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Research Article

Morphometrical study of sacral hiatus in dry human sacra

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ABSTRACT

Background: The sacral hiatus is the site for caudal epidural anaesthesia during perineal surgery and also for a painless delivery. It is also used for three dimensional colour visualization of lumbosacral epidural space in orthopaedic practice for diagnosis and treatment. Sacrum is one of the bones which exhibit variations. Therefore the importance of the normal sacral hiatus and its variations is of great clinical significance. The reliability of caudal epidural anaesthesia is 70% - 80% in the literatures. The objective of the study was to examine, measure and record the morphometry of sacral hiatus under the following headings in order to study the anatomical variations which would be useful for caudal epidural anaesthesia and improve the reliability of the same. a) Shape of sacral hiatus, b) level of apex, c) level of base, d) length of the sacral hiatus, e) transverse width at the base, and f) anteroposterior depth at the apex.
Methods: A total of 200 dry, complete, undamaged human sacra of unknown sex were used in this study. Measurements were taken using vernier calipers. In this study six parameters were taken. All the readings were tabulated and subjected to analysis.
Results: Various shapes of sacral hiatus were observed which included Inverted-U (50%), Inverted-V (27.5%), Irregular (15.5%), Dumb bell (2%), and Bifid (2%). The mean anteroposterior depth of sacral canal at the level of apex of sacral hiatus was 4.25mm. The mean length of sacral hiatus was 19.63 mm and the mean transverse width of sacral hiatus at the level of base was 11.42 mm. There was complete spina bifida in 4 (2%) and absence of sacral hiatus in 2 (1%) cases.
Conclusion: The sacral hiatus has anatomical variations. Understanding of these variations may improve the reliability of caudal epidural anaesthesia.

Keywords: Sacrum; Sacral canal; Sacral hiatus; Sacral apex; Caudal Epidural Anaesthesia

INTRODUCTION

The sacrum is a large, triangular fusion of five vertebrae and forms the posterosuperior wall of the pelvic cavity, wedge between the two hip (innominate) bones. The sacrum consists of trabecular bone enveloped by a shell of compact bone of varying thickness.[1]

Sacral canal is formed by sacral vertebral foramina, and is triangular in transverse section. Its caudal opening is the sacral hiatus. The sacral canal contains the caudal equina including filum terminale and the spinal meninges.[1] The opening at the caudal end of sacral canal is known as sacral hiatus. It is formed due to the failure of fusion of laminae of the fifth (occasionally 4th) sacral vertebra. It is located inferior to the 4th (or 3rd) fused sacral spines or lower end of median sacral crest.[1]

The sacral hiatus is identified by palpation of the sacral cornua. Sacral cornua are felt at the upper end of the natal cleft 5 cm above the tip of the coccyx. Alternatively, the sacral hiatus may be identified by constructing an equilateral triangle based on a line joining the posterior superior iliac spine: the inferior apex of this triangle overlies the sacral hiatus.[1] After local anaesthetic infiltration, a needle is introduced at 45^0 to the skin, to penetrate the posterior sacrococcygeal ligament and enter the sacral canal.[2] The sacral hiatus is variable in its shape and size.

The sacral hiatus contains fifth sacral nerve, coccygeal nerve roots, filum terminale externa and fibro fatty tissue. In recent state the sacral hiatus is covered by superficial posterior sacrococcygeal ligament which is attached to the margins of the sacral hiatus and the deep posterior sacrococcygeal ligament attached to the floor of sacral hiatus.[1]

Caudal Epidural Anaesthesia was first performed in 1900. It involves injection of a drug into the epidural space through the sacral hiatus to provide analgesia and anaesthesia in various clinical settings.[3]

Caudal analgesia is used during surgical procedures in urology, proctology, general surgery, obstetrics and gynecology and orthopaedics. It is also used for three dimensional colour visualization of lumbosacral epidural space.[4]

The sacral hiatus shows variations during its development. Nonfusion of laminae of fourth or the upper vertebrae results in an elongated sacral hiatus. Nonfusion of all the sacral vertebrae, results in sacral spina bifida. This leads to decreased surface area for the attachment of extensor muscle at the back, which may be a cause of backache.[5]

The administration of continuous caudal analgesia may present technical difficulty while inserting a malleable needle through the sacral hiatus into the sacral canal. The increasing application of this method of analgesia is important for clinicians. However knowledge of anatomical confirmation and common structural modification of sacral hiatus is essential.[6]

The shape and extent of sacral hiatus is important because frequently during perineal surgery, the anaesthetic agent is injected into the sacral canal through sacral hiatus to obtain caudal epidural anaesthesia. The same route is also often used for continuous caudal analgesia for a painless delivery. This route was used for the first time in 1941. Since then this method has become widespread.[7]

In clinical studies, success rate of caudal epidural anaesthesia has been reported to be about 70% to 80%. It is reported that 82% of patients with lumbar pain had pain relief one day after caudal epidural anaesthesia. Some workers showed that there was a successful injection without using fluoroscopic view in 74% of the cases.[8]

Sacral hiatus has been used for administration of caudal epidural anaesthesia in obstetrics[7] as well as in orthopedic practice for diagnosis and treatment of lumbar spinal disorders.[8] The reliability and success of caudal epidural anaesthesia depends upon anatomical variations of sacral hiatus as observed by various authors.

In 1942, Continuous Caudal Epidural Anaesthesia was introduced[7] for the first time in the field of obstetrics. It has been proposed that "The fundamental knowledge of the anatomy of the sacral area is prerequisite for success in continuous caudal epidural analgesia".

It is also used for three dimensional colour visualization of lumbosacral epidural space in orthopaedic practice for diagnosis and treatment. Sacrum is one of the bones which exhibit variations. Therefore the importance of the normal sacral hiatus and its variations is of great clinical significance. The reliability of caudal epidural anaesthesia is 70% - 80% in the literatures.

The reliability and success of caudal epidural anaesthesia depends upon anatomical variations of sacral hiatus as observed by various authors. The present study was undertaken to find out the anatomical variations of sacral hiatus.

***Objectives*:** To examine, measure and record the morphometry of sacral hiatus in order to study the anatomical variations which will be useful for caudal epidural anaesthesia and improve the reliability of the same.

METHODS

A total of 200 dry, complete, undamaged human sacra of unknown sex were used in this study. The measurements were taken using vernier calipers of 0.02 mm accuracy. The different parameters of each sacrum were studied under the following headings:

1) The shape of sacral hiatus.
2) Level of apex of sacral hiatus was noted with respect to sacral vertebra.
3) Level of base of sacral hiatus was noted with respect to sacral vertebra.
4) The length of sacral hiatus was measured from midpoint of base to apex
5) Anteroposterior depth of sacral hiatus at the apex
6) Transverse width of sacral hiatus at the base was measured between the inner aspects of inferior limit of sacral cornua

STATISTICAL METHOD[14,15]

95% Reference interval were calculated using the normal distribution if acceptance of normal by D Agostino pearson test for normality other wise 95% reference interval were calculated using the percentile method.

Statistical Software[14, 15]

The Statistical software namely SPSS 15.0, stata 8.0 Medcalc 9.0.1 and Systat 11.0 were used for the analysis of the data and Microsoft Word and Excel have been used to generate graphs, tables etc.

OBSERVATIONS AND RESULTS

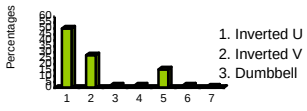
Observations were made in 200 dry, complete, undamaged human sacra, of unknown sex were used in this study.

Study Design: A Cross-sectional study was carried out on 200 dry human sacra to study the Anatomical variations of sacral hiatus.

Shape of Sacral Hiatus: Table 1 and Graph 1

Table 1: Shape of Sacral Hiatus.

Sl. No	Shape	Number	%
1	Inverted U	100	50.0
2	Inverted V	55	27.5
3	Dumbbell	4	2.0
4	Bifid	4	2.0
5	Irregular	31	15.5
6	Complete Spina bifida	4	2.0
7	Absence of sacral hiatus	2	1.0
	Total	200	100.0



Shape of Sacral Hiatus

Graph 1: Shape of sacral hiatus.

There were many variations in the shape of sacral hiatus. In 100 (50%) sacra the shape was Inverted-U (Fig.10) and in 55 (27.5%) sacra Inverted-V (Fig.11). Both the above types were considered as normal and the sacral hiatus was present against 5th and 4th sacral segments. In 41 (21.1%) specimens, the sacral hiatus was elongated up to the level of 2nd sacral segment in 1 bone and 3rd sacral segment in 40 bones. A "Dumb-bell" shaped sacral hiatus (Fig.12) was observed in 4 (2%) cases with a nodular bony growth projecting medially from both margins. A Bifid shaped sacral hiatus (Fig.13) was observed in 4 (2%) bones. Irregular shaped sacral hiatus (Fig.14) was observed in 31(15.5%) bones. The dorsal wall of sacral canal was entirely Incomplete (Complete spina bifida) in 4 (2%) cases (Fig.15). Absence of sacral hiatus, a rare phenomenon, was observed in 2 (1%) specimens (Fig. 16).

Level of Base of Sacral Hiatus: Table 3 And Graph 3

It was present between middle of 4th sacral segment to middle of 1st piece of coccyx. In 2 (1%) sacral the sacral hiatus was completely obliterated and the lower end of the sacral canal was closed due to bony over growth. In 194 (100%) sacra the base of the sacral hiatus was present against the body of 5th and 4th sacral segment.

Length of the Sacral Hiatus from Apex to Base: Table 4 & 7 and Graph 4

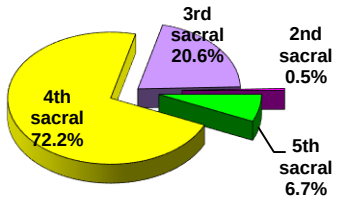
The length of the sacral hiatus ranged between 4mm to 51 mm. The arithmetic mean length of the sacral hiatus was 19.63 mm. Complete absence of dorsal wall of sacral canal was observed in 4, and obliteration of sacral hiatus in 2 specimens. These 6 specimens were not considered for the measurements of length.

Level of Apex of the Sacral Hiatus: Table 2 and Graph 2

Table 2: Level of Apex of Sacral Hiatus With respect to level of Sacral Vertebra.

Sl. no	Level of Apex	Number	%
1	5th sacral vertebra	13	6.7
2	4th sacral vertebra	140	72.2
3	3rd sacral vertebra	40	20.6
4	2nd sacral vertebra	1	0.5
	Total	194	100.0

Level of apex of sacral hiatus is presented in Table 2. level of apex at 4th sacral vertebra was 72.2% followed by at 3rd sacral vertebra was 20.6% and at 5th sacral vertebra was 6.7%.



Graph 2: Level of Apex of Sacral Hiatus With respect to level of Sacral Vertebra.

The level of the apex was quite variable and extended between middle of 2nd and middle of 5th sacral segments. In 140 (72.2%) cases the apex was present at the level of 4th sacral segment. In 41 (21.1%) specimens where sacral hiatus was much elongated, the apex was found to be present against 2nd sacral segment in 1 and against 3rd sacral segment in 40, while in 13 (6.7%) cases apex extended only up to the middle of 5th sacral segment. In 6 (3%) sacra, the apex of the sacral hiatus could not be ascertained due to complete sacral spina bifida in 4 specimens and absence of sacral hiatus in 2 specimens.

Anteroposterior Depth of Sacral Canal at the Apex

It ranged between 1.5 mm to 8.5 mm (Table 5 & 9 and Graph 5).

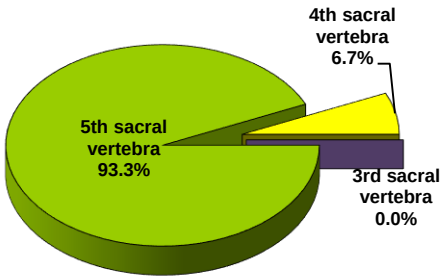
Transverse Width of Sacral Hiatus at the base

It ranged between 1mm to 19mm (Table 6 & 8 and Graph 6).

Table 3: Level of Base of Sacral Hiatus With respect to level of Sacral Vertebra.

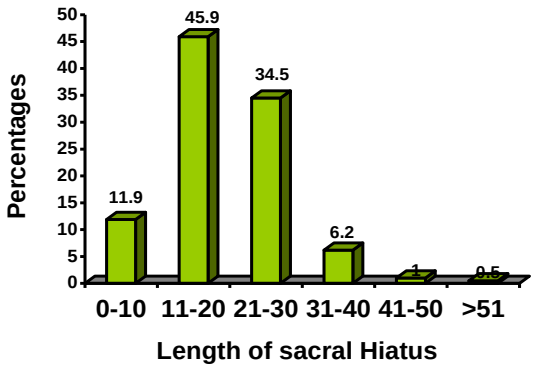
Sl. No	Level of base	Number	%
1	5th sacral vertebra	181	93.3
2	4th sacral vertebra	13	6.7
3	3rd sacral vertebra	0	0.0
	Total	194	100.0

Level of base at 5th sacral vertebra was 93.3%, followed by at 4th sacral vertebra was 6.7%, while at 3rd sacral vertebra was none.



Level of Base of Sacral Hiatus

Graph 3: Level of Base of Sacral Hiatus With respect to level of Sacral Vertebra.



Graph 4: Length of Sacral Hiatus from Apex to Mid Point of Base.

Table 4: Length of Sacral Hiatus from Apex to Mid Point of Base.

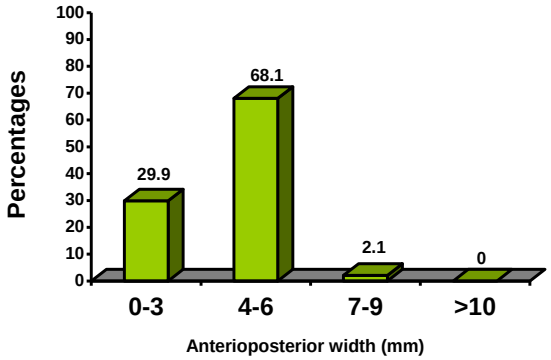
Sl. No	Length of Sacral Hiatus in mm	Number (n=194)	%
1	0-10	23	11.9
2	11-20	89	45.9
3	21-30	67	34.5
4	31-40	12	6.2
5	41-50	2	1.0
6	>51	1	0.5

Number of sacrum having Length of sacral hiatus from 0-10 mm were 11.9%, and from 11-20 mm were 45.9% and from 21-30 mm of length of sacral hiatus there were 34.5% of human sacra. Only 7.7% had the length of Sacral hiatus more than >31 mm.

Table 5: Anteroposterior depth of sacral Canal at the level of Apex.

Sl. No	AP width mm	Number (n=194)	%
1	0-3	58	29.9
2	4-6	132	68.1
3	7-9	4	2.1
4	>10	0	0.0

Largest proportion (68.1%) of human sacra had the AP width between 4 and 6, followed by 29.9 with 0-3mm AP width and only 2.1% associated with the AP width 7-9 mm.

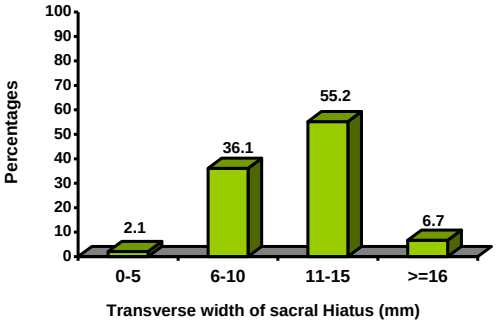


Graph 5: Anteroposterior depth of sacral Canal at the level of Apex

Table 6: Transverse width of sacral Hiatus at the base-measured between the Inner Aspect of inferior limit of sacral cornua.

Sl. No	Distance (mm)	Number (n=194)	%
1	0-5	4	2.1
2	6-10	70	36.1
3	11-15	107	55.2
4	≥16	13	6.7

Majority of human sacra 55.2% had the Transverse width between 11-15mm, 36.1% had 6-10 transverse width, 6.7% of the human sacra had ≥16 mm and only 2.1% had the transverse width between 0-5 mm.



Graph 6: Transverse width of sacral Hiatus at the base-measured between the Inner Aspect of inferior limit of sacral cornua.

Table 7: Length of sacral hiatus from apex to mid point of base.

Sl. No	Length of sacral Hiatus (mm)	
1	Lowest value	4.0
2	Highest value	51.0
3	Arithmetic mean	19.63
4	Median	19.00
5	Standard Deviation	8.40
6	Reference Interval	6.68-38.62

Reference interval has been presented in table 7, which suggest that for the Length of Sacral Hiatus, the reference range was 6.68 to 38.62 with mean 19.63 and median was 19.00.

Table 8: Transverse width of sacral hiatus at the level of base.

Sl. No	Transverse width of sacral Hiatus (mm)	
1	Lowest value	1.00
2	Highest value	19.00
3	Arithmetic mean	11.42
4	Median	11.84
5	Standard Deviation	3.08
6	Reference Interval	5.38-17.45

The reference interval for Transverse width was presented in table 8. The reference range observed to be 5.38-17.45 with mean 11.42 mm and median value of 11.84 mm.

Table 9: Anteroposterior depth of sacral Canal at the level of Apex.

Sl. No	Anteroposterior width of sacral Canal (mm)	
1	Lowest value	1.5
2	Highest value	8.5
3	Arithmetic mean	4.25
4	Median	4.0
5	Standard Deviation	1.13
6	Reference Interval	2.16-6.54

The reference range for Anteroposterior depth was presented in table 9. The reference range observed to be 2.16-6.54 with mean 4.25 mm and median value of 4.0mm.

Table 10: Incidence of Various Shapes of Sacral Hiatus by Various Authors in Dry Human Sacral Bones.

Shape of Sacral Hiatus	Vinod Kumar[10] 1992	Nagar Sk[9] 2004	Present Study
Inverted-U	29.70%	41.5%	50%
Inverted-V	46.53%	27.0%	27.5%
Irregular	-	14.1%	15.5%
Dumb-Bell	7.43%	13.3%	2%
Bifid	-	1.5%	2%
Complete Spina Bifida	1.49%	1.5%	2%
Absence of Sacral Hiatus	0.99%	1.1%	1%

Table 11: Incidence of Level of Apex of Sacral Hiatus by Various Authors in Dry Human Sacral Bones.

Level of Apex of Sacral Hiatus	Vinod Kumar[10] 1992	Sekiguchi[8] 2004	Nagar Sk[9] 2004	Present Study
S2	4.95%	4%	3.4%	0.5%
S3	8.91%	15%	37.3%	20.6%
S4	76.23%	65%	55.9%	72.2%
S5	7.43%	15%	3.4%	6.7%

Various Shapes of Sacral Hiatus

Figure 10: Inverted U- Shaped.

Figure 11: Inverted V- Shaped.

Figure 12: Dumb-Bell Shaped.

Figure 13: Bifid Shaped.

Figure 14: Irregular.

Figure 15: Complete Spina Bifid.

Figure 16: Absence of Sacral Hiatus.

DISCUSSION

The detailed morphometric study of sacral hiatus is of great relevance, since this route is frequently utilized for caudal epidural anaesthesia in perineal surgery and caudal analgesia for a painless delivery. Caudal analgesia is used during surgical procedures in urology, proctology, general surgery, obstetrics and gynecology and orthopaedics. It is also used for three dimensional colour visualization of lumbosacral epidural space in orthopaedic practice for diagnosis and treatment.[12]

In the present study the shapes of sacral hiatus were variable; most commonly inverted-U in 100 (50%) sacra and inverted-V in 55 (27.5%) sacra. Both the above types were considered as normal. In 4 (2%) its outline was like a Dumb-bell which was very low when compared to previous workers namely Nagar SK. in 36 (13.3%) sacra[9] and Vinod kumar et al. in 15 (7.43%) sacra.[10] Bifid sacral hiatus was seen in 4 (2%) sacra which was similar to that reported by Nagar SK. in 4 (1.5%) sacra.[9] There was complete agenesis of sacral hiatus reported by previous workers namely Trotter et al 1.8%, Vinod kumar et al in 3 (1.49%) sacra and Nagar SK. in 4 (1.5%) sacra. In the present study absence of sacral hiatus due to bony over growth which is a rare phenomenon was observed in 2 (1%) sacra which were similar to other authors like Nagar SK. in 2 (0.7%) sacra and Vinod kumar et al. in 2 (0.99%) sacra specimens only. But in a study conducted by Sekiguchi M et al. sacral hiatus[8] was absent in 3% cases which was higher. Nagar SK. also noted various shapes of sacral hiatus most common being inverted-U in 112 (41.5%) sacra and inverted-V in 73 (27%) sacra. Vinod kumar et al. also noted various shapes of sacral hiatus, most common being inverted-V in 94 (46.53%) and inverted-U in 60 (29.70%). The shape of the sacral hiatus was irregular in 31 (15.5%) sacra in the present study which was again similar when compared to Nagar SK. in 38 (14.1%) sacra.

Susan Strandring[1] et al states that the apex of sacral hiatus is present at the level of 4th sacral vertebra. In the present study the apex of sacral hiatus was seen most commonly at the level of 4th sacral vertebra in 140 (72.2%) sacra, which was almost similar to Vinod kumar et al in 154 (76.23%) sacra, but was lower in study conducted by Sekiguchi M et al. in 60 (65%) sacra and much lower in study observed by Nagar SK. in 147 (55.9%) sacra. Earlier studies by Trotter[11] et al (1944) and Lanier[12] et al in their series have reported the mean level of apex of sacral hiatus to be at lower third of 4th sacral vertebra. All studies including the present study noted that location of apex can vary from upper part of second sacral vertebra to lower part of fifth sacral vertebra.

Base of the sacral hiatus was seen at the level of fifth sacral vertebra in 181 (93.3%) sacra in the present study, which was higher when compared to study conducted by Vinod kumar et al seen in 168 (83.17%) sacra and much lower when compared to Nagar SK. noted in 191 (72.6%) sacra at the level of fifth sacral vertebra out of 270 bones studied.

Length of sacral hiatus varied from 4mm to 51mm and the arithmetic mean was 19.63mm and median was 19.00 mm and reference range was between 6.68 to 38.62 mm in the present study. This is similar to that reported by earlier workers namely Vinod kumar et al. observed

arithmetic mean length of sacral hiatus as 20 mm in males and 18.9 mm in females in north Indians and the reference range was between 3 mm to 37 mm. Trotter[13] et al. (1945) have reported sacral hiatus length as 24.8 mm and 19.8 mm in American males and females respectively. Similar results were noted by Trotter[11] et al., (1944) in which the length of sacral hiatus varied from 0 to 60mm with arithmetic mean of 22.5 mm and Lanier et al. noted arithmetic mean length of sacral hiatus being 25.3 mm.

In the present study the anteroposterior depth ranged from 1.5 mm to 8.5 mm with arithmetic mean of 4.25 mm and median of 4.0 mm and reference range present between 2.16 mm to 6.54 mm. Arithmetic mean of anteroposterior depth reported by various workers are similar Trotter[11] et al. (1944) 5.3mm (range of 0-11mm), Lanier[12] et al. (1944) 6.1 mm, Trotter[6] et al. (1947) 5 mm in whites and 6mm in negro groups, Vinod kumar et al. (1992) 4.8 mm (range of 0-12 mm). Nagar SK. 4.8 mm (range of 2 – 14 mm) and Seikuguchi M et al., 6.0 mm.

In the present study, sacra having anteroposterior depth of sacral canal at apex of sacral hiatus less than 3mm was observed in 58 (29.9%) bones which is much more higher than the earlier studies namely Trotter et al. (1947) who reported only 5% of cases with 0 – 2 mm depth, Trotter et al. (1944) only 4% sacra with depth 0 – 2 mm depth, and Nagar SK noted in 4 (15.6%) sacra with 0 – 3 mm depth while Lanier et al (1944) noted no cases with depth less than 3mm. In present study anteroposterior depth of sacral canal at apex of sacral hiatus between 4 mm – 6 mm was seen in 132 (68.1%) bones which were similar to Nagar SK observed in 169 (64.2%) sacrum bones. Arithmetic mean was 4.25 mm in the present study, which was similar to Vinod kumar et al., as 4.8 mm.

In the present study the transverse width varied from 1mm to 19 mm, having arithmetic mean of 11.42mm, median 11.84 mm and reference range between 5.38mm to 17.45 mm. In more than half 55.2% cases transverse width of sacral hiatus at base was from 11 mm – 15 mm and in 91.3% cases transverse width was from 6mm – 15mm which was similar to study conducted by Nagar SK with range from 3 mm – 19 mm and in more than half 54% cases it was 10 mm – 15 mm and in 84% cases it was from 6 mm – 15 mm. Trotter et al (1944) who noted the transverse width to vary from 7 mm – 26 mm with arithmetic mean of 17 mm was higher compared to present study. Lanier et al reported arithmetic mean of transverse width at base to be 19.3mm which was also higher to the present study.

Vinod kumar et al., who reported range between 5 mm – 20 mm with arithmetic mean of 13 mm in male sacra and range between 8 mm – 18 mm with arithmetic mean of 12.5 mm in female sacra of his series which was similar to the present study. Sekiguchi M et al., have reported a lower arithmetic mean of transverse width to be 10.2 mm.

CONCLUSION

There are anatomical variations in the sacral hiatus, which may relate to the failure of caudal epidural anaesthesia. Understanding of these variations may improve the success of caudal epidural anaesthesia.

In the present study the rate of impossible caudal epidural anaesthesia is 1% (2) since the sacral canal was closed and there were other bony anatomical abnormalities such as: irregular shape – 31 (15.5%), bifid shape – 4 (2%), complete spina bifida – 4 (2%), dumb-bell shape – 4 (2%), absence of sacral hiatus – 2 (1%). Narrowing of sacral canal at apex of sacral hiatus was found in significant percentage 58 (29.9%) bones. Out of 200 bones, 45 (22.5%) bones showed abnormal shape of sacral hiatus, which should be kept in mind while applying caudal epidural anaesthesia. These anatomical variations may be a factor in caudal epidural anaesthesia failure.

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