Turk Neurosurg, 2021

Original Investigation

DOI: 10.5137/1019-5149.JTN.35322-21.2

Received: 28.05.2021
Accepted: 03.09.2021

Published Online: 13.12.2021

Clinically Relevant Morphometry of Sacral Hiatus and Morphology of Sacrum

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ABSTRACT

AIM: To outline the variations in morphology and a few clinically relevant morphometric parameters of the sacral hiatus.

MATERIAL and METHODS: The study included 50 dry human sacra, of unspecified sex, in the Department of Anatomy at a medical college in South India. The sex was determined using the sacral, auricular and curvature index. The variations and morphometry of the sacra were documented and tabulated.

RESULTS: It was observed that the inverted U shape of sacral hiatus was common in both males (n=24) and females (n=26). There was one female sacrum with complete dorsal wall agenesis. In males, the length of the apex of sacral hiatus from 1st sacral spine was 5.82 cm ± 1.27 and in females, it was 6.02 cm ± 1.08. Sacral hiatus depth in males was 0.56 cm ± 0.16 and in females 0.54 cm ± 0.14. The width of sacral hiatus at the cornua in males was 1.42 cm ± 0.29 and in females, it was 1.46 cm ± 0.38

CONCLUSION: Knowledge of incidences of variations in the morphology and morphometry of the sacral hiatus across various population groups is paramount for the success and reliability of epidural anesthesia. The success rate of such procedures depends on the clinicians' understanding of the discrepancy in the sacral hiatus.

KEYWORDS: Caudal epidural anesthesia, Sacral canal, Sacral hiatus, Spina bifida, Back pain

ABBREVIATIONS: SH: Sacral hiatus, **CEB:** Caudal epidural block

INTRODUCTION

The sacrum articulates with the hip bone on each side forming the dorsal wall of the pelvic cavity (28). The sacral canal is formed by the union of the pedicle and lamina of the five sacra. The sacral hiatus (SH) is formed due to the non-union of the lamina of the last sacral vertebrae (8). Cauda equina, filum terminale, sacral and coccygeal nerve along with the meningeal coverings are principal contents of the sacral canal (8,23).

Caudal epidural block (CEB) effectively relieves spinal disorders of the lumbar region and back pain. Precise knowledge of SH is essential to perform audal epidural anesthesia to avoid any complications (8,15). An anatomical variation would also contribute to an unsuccessful CEB and transpedicular as well as lateral mass screw placement in the sacrum (27).

Variations in the shape of the sacrum could be one of the factors for lower backache, spondylolysis and spondylolisthesis. Sacralization could lead to labor related complications and knowledge of its incidence is important to gynecologists (15,27,28).

Anesthesia of the perineal musculature for painless labor is performed by injecting anesthetic agents into the SH which has an effect on the coccygeal and sacral nerves and relaxes them. Hence, caudal analgesia is useful during most clinical practices mainly in the fields of gynecology, obstetrics, orthopedics, urology, surgery on the scrotum or penis, and

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some operations on the lower limb and anal surgeries (1,6,22). The sacrum is also significant to the paleoanthropologist and for the forensic researcher for sex determination (23).

The study aims to outline the variations in morphology and a few clinically relevant morphometric parameters of the sacral hiatus after determining the sex of the sacra.

MATERIAL and METHODS

The study included 50 dry human sacra, of unspecified sex, in the Department of Anatomy at a medical college in South India. Bones that were deteriorated and worn away were excluded from the study.

The sacrum was grouped into male and female using the formulas based on Sacral Index (SI), Auricular Index (AI) and Curvature Index (CI) as shown in Table I.

The following morphological parameters such as the shape of the SH, incidence of lumbarization and sacralization, and level of apex of SH corresponding to the sacral spine were observed for male and female sacra.

Table I: Formulas Used to Determine the Sex of the Dry Sacral Bones

Sacral Index	$\frac{\text{Maximum breadth}\times 100}{\text{Maximum height}}$
Curvature Index	$\frac{\text{Maximum height}\times 100}{\text{Midventral curved length}}$
Auricular Index	$\frac{\text{Length of Auricular surface}\times 100}{\text{Width of surface}}$

The morphometric parameters of the SH were documented using a Digital Vernier Caliper (Aerospace 150 mm). Interobserver measurements were also done for all the parameters mentioned below (Figure 1).

1. Length from the 1st sacral spine to the apex of the SH (S1SH)
2. Length from the 2nd sacral spine to the apex of SH (S2SH)
3. Length of SH (LSH)
4. Depth of SH at the apex (DSH)
5. Width of SH at the apex (WSHA)
6. Width of SH at the Sacral Cornua (WSHC)
7. Length of base of the triangle (distance between two superolateral sacral crests) (B)
8. Length of the right border of the triangle (distance between the apex of SH and right superolateral sacral crest) (R)
9. Length of the left border of the triangle (distance between the apex of SH and left superolateral sacral crest) (L)

RESULTS

The results obtained are categorized into metric and non-metric parameters for 50 sacra (males=24; females=26). The inverted U-shape SH was the commonest observed in both males (50%) and females (34.7%) as shown in Figure 2. The incidence of sacralization was higher in males (45.8%) than females (15%). Lumbarization was not observed in males but 1 sacrum was lumbarized in females (Table II). The level of the

Figure 1: The morphometric parameters of the sacral hiatus measured. **WSHC:** Width of SH at the Sacral Cornua, **LSH:** Length of the SH, **S1SH:** Length from the 1st sacral spine to the apex of the SH, **B:** Length of base of the triangle (distance between the two superolateral sacral crests), **R:** Length of the right border of the triangle (distance between the apex of SH and right superolateral sacral crest), **L:** Length of the left border of the triangle (distance between the apex of SH and left superolateral sacral crest).

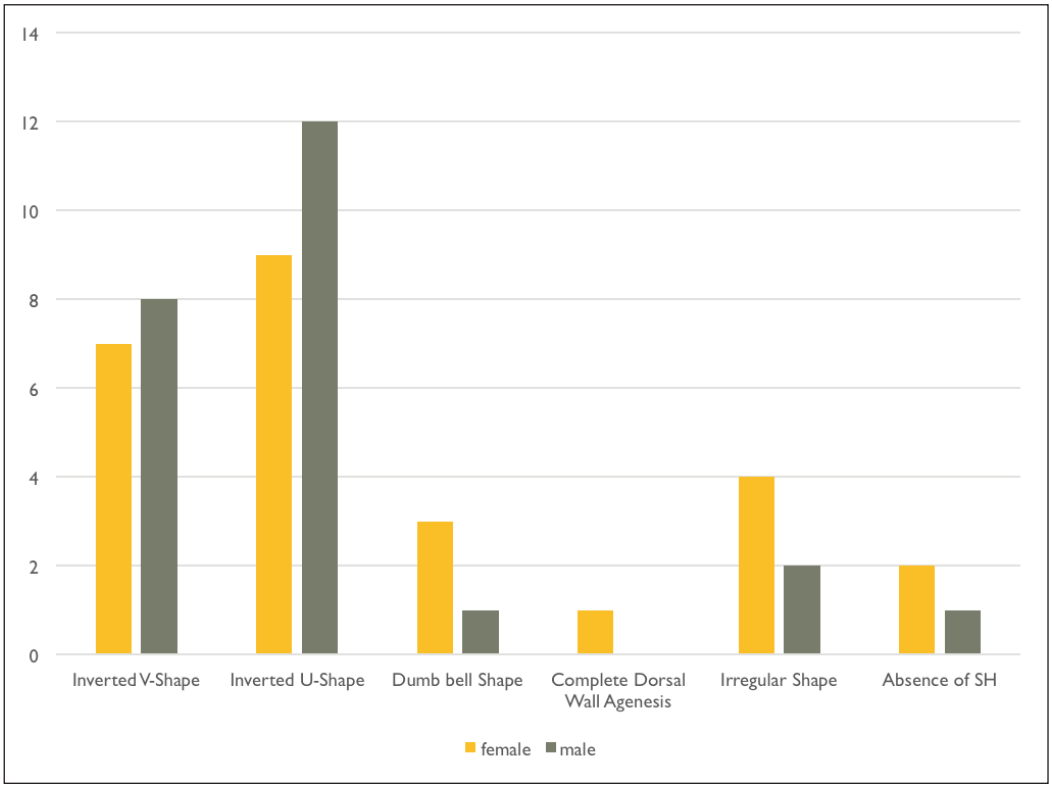

Figure 2: The incidence of various shapes of sacral hiatus as observed in male and female sacra (**SH:** sacral hiatus).

apex of SH corresponds to S3 sacral spine in males (50%) and the S4 sacral spine in females (53.8%) (Table III). The metric parameters of the SH are shown in Table IV. Mean and standard deviations for the values obtained were calculated. Few of the parameters were higher in females compared to males.

DISCUSSION

SH is clinically useful to physicians and surgeons. This study highlights morphological and morphometric parameters in relation to the SH. CEB has been traditionally used for the treatment and management of spinal disorders of the lumbar region to induce anesthesia and analgesia in various surgical procedures in obstetrics and orthopedics (1). The technique of CEB depends on the precise knowledge of identifying the SH by way of which the epidural space is reached. Morphological variations and differences in the dimensions of the SH are attributed to the difficulty in determining the location of the SH and the epidural space which has led to a failure rate of 25% (32). An important factor for successful caudal epidural anesthesia is a thorough knowledge of the anatomy of SH and adjacent structures (7,8). Thus, the awareness of incidences of variations in the morphology and morphometry of the SH across various population groups is paramount for reliable and successful epidural anesthesia.

This study observed five different shapes of the SH that are inverted U, V, dumbbell, irregular and complete dorsal wall agenesis (Figure 3). The inverted U (male=50%; female= 34.6%) and inverted V (male= 33.3%; female= 26.9%) shape

Table II: Incidence of Lumbarization/Sacralization in Male and Female Sacrum

	Male [n=24]	Female [n=26]
Normal	13 (54%)	21 (80.7%)
Sacralization	11 (45.8%)	4 (15%)
Lumbarization	0	1 (3.9%)

Table III: Level of the Apex of SH Corresponding to Sacral Spine

Level of the apex of SH corresponding to sacral spine	Male [n=24]	Female [n=26]
S4	9 (37.5%)	14 (53.9%)
S3	12 (50%)	8 (30.7%)
S2	2 (8.3%)	1 (3.8%)
Absence of SH	1 (4.1%)	3 (11.5%)

SH: *Sacral hiatus.*

of SH was most commonly seen in the present study. Inverted U and V shapes provide adequate space for the passage of the needle while performing CEB. The dumbbell (male=4.2%; female=11.5%) and irregular shaped (male=8.3%; female=15.4%) SH were not prevalently seen in this study. As a result of the varied shapes, CEB is highly challenging in

Table IV: The Various Metric Parameters of Sacral Hiatus that were Documented

Measured Parameter	Range (cm)		Mean (cm)		Standard Deviation (cm)	
	Male	Female	Male	Female	Male	Female
S1SH	3.11-8.77	4.23-7.86	5.82	6.02	1.27	1.08
S2SH	2.01-7.10	3.53-6.26	4.36	5.09	1.36	1.01
LSH	1.42-4.43	1.54-3.89	2.45	2.53	0.51	0.43
DSH	0.22-0.90	0.32-0.77	0.56	0.54	0.16	0.14
WSHA	0.13-0.19	0.12-0.19	0.16	0.15	0.02	0.02
WSHC	1.01-1.98	0.98-2.03	1.42	1.46	0.29	0.38
B	5.21-7.22	5.56-7.02	6.12	6.25	0.65	0.42
R	2.83-6.93	3.16-6.13	4.73	4.11	1.04	0.98
L	2.83-6.72	3.15-6.11	4.62	4.09	1.04	0.98

S1SH: *Length from the 1st sacral spine to the apex of the SH,* ***S2SH:*** *Length from the 2nd sacral spine to the apex of the SH,* ***LSH:*** *Length of the SH,* ***DSH:*** *Depth of SH at the apex,* ***WSHA:*** *Width of SH at the apex,* ***WSHC:*** *Width of SH at the Sacral Cornua,* ***B:*** *Length of base of triangle (distance between the two superolateral sacral crest),* ***R:*** *Length of right border of triangle (distance between apex of SH and right superolateral sacral crest);* ***L:*** *Length of left border of triangle (distance between apex of SH and left superolateral sacral crest.*

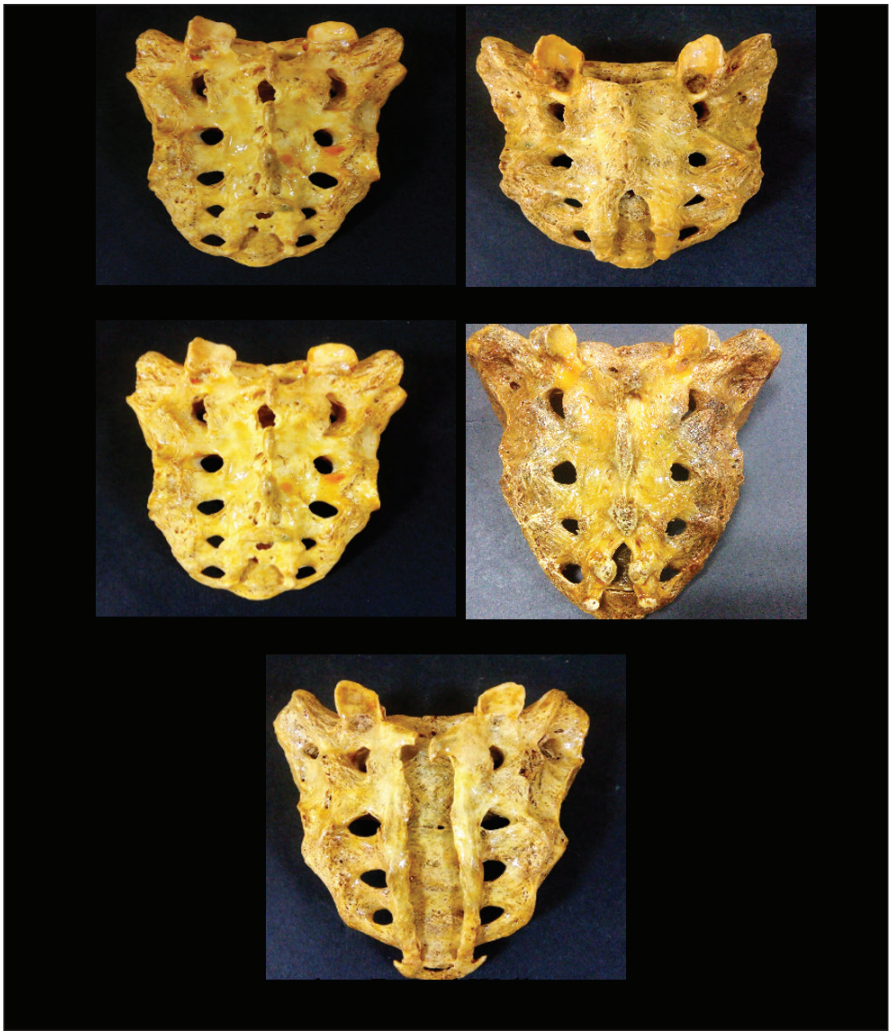

Figure 3 : The various shapes of sacral hiatus.

individuals. Interestingly, the study found one dry sacrum with a deficient dorsal wall, which was also reported by Gaikwad et al. (11). Further, Kumar et al. reported a case of a partially deficient posterior sacral wall in a dry sacrum (17). The failure of the development of the dorsal wall of the sacral canal may lead to risky complications such as accidental puncture of the dura mater during CEB. During the placement of the trans-pedicular screw for spinal fusion, the spine surgeon must be aware of these different shapes of SH (26).

The prevalence of sacralization of L5 vertebrae and lumbarization of S1 vertebrae is observed in the current study. Incidence of sacralization/lumbarization varies with race and origin. It has been observed that sacralization is reported in 4% to 36% of the general population (5,10,14,16,21,29). Similarly, incidences of lumbarization of the first sacral vertebra are reported in 4.2% to 30% of the general population (2,4,5). In the current study sacralization of L5 vertebrae among the South Indian population was 45.8%, in males and 15.3% in females, which is more than what has been reported earlier. Occurrence of lumbarization is often reported in the literature, though in this study incidence of lumbarization was only seen in 3.8% of females which is comparatively less than those reported previously. Gupta et al. in their study stated lumbarization and sacralization may be predisposing factors for the development of lower backache (13). Bulut et al. opined that the relationship between lower back pain and sacralization is not definite and further studies need to be done to confirm this (3). It has been suggested that this may be a risk factor for herniated nucleus pulposus (24). A study by Gopalan B and Yerramshetty confirms that females more than 45 years of age, with lumbosacral transitional vertebra along with other associated spinal disorders are prone to lower backache (12). This might suggest that the study population is susceptible to lower back pain due to lumbarization.

The mean length of SH was 2.45cm. The previous studies observed the length of SH ranged between 2-4 cm (26). However, a study by Letterman and Trotter, Trotter et al observed the length of hiatus to be 2.48 and 1.98 cm in American male and female sacra, respectively (19,30). A study by Kumar et al. reported the length of SH in Indian males to be 2.0 cm and 1.89 cm in females (17). SH is the site for the administration of epidural anesthesia. Detailed anatomical knowledge of SH is essential for the successful administration of epidural anesthesia.

The intercornual length in males=1.42 cm and females=1.46 cm were observed to be greater than the measurement obtained by Sekiguchi et al. (1.02 cm) (25). It was observed that the length between the S2 spine and the apex of the SH (male=4.36 cm; female=5.09 cm) was greater than the measurement recorded by Senoglu et al. (3.54 cm) (26). The width of the hiatal apex was 0.16 cm and 0.15 cm respectively in males and females which is not recorded in the previous study. The measurement of AP diameter of SH at the apex plays a major role in CEB. Sekiguchi et al. (25) in their study stated that the sacral canal diameter should be more than 2 mm. If it is less than 2 mm, it may impede the administration of 22 G needles for CEB (25). Further, it states that complete agenesis, bony septum or nonspecific location of the SH will result in the failure of CEB. In this study, the AP diameter of the SH ranged between 0.22-0.90 cm in males and 0.32-0.77 cm in females with an average of 0.56 and 0.54 cm in males and females, respectively. The value is consistent with previous studies reported by Aggarwal et al. 0.5 cm (1), Trotter et al. 0.53 cm (30), Lanier et al. 0.61 cm (18), Trotter 0.5 cm in whites and 0.6 cm in Negro sacra (31), Kumar et al. 0.48 cm (17), Nagar 0.48 cm (20), Sekiguchi et al. 0.6 cm (25) and Senoglu et al. 4.46 cm (26). Since the present study did not report any sacra with the depth of the hiatus less than 2mm, it suggests that the needle can be passed easily during CEB in the present study group as the AP diameter of the SH is sufficiently sized.

A common problem encountered during CEB is a failure in needle placement. According to Chen et al (6) for a successful administration of CEB, it should be performed under the guidance of ultrasonography (6). The presence of an equilateral triangle formed between the two sides of the superolateral crest and the apex of the sacral hiatus is considered to practically benefit the clinician (26). This is used by clinicians to locate the sacral hiatus during CEB (26). In the present study, measurements required for determining the equilateral triangle were assessed.

Surprisingly the length between the right and left superolateral crests were male=6.12 cm and female=6.25 cm, the length between the right superolateral sacral crest and SH apex was male=4.73 cm and female=4.11 cm and the length between the left superolateral sacral crest and SH apex was in male=4.62 cm female=4.09 cm, which was not consistent with previous studies (9,26). Extensive clinical trials are required in this area, and the concept of the equilateral triangle may not hold good for all the populations as encountered in this study. Hence, adequate knowledge of SH morphometry and morphological variations of the sacrum is essential for specific gender and population.

CONCLUSION

For caudal epidural anesthesia to be successful a clear concept of the anatomy of the SH and the structures surrounding it is essential. The knowledge of incidences of variations in the morphology and morphometry of the sacral hiatus across various population groups is paramount for the success and reliability of epidural anesthesia. This study highlights population-specific metric parameters of the sacral hiatus in known sex. It also categorizes the sacrum based on the shape of the sacra hiatus as well as seen the number of cases of lumbarization and sacralization.

SOURCE of FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sector.

AUTHORSHIP CONTRIBUTION

Study conception and design: RP

Data collection: FA

Analysis and interpretation of results: MH, RP

Draft manuscript preparation: SS

Critical revision of the article: MH

All authors (RP, SS, FA, MH) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Aggarwal A, Aggarwal A, Harjeet, Sahni D: Morphometry of sacral hiatus and its clinical relevance in caudal epidural block. Surg Radiol Anat 31(10):793–800, 2009
2. Bron JL, van Royen BJ, Wuisman PI: The clinical significance of lumbosacral transitional anomalies. Acta Orthop Belg 73(6):687-695, 2007
3. Bulut M, Ucar BY, Ucar D, Azboy I, Demirtas A, Alemdar C, Gem M, Ozkul E: Is sacralization really a cause of low back pain? ISRN 2013:83901, 2013
4. Castellvi AE, Goldstein LA, Chan DP: Lumbosacral transitional vertebrae and their relationship with lumbar extradural defects. Spine 9(5):493-495, 1984
5. Chang HS, Nakagawa H: Altered function of lumbar nerve roots in patients with transitional lumbosacral vertebrae. Spine (Phila Pa 1976) 29(15):1632-1635, 2004
6. Chen CP, Tang SF, Hsu TC, Tsai WC, Liu HP, Chen MJ, Date E, Lew HL: Ultrasound guidance in caudal epidural needle placement. Anesthesiology 101(1):181-184, 2004
7. Eastwood D, Williams C, Buchan I: Caudal epidurals: The whoosh test. Anaesthesia 53(3):305-307, 1998
8. Edwards WB, Hingson RA: Continuous caudal anaesthesia in obstetrics. Am J Surg 57:459-464, 1942
9. El-Monem AH, Neven MG: A morphological study of the sacral hiatus. Zagazig University Medical Journal 12:2877-2886, 2006
10. Elster AD: Bertolotti's syndrome revisited. Transitional vertebrae of the lumbar spine. Spine (Phila Pa 1976) 14(12):1373-1377, 1989
11. Gaikwad M, Kujur B, Jain M, Das SS, Behera S: Complete agenesis of dorsal wall of sacral canal: A case report. Cureus 11(9):5720, 2019
12. Gopalan B, Yerramshetty JS: Lumbosacral transitional vertebra-related low back pain: Resolving the controversy. Asian Spine J 12(3):407-415, 2018
13. Gupta R, Garg R, Singh B, Ghatak S, Agrawal D: Incidence of lumbarization and sacralization in normal and low backache patients - A roentgenogram study. International Journal of Biomedical Research 5:543-546, 2014
14. Hughes RJ, Saifuddin A: Imaging of lumbosacral transitional vertebrae. Clin Radiol 59(11):984-991, 2004
15. Kao SC, Lin CS: Caudal epidural block: An updated review of anatomy and techniques. Biomed Res Int 2017:9217145, 2017
16. Konin GP, Walz DM: Lumbosacral transitional vertebrae: Classification, imaging findings, and clinical relevance. AJNR Am J Neuroradiol 31(10):1778-1786, 2010
17. Kumar V, Pandey SN, Bajpai RN, Jain PN, Longia GS: Morphometric study of sacral hiatus. J Anat Soc India 41:7–13, 1992
18. Lanier VS, McKnight HE, Trotter M: Caudal analgesia: An experimental and anatomical study. Am J Obstet Gynecol 47:633-641, 1944
19. Letterman GS, Trotter M: Variations of the male sacrum: Their significance in caudal analgesia. Surg Gynecol Obstet 78:551-555, 1944
20. Nagar SK: Shah medical college, jamnagar, gujarat: A study of sacral hiatus in dry human sacra. J Anat Soc India 53:18-21, 2004
21. Otani K, Konno S, Kikuchi S: Lumbosacral transitional vertebrae and nerve-root symptoms. J Bone Joint Surg Br 83(8):1137-1140, 2001
22. Patil DS, Jadav HR, Binodkumar, MCD, Patel VD: Anatomical study of sacral hiatus for caudal epidural block. National Journal of Medical Research 2(3):1-6, 2012
23. Sachdeva K, Singla RK, Kalsey G, Sharma G: Original research paper role of sacrum in sexual dimorphism-a morphometric study. Journal of Indian Academy of Forensic Medicine 33(3): 206-210, 2011
24. Sahoo PK, Mohanty PP, Pattnaik M: Sacralization and herniated nucleus pulposus - an association study. J Spine 5: 297, 2016
25. Sekiguchi M, Yabuki S, Satoh K, Kikuchi S: An anatomic study of the sacral hiatus: A basis for successful caudal epidural block. Clin J Pain 20:51-54, 2004
26. Senoglu N, Senoglu M, Oksuz H, Gumusalan Y, Yuksel KZ, Zencirci B, Ezberci M, Kizilkanat E: Landmarks of the sacral hiatus for caudal epidural block: An anatomical study. Br J Anaesth 95(5):692-695, 2005
27. Srijit D, Shipra P: Spina bifida with higher position of sacral hiatus: A case report with clinical implications. Bratisl Lek Listy 108(10-11):467-469, 2007
28. Standring S: Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th ed. London: Elsevier Churchill Livingstone, 2008:724-725
29. Stinchfield FE, Sinton WA: Clinical significance of the transitional lumbosacral vertebra; relationship to back pain, disk disease, and sciatica. J Am Med Assoc 157(13):1107-1109, 1955
30. Trotter M, Letterman GS, Gordon S: Variations in female sacrum. Their significance to continuous caudal anesthesia. Surg Gynecol Obstet 78:419-424, 1944
31. Trotter M: Variations of the sacral canal; Their significance in the administration of caudal analgesia. Anesth Analg 26:192–202, 1947
32. Tsui BC, Gupta S, Finucane B: Determination of epidural catheter placement using nerve stimulation in obstetric patients. Reg Anesth Pain Med 24(1):17-23, 1999