and presence of ossified sacrococcygeal ligament in SH is the causative factor for change in the shape of sacral hiatus. Different shapes of SH were studied, the most common being the inverted U shape: 58 (42.02%). This finding is similar to those reported by Aggarwal *et al.* (7) (40.35%), Seema *et al.* (8), and (42.47%) Desai *et al.* (9) (42.12%). U shape was significantly more frequent in male than female sacra (48.21%). The second commonest shape noted was the inverted V shape (26.08%). These findings were similar to those reported by Seema *et al.* (8) (27.51%) and Mustafa *et al.* (10) (24%). Inverted V shape was more significantly seen in female than male sacra (34.61%). We found dumbbell shaped sacra in both sexes: 15.11% in men and 17.39% in women. Sacral hiatus was absent in 2.17% of cases, which was close to the findings described by Seema *et al.* (8) (2.51%). In the study of Sengoku N *et al.* (11), absent SH was found in 4% of cases, which was a significantly higher percentage than ours. Sacral hiatus absence is one of the anatomical regions for caudal epidural anesthesia failure and needle damage (12). Radiograph of anteroposterior view of the pelvis showed the highest incidence (6.36%) of agenesis SH, and it was significant in female radiographs. Agenesis of SH be due to condyle regression syndrome, spina bifida, and Currarino syndrome.

### Apex of the sacral hiatus

In the dry sacra, the apex of SH was located at the level of S4 in 81 (58.69%) of cases. Radiographs of anteroposterior view of the pelvic sacra showed apex of SH at S3 level vertebra in 54 (49.09%) of cases. Incidence of SH at S3 level was significantly higher in female 33 (51.56%) than male radiographs. The apex of SH is a notable landmark for carrying out the successful caudal epidural block. Knowledge about the apex of SH is important when it is located at the level of S2 or S3 vertebra because of more chances of puncture of the dural sac during CEA as the apex is very close to the lower limit of the dural sac (13). When it is extended up to lumbar spinous processes, it is important to develop the techniques to prevent neurological injury associated with neuraxial injections.

### Base of sacral hiatus

In the present study, the base of SH was most commonly seen at the level of the fifth sacral vertebra in 97 (70.28%) of all sacra. The findings were more similar to those reported by Kumar *et al.* (14) (81.17%) and Seema *et al.* (8) (71.67%). On the other hand, it was least found at the level of coccyx: 9 (6.52%). Precise knowledge about the shape and extent of SH is important because it is the site where caudal anesthesia is given in surgical, obstetric and gynecological, and urological operations. Results of anteroposterior radiographic observations of pelvic sacra at the level of the fifth sacral vertebrae were observed in 71 (64.54%) of cases. Anteroposterior view of a radiograph of the base of SH at the level of the coccygeal vertebra was found in 6 (5.45%) of cases. The base of SH at the coccygeal vertebra level may lead to coccygeal ankylosis.

### Length of the sacral hiatus

In the present study, the length of SH was  $27.81 \pm 1.17$  mm in males and  $24.73 \pm 2.21$  mm in females, similarly to the study of Kumar *et al.* 1992 (14), in which the mean length of SH was 20 mm. Similar results have been also noted in earlier studies of Trotter *et al.* 1944 (15), in which the length of SH varied between 0–60 mm, with a mean value of 22.5 mm. Nagar SK, Nadeem G, Sinha MB (16-18) reported the length of SH from 10-30 mm. Longer SH reduce the length of the



sacral canal, increasing the possibility of needle puncture of the dural sac. Deposition of fat in other connective tissue reduces the length of SH in obese people, which makes it difficult to locate the SH and increases the likelihood of caudal epidural block (CEB) failure rate (19).

#### Width of sacral hiatus at the base

The width at the base of SH was  $17.56 \pm 1.81$  mm in males and  $17.92 \pm 2.59$  mm in females. This was almost similar to an earlier study conducted by Trotter and Letterman (15), in which the width at the base varied between 7–26 mm, with a mean of 17 mm, Lanier *et al.* (20), who reported a mean width at the base of  $19.3 \pm 0.3$  mm, and Pandey *et al.* (21), who reported 5–20 mm in male sacra and 8–18 mm in female sacra. Sekiguchi *et al.* (22) reported less than 10 mm of the width of SH at the base, while Patil Dhananjay *et al.* (23) found a width of SH ranging between 9–20 mm, with a mean of 13.71. Morphometry of SH at the base is important in caudal anesthesia, and it would not be safe to push the needle beyond 7 mm to avoid dural puncture.

#### Anteroposterior diameter

The anteroposterior diameter of the sacral canal at the apex of SH is important as it should be sufficiently large to introduce a needle. Various anteroposterior diameters of SH lead to subcutaneous deposition of an anesthetic drug. In the present study, the anteroposterior diameter at the apex of SH was  $6.24 \pm 2.73$  mm in males and  $6.63 \pm 2.81$  mm in females. Earlier studies reported the following values of the mean diameter of SH:  $6.1 \pm 0.2$  mm [Lanier *et al.* (20)], 5 mm in white people and 6 mm in black people [Trotter *et al.* (15)], and 5–20 mm (mean of 1.3 mm) in male sacra and 8–18 mm (mean of 1.25 mm) in female sacra [Vinod Kumar *et al.* (14)]. Sekiguchi *et al.* (22) found an anteroposterior diameter of the sacral canal less than 2 mm in 1% of specimens, which made it difficult to use a 22 gauge needle for caudal epidural block.

#### Caudal epidural anaesthesia

Sacrum provides a reliable and effective block for operations that involve low lumbar and sacral dermatomes. A caudal epidural block is a commonly used technique for surgical anesthesia in children and chronic pain management in adults, especially in control of intraoperative analgesia such as genitourinary surgery and labor pain. It is performed by inserting a needle through the SH to gain entrance into the sacral epidural space. For the caudal epidural catheter insertion, posterior superior iliac spines of the ilial part of the hip bone are palpated. The line between both the spine is called the Tuffiers line forms the base of the equilateral triangle of the sacrum (Figure 1). The success rate depends on accurate localization of SH, but these considerable anatomical difference in its size and shape makes the CEB difficult and increases the likelihood of failure. □

#### CONCLUSIONS

The knowledge of anatomical variations of sacral hiatus is important while the administration of caudal epidural anesthesia. Variations in the shape and level of hiatus may lead to failure of caudal epidural block. Knowledge of these variations may improve the success of CEB. It is also important during the reporting of CT and MRI and for the differential diagnosis of low backache and other neurological symptoms, clinical cases related to the lumbosacral and sacrococcygeal region. This study has some limitations related to the fact that measurements were performed on the Indian adult dry sacra. Hence, a generalization of these results to other races is not straightforward and may limit their applicability. □

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