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Morphometric Study of Sacral Hiatus in Central Part of Rajasthan& its Correlation with Caudal Epidural Block

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Abstract
Introduction:*Sacrum is a triangular bone forming the caudal end of the vertebral column, formed by fusion of five vertebras.Sacral hiatus is the opening present at the caudal end of sacral canal formed by the nonfusion of the lamina of the fifth (occasionally fourth) sacral vertebra.The structures passing through sacral hiatus are a pair of 5th sacral nerves, a pair of coccygeal nerves, filumterminaleexterna. Caudal.epidural block (CEB) is widely used to provide anesthesiafor various clinical procedures. Knowledgeof sacral hiatus anatomy play major role in the success of needle placement for desired results of caudal epidural block.*
Aim: *Morphometric study of sacralhiatus, for caudalepidural block point of view. This knowledge will help foroptimal access into sacral epidural space and to prevent the hazard of Dural sac puncturein population of central partof Rajasthan.*
Materials and Methods: *This study was carried out on 75 dry human sacra to know the variations in morphology of the sacral hiatus.*
Results: *Various shapes of sacral hiatus were observed which included inverted V 32 (42 %), inverted U 23(30.66%), and irregular 10 (13.66%) M shaped 8(10.66%) anddumbbell shape 8(10.66%), Spina bifida 1(1.33%) and complete agenesis of dorsal wall of sacrum was in 1(1.33%). The apex of sacral hiatus was commonly found at the level of 4th sacral vertebra in 54.66% at S3 sacral vertebra in 29(38.66%) and S5 in 4(5.33%) and at S1 levelin only one (1.33%) of the sacral vertebra studied. Base of the hiatus was commonly found at the level of S5 in50 (63.66%) at S4 in 15(20%), C1 level in 9(12%) and at C2 in one (1.33) of sacral vertebra. Length of sacral hiatus ranged between 8.0 mm to 60 mm, breadth at base was 10-25 mm and AP diameter at apex was 3–10 mm.*
Conclusion:*The knowledge of anatomy of sacral hiatus plays importantroleinneedle placement in Extra DuralBlock for various treatment of lumbar spinal disorders and for the management of chronic back pain. Absent sacral hiatus leads to poor outcome of the caudal epidural anesthesia and dorsal agenesis of the sacrum would lead to only partial anesthesia. The formation of equilateral triangle by joining super-lateral sacral crests at S2 and apex of sacral hiatus forms a practical guide in locating sacral hiatus for caudal epidural anesthesia.*
Keywords:*Absent sacral hiatus, Caudal epidural anesthesia, Dorsal agenesis of sacral hiatus, Sacral hiatus, CEB*

I. Introduction

Sacrum is considered to be most variable portion of spine[1].Sacrum is a triangular bone forming the caudal end of the vertebral column, formed by fusion of five vertebrae. Its caudal apex articulates with the coccyx and its superior, wide base with the fifth lumbar vertebra at the lumbosacral angle.[2]Sacral hiatus is the opening present at the caudal end of sacral canal formed by the non-fusion of the lamina of the fifth occasionally fourth sacral vertebra. The fifth inferior articular processes project caudally and flank the sacral hiatus as the sacral cornua. The structures passing through sacral hiatus are a pair of 5th sacral nerves, a pair of coccygeal nerves, which passes to coccyx and fibro‑fatty tissue.[3]It is located inferior to lower end of median sacral crest and can be marked onthe body surface two inches above the tip of coccyx beneath the skin of natal cleft[4].

This variation may occur due to different genetics and racial factors.Congenital malformation range from variation in sacral hiatus and in caudal agenesis[5].Caudal epidural block (CEB) is widely used to provide anesthesia for various clinicalprocedures; treatment of lumbar spinal disorders and for the management of chronic back pain. It involves the injection of anesthetic medications into the epidural space through the sacral hiatus. It is useful when anesthesia of the lumbar and sacral dermatomes is needed.

Sacral hiatal route was used in obstetrics for first time in 1941 for administration of epidural anesthesia for painless delivery and in orthopedic practice for transpedicular and lateral mass screw placement. It is also used in surgery below the umbilicus such as hernia repair, surgery on lower limb, skin grafting and procedures on the anal canal and rectum. Even though caudal anesthesia has a wide range of clinical applications, it is sometimes hard to determine the anatomical location of the sacral hiatus and the caudal epidural space, especially in adults. The determination of landmarks by the clinician enables the sacral hiatus to be ascertained and may increase the success rate of CEB[5]

Dural sac ends at the lower level ofsecond sacral vertebra. The distance between the tip of Dural sac and apex of sacral hiatus is 4.5cm.So the needle should not be advanced more than 1-2cmsas it can injure the Dural sac resulting in spinal headache[6].The dura and the arachnoid sheath of spinal cord ends at the level of the second piece of sacrum within the vertebral canal in adults but varies up to lower boarder of S3 in children. The sacral canal below this level is called epidural space or caudal space[7]. The reliability and success of caudal epidural block depends upon accurate localization of sacral hiatus. Thusan attempt has been made to study the various dimension of sacral hiatus and variations present in population of central Rajasthan.

II. Aims

For optimal access into sacral epidural space and to prevent the hazard of dural sac puncture, it is necessary to have a detailed knowledge of the anatomical variations in sacral hiatus shape and size. Therefore the present study was undertaken to find out the morphology andanatomical variations of sacral hiatus.

III. Materials And Method

The present study was conducted on 75 dry human sacra collected from the Department of Anatomy, Govt.Medical College Kota,Rajasthan. The sex and age of bones was unknown. Bones showing wear and tear, fracture or pathology were excluded. All the measurements were taken using Digital Vernier Calliper.Fig:1 linear recording was taken to the nearest millimeter and statistical analysis was carried out. Each sacrum was studied with regards to its composition and different features of sacral hiatus. The parameters noted were: 1.Composition of Sacrum 2.Shape of hiatus 3.Level of apex of hiatus 4.Level of base of hiatus 5. Length of hiatus:Measured from apex to midpoint of base 6.Anteroposterior diameter of the hiatus at the apex 7. Transverse width of hiatus at the base: 8. Distance from the apex of sacral hiatus to S2 spinous process 9. Distance from the base of sacral hiatus to S2 spinous process. Total nine morphometric measurements relating to the sacrum and hiatus were obtained.(Fig: 1-3)

Fig: 1 Measuringsacral Hiatus length with Digital Vernier Caliper

Fig :2 Measuring of Breadth of Sacral Hiatus

Fig: 3 Measuring of AP Diameter of Sacral Hiatus

IV. Observations And Results

The most common composition was 5 segments(74.66%) followed by 6 segments having sacralisation in 7(9.33%), coccyx ankylosis in 8(10.66%) and 4segments in4(5.33%) found .(Table : 1)

Table1: Composition of Sacrum & Shape of Sacral Hiatus

Sr. no.	**Sacral composition**	**No. of sacra**	Percentage	**Sacral shape**	**No. of sacra**	Percentage
1	**4 segments**	**4**	**5.33%**	**Inverted V**	**32**	**44.66%**
2	**5 segments**	**56**	**74.66 %**	**Inverted U**	**23**	**30.66%**
3	**6 segments Sacralisation**	**7**	**9.33 %**	**Irregular**	**10**	**13.66 %**
4	**6 segments coccyx ankylosis**	**8.**	**10.66%)**	**Dumbbell Shape**	**5**	**6.66%**
5	-		-	**M shape**	**3**	**4.00%**
7	-		-	**Spina bifida**	**1**	**1.33%**
8	-			**Complete agenesis of dorsal wall of sacrum**	**1**	**1.33%**
Total		**75**	**100**		**75**	**100**

Table: 2 Level of Apex and Base of Sacral Hiatus in Relation to sacral/coccyx vertebra

Sr. No.	Level of Apex	No of vertebra	Percentage	Level of Base	No of vertebra	Percentage
1	4thsacral vertebra	41	54.66%	5thsacral vertebra	50	66.66%
2	3rdsacral vertebra	29	38.66%	4thsacral vertebra	15	20%
3	5thsacral vertebra	4	5.33%	1stCoccyx vertebra	9	12%
4	2ndsacral vertebra	1	1.33%	3thsacral vertebra	1	1.33%

	Total 75	100%		Total 75	!00%	

Table 3 Length, Breadth & AP diameter of Sacral Hiatus

Sr. No.	Length	No. of sacra	Percentage	Breadth	No. of sacra	Percentage	AP diameter	No. of sacra	Percentage
1	1-10mm	1	1.33%	0-5mm	-	-	0-3mm	11	14.66%
2	11-20mm	34	45.33%	6-10mm	3	4%	4-6mm	42	56%
3	21-30mm	29	38.66%	11-15mm	28	37.33%	7-9	19	25.33%
4	31-40mm	8	10.66%	16-20mm	40	53.33%	10 12mm	3	4%
5	41-50mm	2	2.66%	21-25mm	4	5.33%	-	-	-
6	51-60mm	1	1.33%	25-30mm	-	-	-	-	-
total		75	100%		75		-	75	100%1

Table 4: Morphometryof Sacrum

Sr.No.		Mean (mm)	SD (mm)	Min (mm)	Max (mm)
1	Length of Sacral Hiatus	22.46	±12.393	10	65
2	Breadthof Sacral Hiatus	15	±2.449	10	20
3	AP diameter at Apex	0.5	±0.118	0.3	0.8
4	Distance from apex to S2	51.63	±7.644	25	67
5	Distance from base to S2	56.83	±6.961	40	80

The most common shape of sacral hiatus in present study was Inverted V in 32(42.00%) followed by Inverted U in 23(30.66%) ,Irregular sacral hiatus in 10(13.66%), Dumbell shape hiatus in 8 (10.22%), M shaped 3(4%) ,Spina Bifida hiatus in 1(1.33%) and complete agenesis of dorsal of the sacrum was in 1 (1.33%) only. (Table: 2 &Figure 4-11)

Apex of sacral hiatus was most commonly seen at 4th sacral vertebra in 41(54.66 %), at 3rd sacral vertebra in38.66%, at 5th sacral vertebra 4(5.33%) and at 2nd sacral vertebra in 1(1.33%) only. Base of sacral hiatus was commonly located at the level of 5th sacral vertebra in50 (66.66%), at 4th sacral vertebra in 15(20.00%), at 1stCoccyxin 9(12.00%) and at S3 in 1(1.33%) of sacra studied (Table:2).

The mean length of sacral hiatus was 22.46±12.393 mm ranging 10-56mms .The mean width was 15±2.449 with range from 10 to 20 mms and mean AP diameter of sacral hiatus at apex 0.5±0.118mmrespectively with range 0.3 –0.8mms (Table 4).

The mean *distance from apex to S2 vertebra 51.63±7.644 mm range from 25-67 mms and*mean *distance from base of sacral hiatus to S2* was 56.83±6.961 with rang from 40 to 80mms respectively. (Table4)

Transverse distance at level of S2 sacral crest was 57.264±9.504 with range from 45 to 70 mms.

Figure: 4 Small inverted V Shape Sacral Hiatus

Figure: 5 Long inverted V Shape Sacral Hiatus

Figure: 6 U shape Sacral Hiatus

Figure:7 M Shape Sacral Hiatus with Ankylosis Coccyx

Figure: 8DumbbellShape Sacral Hiatus with Ankylosis Coccyx

Figure:9 Irregular Sacral Hiatus

Figure:10AbsentSacral Hiatus

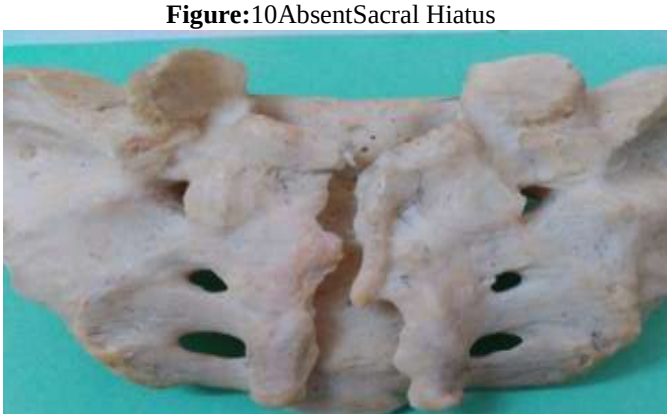

Figure:11Spina bifida (absent dorsal lamina)

V. Discussion

With growth of individual, axis of sacrum changes and it becomes difficult to locate sacral hiatus in adult. Caudal epidural blockhas 25% failure rate[8].The apex of the sacral hiatus is an important bony landmark in the success of CEB but it may be hard to palpate, particularly in obese patients.

Table: 6 Comparison of Present study with theother studies.

Morphology Ofsacrum	**Present Study (2017)**	**Arora S (2016)[9]**	**ChabraN (2014)[10]**	**VinodK(1992)[11]**	**Nagshree M (2014)[12]**	**ShindeA (2015)[13]**	**DonaS (2016)[14]**	**ShewaleS (2013) [15]**	**Bharthi A (2016) [16]**
Composition									
5 Segments	74.66%	70.11%	75.0%	69.80%	.			69.6%	-
6 Segments					-	-	-		
a.Sacralisation	9.33%	11.4%	6.25%	-					
b.Coccyx ankylosis	10.66%	14%	12.5%	-			-		
4Segments	5.33%	-	6.25%	1.48%	-	-		2.45%	-
Shape									
V-shape	44.66%	29.12%	43.75%	46.53%	39.2%	24.00%	14.09%	32.55%	45%
U-shape	30.66%	22.47%	28.12%	29.7%	23.5%	56.00%	70.09%	40.69%	40%
Irregular	13.66%	-	-	-	25.4%	10.00%	12.82%	-	-
Dumbell shape	6.66%	-	-	-	9.8%	5%	08.5%	9.8%	1.7%
Spina bifida	1.33%	-	-	-	1.9%	2.00%	-	0.98%	1.7%
Agenesis of dorsal wall	1.33%	-	-	-	1.9%	2%	-	-	1.7%

Level of Apex									
S4	54.66%	-	-	-	56%			66.5%	
S3	38.66%	-	-	-	-	-	-	-	
S5	5.33	-	-	-	-	-	-	-	
S2	1.33	-	-	-	-		-	-	
Baseof hiatus									
S5									
S4	66.66%	-	63.33%	-	72.4%	77.03%	95.7%	60%	
Coccyx	20.00%	-	20.00%	-	18.9%	11.82%	-	5%	
	12.00%	-	16.67%	-	8.6%	11.15%	-	3.5%	
Sacral Hiatus length	10-65 mm	-	10-62mm	-	7-76 mms	21-77 mms	8.8-54 mms	23-44 mm male	9-60
Breadth	10-20mm	-	6-17mm.	5-20mms	9-20 mms	-	6-21mm	&20-44female	6-29
AP diameter	0.3-0.8mm		0.4-0.9mm (in mms)	-	0.2-0.7mms	-	0.2-0.5 mms	0-20 1-9mms AP less tha 0.3 mm in7.5%	0.6-1.3

Composition of Sacrum: Table: 6 In the present study 56 (74.66%) , were made up of 5 segments whereas 8(10.66%) had coccyx ankylosis, 7(9.33) sacralisation , 4(5.33%) cases showed 4 segments. Our study was similar toAroraSetal[9]and ChabraN etal[10] **,** Vinod K et al **[11]**and Shewaleet al[14] ,they hadnoted 5 segmented sacra in 61(70.11%) ,24(75.0%),141(69.80%) and 69.6% cases and 4segmented sacra in 14%,6.25% ,1.48% and 2.45% cases respectively.

However in our study 4 segments were in 4(5.33%) which was lower than AroraS et al[9]and ChabraN et al**[10]**and higherthanVinod K et al **[11]**and Shewale et al**[15]**

Partial or complete sacralisation of 5th lumbar vertebra and coccygeal ankylosis was observed in 7 (9.33%) cases and 8(10.66%) cases respectively in thepresent study.

Trotter and Lanier**[17]** observed sacralisation of 5th lumbar vertebra and coccygeal ankylosis in 12.6% and 39.3% respectively which are higher than our study

Vinod K et al**[11]**and Shewale et al**[15]**noted partial or complete sacralisation and coccygeal ankylosis in 1.48% and 2.25 %cases respectively and their finding are lower thanour study.

Shape of sacral hiatus: In the present study the most commonly encountered shape of sacral hiatus was Inverted 'V' in 32(42.75%) cases while Inverted 'U' shaped sacrum was found in23(30.25% cases. These two shapes provide enough room for introducing needle into sacral canal without any obstacle and thus may be the most favourable shapes for CEB. The other shapes found in the present study were irregular and dumbbell in 10(13.66%)&5(6.66%) cases respectively and M shape in3(4%) and Spina bifida 1(1.33%) and complete agenesis of dorsal wall in 1(1.33%). Comparative analysis of the shapes of the sacral hiatus in the present study was done with those of previous workers. The findings of the present study are similar to that ofChabraN et al [10]**,** Arora S etal[9] and Vinod K et al**[11]**who found Inverted 'V' and Inverted 'U' shapes in 29.12%% and 22.40% cases, 43.75% and28.12%, 46.53% and 29.7%, respectively, while Shinde AA et al[13] in northern and Dona et al[14]in Benagali population found most common U shape sacral hiatus56.00% and 70.09% respectively.

Complete agenesis of the dorsal bony wall of the sacral canal or spina bifida occurs due to failure in complete fusion of sacral vertebrae. In spina bifida caudal epidural block is still possible.In the present study spina bifida and complete absence of the sacral hiatus was found in one sacra in each (1.66%) which are in accordance with Nagashree[12] and Bharti et al(2016)[16]who observed absence of sacral hiatus and complete spina bifida in 1.9%% & 1.7% cases respectively.

Apex of sacral hiatus: In the present study most common in 41(54.66%) of the sacra the apex was located at the level of S4 vertebra, in29(38.66%) cases at the level of S3 and in only in 4(5.33%)at the level of S5 and 1(1.33) at 2nd sacral vertebra. The findings are in accordance with the studies done by A.Bharathiet al**[16]**where apex was found at S4 in 55%.Our study wasalso similar toChabra N et al **[10]**andDonaS et al (2004) [14]**,**whofound the apex at S4 in 79.36% and at S3 in 31.75% of studied sacra..Apex of sacral hiatus is an important landmark for carrying out successful caudal epidural block. It shows considerable variation ranging from S2 to S4. When the apex of sacral hiatus is located at 2nd or 3rd sacral vertebra, there are more chances for the puncture of Dural sac during caudal epidural block. If the apex is higher, more precaution should be taken while deciding length of the needle to be introduced into the canal.

Base of sacral hiatus: Inthe present studybase of the sacral hiatus in 50(66.66%) sacrum was seen at 5th sacral vertebra, in 15(20.00%) at 4th sacral vertebra,in9(12.00%)at coccyx C1 9 (12.00%) and 1(1.33%) at S3 level .The findings of the present study are more or less in agreement with those of others authors namely

A. Bharathi et al[16]and DonaS et al et al[15] they found the base at 5th sacral vertebra in 61.40% and 95.7% cases respectively.

In 20.0% cases the base was at the level of S4 vertebra.

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Length of sacral hiatus: In the present study the length of the sacral hiatus varied from 10.00 mm to 65.00 mm with a mean of 22.46 ±12.393 mm. In 34(45.33%) cases varies from11 to 20 mm and 29(38.66) sacral was 21-30 mm 8(10.66%) sacra was 31-40mm and 2(2.66%) 41-50mm and 1(1.33%) had 51-60 mm . Less than 10 mm and more than 40 mm long sacral hiatus had lowest frequency (1.33%) each. These findings are similar to the studies done by Trotter& Lanier (1945)[17] who reported a mean hiatal length of 24.8 mm in American males and19.8 mm in females. Similar results were observed by earlier studies of Trotter & Letterman (1944)[18] in which the length of the hiatus varied from 0-66 mm with a mean of 22.5 mm and Lanier et al (1944)[17]where he noted a mean hiatal length of 25.00 ±9 mm. The present and past studies clearly show that the increase in length of hiatus is influenced by the defect and non-union of 2nd or 3rd pair of sacral lamina and also by coccygeal ankylosis.

Breadth of sacral hiatus at the base: In the present study the breadth at the base of sacral hiatus varied from 10 to 20 mm with a mean of 15.00 mm. In 40(53.33%) sacral breadth was 16-20mm , in 28(37.33%) breadth was 11-55mm and 3(4%) breadth was 6-10mm ,4(5.33%) breadth was 21-30mm. The present study similar with the studies done by A. Bharathi[16]who found mean transverse width of 13 mm with a range of 11-20 mm(90%) and 1-10 mm (5%) and 21-30mm (5%) .Our reading are higher thaChabraN et al[10]and Arora et al[9] who observed mean breadth 12.84 mm range from 6.53-16.99 mm. and mean transverse width of 11.95±2.78 mm. respectively.

AP Diameter Apex of sacral Hiatus: The anteroposterior diameter of sacral canal at the apex of hiatus is important to decide on the accurate needle usage for the epidural block. It should be sufficiently large to admit a needle. The mean anteroposterior diameter of sacral canal at the apex in present study was 0.5±0.118 mm with a range of 0.3 to 0.8 mm. The findings of the present study is similar to studies done by Sekiguchi et al (2004)[19]and Lanier et al [17]where they noted a mean anteroposterior diameter of 6.1±0.2 mm and 6.0±1.9 mm respectively. In the present study42(56.00%) of sacra showed anteroposterior diameter of sacral hiatus between 4-6 mm,19(25.33%) 7-9mm ,11(14.66%) was 0-3mm and 3(4.0%) AP diameter was 10-12mm In our study AP diameter was less than 0.3mm in 14.66% as compared to study by Shewale et al[10]whohad noted AP Diameter less than 0.3 mm in 7.5% sacra,whileLanier,Mc Knight & Trotter[17] did not find any sacra having AP Diameter less than 0.3mm.

Distance from apex of sacral hiatus to S2: An important part in CEB is awareness of the distance between the sacral hiatus and dural sac anatomically in relation to the risk of dural puncture. The level of S2 foramina is important because in adults duramater and arachnoid end at the level of second sacral vertebra[3]. Hence this distance decides the length of the needle that can be safely introduced into the canal. The mean distance from apex to S2 in present study was 51.63±7.644 mm with a range of 25 to 67 mm. These findings are higher to the studies done by Ramamurthi& Anil[20]who found a mean distance of 30.2±10.5 mm with a range of 12-53 mm. Our reading are also higher than the studies done byAggarwal et al[21]&Clarista et al[22]who reported a mean distance of 30.16±14.07 & 32.16±12.96 respectively , Hence from this data it would be safer to advance the needle only few millimeters after penetrating the sacrococcygeal membrane.

Distance from base of sacral hiatus to S2: The mean distance from base of sacral hiatus to S2 vertebra in the present study was 56.83±6.961 with a range of 40 to 80 mm. The findings of the present study coincide with those of Pal etal[23]who found a mean distance of 54.88 mm with a range of 37 mm to 79 mm.

VI. Conclusion

Present study concludes in support of other studies regarding variability in the anatomical structure of sacral hiatus. Variations in the shape and level of the hiatus may lead to failure of CEB. The incidence of variations may be due to genetic and racial factors. Further clinical trials are required to provide more data to support the results of this study.

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