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Morphometric study of Sacral Hiatus and it's clinical significance in Coastal Odisha population

Dr Richa Gurudiwan[*], Dr Chinmayi Mahapatra [**], Dr Surajit Kundu[***]
[*]Assistant Professor, Late Shri Lakhiram Agrawal Memorial Government Medical College Raigarh CG (richadubey2685@gmail.com)
[**] Dean & Principal, Dharanidhar Medical College Keonjhar, Odisha
[***]Professor, Late Shri Lakhiram Agrawal Memorial Government Medical College Raigarh CG

Corresponding author: Dr Surajit Kundu
Email: dr.surajitkundu@rediffmail.com
Contact: 7583828825

Abstract

Background: Anatomical variations of Sacral hiatus play a pivotal role in Caudal epidural block (CEB) anaesthesia injections. Hence correct Anatomical location of the hiatus is vital during successful CEB. The present study was undertaken to dissect out the morphometric variations of sacral hiatus among young adult Odisha population.

Materials and Methods: The study was conducted with 101 normal, dry human sacrum bones for multiple metric and non-metric analysis. Digital vernier calliper was used for metric study including measure sacral dimensions like anteroposterior diameter, transverse diameter, length of sacral hiatus and distance between the apex to mid-point of an imaginary line joining both S2 foramina, distance between mid-point of base to the midpoint of an imaginary line joining both S2 foramina, distance between apex to the highest point of right-side lateral crest /superolateral crest which corresponds to right side posterior superior iliac spine, distance between apex to the highest point of left side lateral crest /superolateral crest which corresponds to left side posterior superior iliac spine and distance between right and left superolateral sacral crest.

Results: The mean length of Sacral Hiatus was 22.36 ± 8.61 mm. The mean transverse diameter of Sacral Hiatus was 15.40 ± 2.17mm. The mean antero-posterior diameter of sacral hiatus at apex was 5.19 ± 1.36 mm. Inverted U shape was most common. Most common level of apex of sacral hiatus with respect to sacral vertebra had been 4th Sacral vertebra and most common location of base of sacral hiatus in relation to the level of sacral/coccygeal vertebra had been found to be 5th Sacral vertebra.

Summary and conclusion: The anatomical knowledge of multiple metric and non-metric variations of sacral hiatus are important in CEB anesthesia contributing to improved success of the procedure.

Key words: Caudal block; epidural anesthesia; sacral hiatus; sacral hiatus variation; sacrum

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

Introduction

Caudal end of vertebral column, with the wedged shaped Sacrum, forming the postero-superior wall of pelvic cavity is formed by fusion of five sacral vertebrae. The sacral canal contains cauda equina along filum terminale, surrounded by spinal meninges, dura and arachnoid mater of which terminate at middle of Sacrum, but Pia mater continues as filum terminale up to coccyx.

Sacrum is called as 'sacer' in Latin, Greeks called it Heiron Ostoum, Romans say 'os Sacrum', literary meaning holy', 'consecrated' or sacred bone. Ancient mythology observed that sacrum, being a bulky bone, appeared to be the last of the bone to decay, hence this bone must be the nidus around which the body should be reassembled after life. Greek 'Heiron' means a temple, and within the concavity of sacrum, lay the sacred organs of procreation and the shape of this bone resembles a vessel used in sacred rituals or the bone itself may have been used in sacred rites. Egyptians considered this bone sacred to "Osiris" the God of resurrection and of agriculture.

The curvature of sacrum is related to child bearing in females, and the flatness to the weight-bearing in both sexes, pelvimetry of sacral promontory and pelvic brim is incomplete without sacrum. Sacral hiatus, (located inferior to 3rd or 4th fused sacral spines) produced due to failure of fusion of laminae of the fifth sacral vertebra, showing attachment of superficial posterior sacro-coccygeal and deep posterior sacro-coccygeal ligament, contains lower sacral and coccygeal nerve roots, filum terminale externa and fibro fatty tissue. Sacral cornua is a remnant of inferior articular process of L5. Both are considered important anatomical landmarks during Caudal epidural block (CEB) techniques, wherein by exact localization of sacral hiatus, clinicians can access the epidural space.

Lanier VS et al. (1944) said S4 as the level of the apex of sacral hiatus. M. Gene Black et al. (1947) and Vishal kumar et al. (2009) spoke on sacrum X rays and Shashikala et at. (2015), Anmol a. shinde et al. (2015), Babita Kujur et al. (2017) and Chen P.C. and Carl P. C. et al. (2004)[8] performed soft tissue ultrasonography to conclude on knowledge of sacral hiatus shape, extent as essential to prevent CEB failure. Tapan kumar jena et al. (1986) observed the average length & breadth of sacral hiatus among male/female to be 2.86 cm/3.86 cm and 1.41cm/1.37cm respectively. Vinod et al. (1992), Nagar S K et al. (2004) and A. Bharathi et al. (2016) studied the various shape of sacral hiatus in Indian population as inverted-V, inverted – U, dumb-bell, elongated irregular, bifid, narrow and complete agencies as well. Sekiguchi et al. (2004) in Japan, N. Senoglu and colleagues (2005) in Turkey, H. Park et al. (2006) Porzionato A, (2011) and Anjali Aggarwal and her colleagues (2009) studied on sacral hiatus. sacral cornua, depth of needle insertion among subjects as anatomic reasons of CEB failure. Ajay Kumar et al (2010) and Vijisha Phalgunan et al. (2013) studied human sacrum and sacral hiatus in Punjab & Pondicherry of India respectively.

Documents on Sacral hiatus was many and from variable regions. Santanu Battacharya et al. (2013) in Kolkata concluded that two Isosceles triangles were obtained by joining the right and left supero - lateral sacral crests with apex of the hiatus and sacral apex. Senoglu et al. and Vandana et al. found mean length of sacral hiatus as 32.1 mm and 33.71 mm respectively. Senoglu et al. also commented on racial variations. Tapan kumar jena et al. observed variations in the mean length and breadth of sacral hiatus among males and female. Anjali Aggarwal and her colleagues reflected those variations in depth of hiatus, surrounding bony irregularities, different shapes of hiatus and defects in dorsal wall are probable causes for failure of CEB and needle insertion. Vishal k.et al reported a case of unusual sacrum with high sacral hiatus as an important factor for patients of low back pain. Mohammad Musthafa and colleagues from Egypt

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

studied morphometric variations of sacrum on adult Egyptian population. Mohammad Musthafa and colleagues and Lakshmi TA and colleagues remarked on features of equilateral triangle with sacral hiatus and hiatal apex.

Shilpa Nilesh shewale et al. studied on location of sacral hiatus, hiatal apex and agenesis of hiatus among Maharashtrian population. Joshi Uttama et al. concluded on shape of sacral hiatus, site of apex of hiatus, length, width anteroposterior diameter and height of hiatus.

Anjali Aggarwal, Harjeet kaur et al. worked on maximum curvature of sacrum and level of termination of dural sac. Suma HY and colleagues observed sacrum for normal and with spina bifida in unknown age and sex in south Indian population. Rajani singh et al. provided comments on classification, causes and clinical implications of spina bifida.

Present study is an attempt to analyze detailed anthropometrical variation of sacral hiatus in coastal Odisha population to correlate the findings with available literatures and likely amalgamation with race. This would improve the reliability of CEB, as fluoroscopy or ultrasound guided CEB (overall success rate 100%), may not be feasible due to time and cost constraints.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

Aims of the study

To study detailed morphometry including anatomical variations of sacral hiatus in coastal Odisha population.

Material and method

1. Study location:
    a) Department of Anatomy, S.C.B. Medical college & hospital, Cuttack, Odisha
    b) Department of Forensic medicine & Toxicology, S.C.B. Medical college, Cuttack, Odisha
    c) Department of Anatomy, KIMS, Bhubaneshwar, Odisha
    d) Department of Anatomy, MKCG Medical college, Berhampur, Odisha
2. **Study population**: 103 complete and undamaged dry Sacrum of unknown age and sex
3. **Informed Consent**: Not required
4. **Inclusion and Exclusion criteria**: Intact, fully mature and ossified Sacrum, devoid of any fractures and bony pathological changes, Damaged, mutilated, and deformed sacrum with complete agenesis of dorsal wall and absent sacral hiatus were excluded from study.
5. **Study design**: Analytical study.
6. **Type of study**: Observational anthropometric study of osteological measurements and landmarks
7. **Data collection**: Prospective.
8. **Data collection tools (Study instruments)**: Manual Sliding vernier calipers, measuring scale, divider, digital camera
9. **Methods used for data collection**: All the bones were numbered carefully to record metric and non-metric analysis.

Non-Metric Analysis	Metric Analysis (mm)
a. Shape of sacral hiatus b. Level of apex of sacral hiatus in relation with sacral vertebrae c. Level of base of sacral hiatus in relation with sacral vertebrae	a. Length of sacral hiatus from apex to base: From midpoint of base to mid-point of apex (With Vernier Caliper) b. Anteroposterior diameter (Depth) of sacral hiatus at the apex (With Divider) c. Transverse diameter (Width) of sacral hiatus at the base: Between the inner aspects of inferior limit of sacral cornua (with Divider and Vernier calipers) d. Distance between the apex to mid-point of an imaginary line joining both S2 foramina e. Distance between mid-point of base to the midpoint of an imaginary line joining both S2 foramina. f. Distance between apex to the highest point of right-side lateral crest /superolateral crest which corresponds to right side posterior superior iliac spine g. Distance between apex to the highest point of left side lateral crest /superolateral crest which corresponds to left side posterior superior iliac spine h. Distance between right and left superolateral sacral

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

	crest

Data confidentiality to be maintained as per ICMR protocol

10. **Study period**: 1 year (May 2016 – May 2017)
11. **Sample size**: Approximate 103 (2 sacra were excluded from the study because of deficient sacral hiatus & 1 sacra was excluded because of absent sacral hiatus.)
12. **Mode of sample selection**: Random sampling
13. **Pre testing and validation**: A pilot study (pre testing) was done for calculation of appropriateness of metric and non-metric parameters on 25 Sacrum bones. Validation – The obtained measurements were cross examined to rule out error
14. **Ethical approval**: Obtained from Institutional ethics committee (SCB Medical college Cuttack, ODISHA, Ref No. 465, IEC/IRB No. 487/19.09.17, dated 31/08/2017)
15. **Statistical software** IBM SPSS statistics version 21, stata 8.0 Medcalc 9.0.1 and Systat 11, Microsoft Word and Excel have been used for analysis and generate graphs, tables etc. Continuous variables are expressed in term of mean and standard deviation while categorical variables are expressed in term of percentage. Pearson correlation test was performed to evaluate the relationship between the variables. The measurements were compared with the findings of other studies to reach a conclusion.

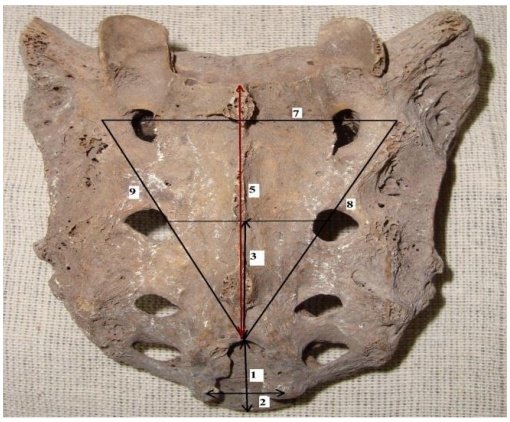


Figure-1: Measurement of sacrum hiatus

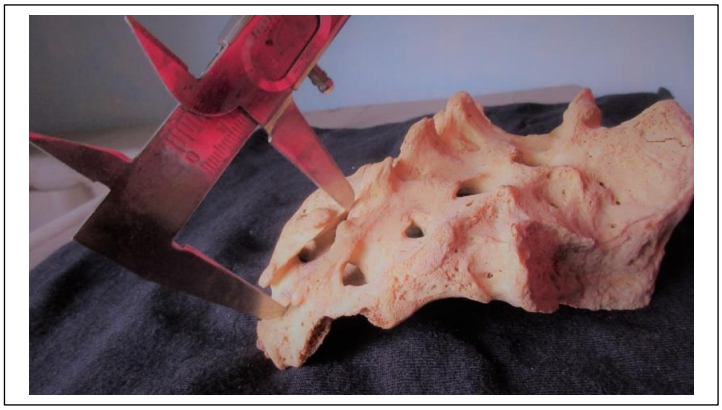


Figure-2: Measurement of the length of sacral

1) Height of Sacral Hiatus
2) Width of Sacral Hiatus at level of sacral cornua
3) Distance from Hiatus apex to the level of S2 foramina
4) (4=1+3) Distance from base of sacral hiatus to the level of S2 foramina
5) Distance between the upper border of S1 and Sacral Apex
6) Distance between two superolateral sacral crest (base of the triangle)
7) Distance between right superolateral sacral crest and sacral hiatus apex
8) Distance between left superolateral sacral crest and sacral hiatus ape

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

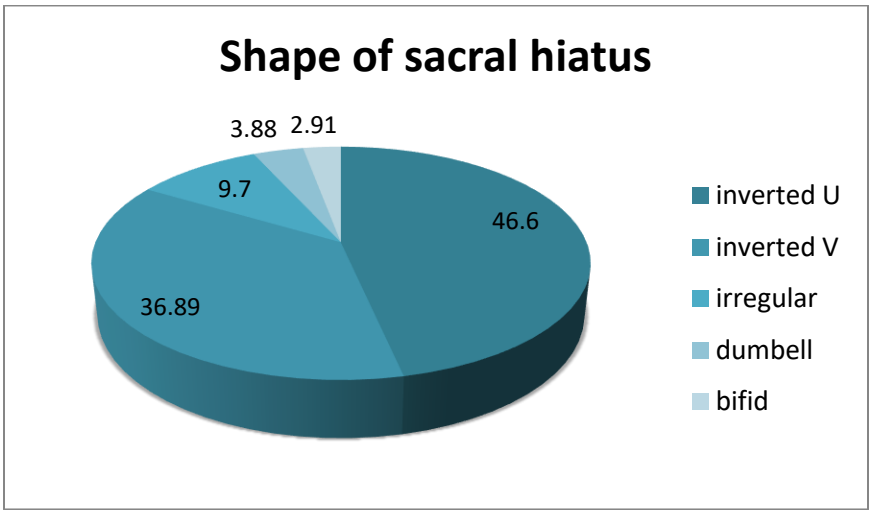
Figure 3: Transverse diameter of sacral hiatus

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

Results

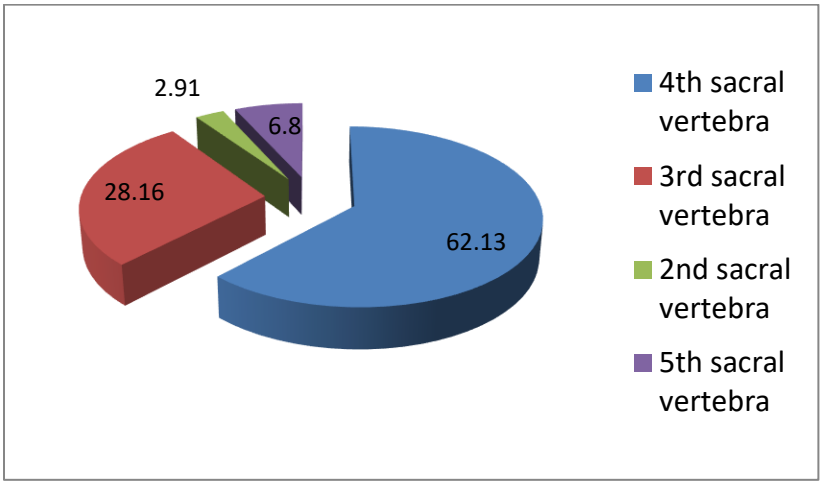
1. Shape of Sacral Hiatus: Variations in shape was noted and classified.

	Inverted U Most common	Inverted V	Dumb bell	Irregular	Bifid Least common
Present study	46.60%	36.89%	3.88%	9.70%	2.91%



2. Level of apex of sacral hiatus with respect to sacral vertebra

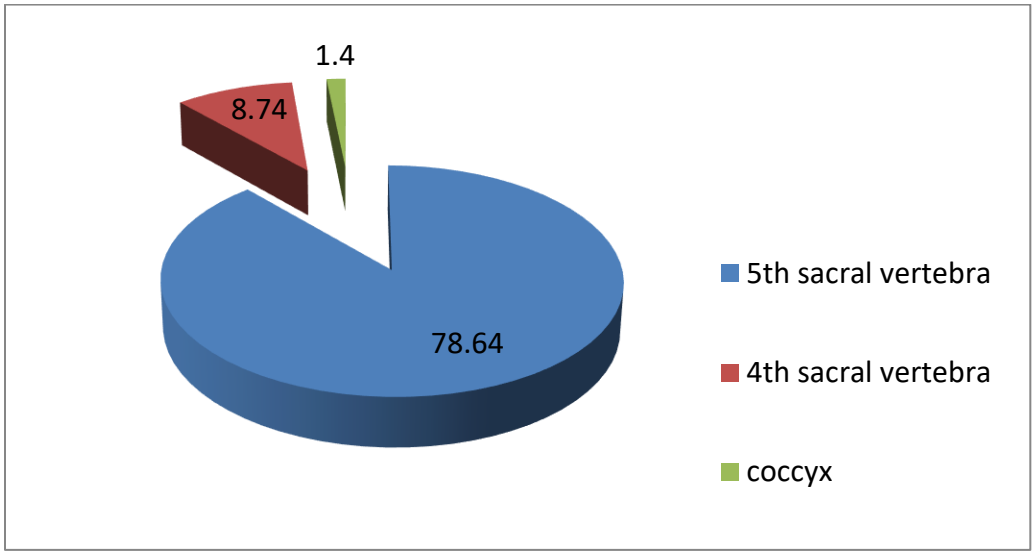
	4th sacral vertebra Most common	3rd sacral vertebra	2nd sacral vertebra	5th sacral vertebra Least common
Present study	62.13%	28.16%	2.91%	6.80%



ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

3. Location of base of sacral hiatus in relation to the level of sacral/coccygeal vertebra

	5th sacral vertebra Most common	4th sacral vertebra	Coccyx vertebra
Present study	81 (78.64%)	8 (8.74%)	13 12.62%

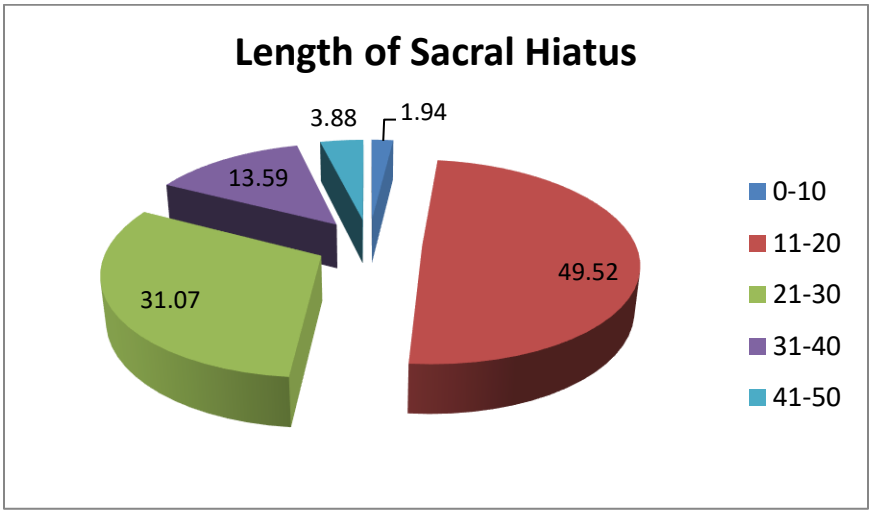


4. Length of sacral hiatus

Range	No. of specimen	Percentage
0-10	2	1.94%
11-20	51	49.52%
21-30	32	31.07%
31-40	14	13.59
41-50	4	3.88

	Mean ± SD (mm)	Range (mm)
Present study	22.36 ± 8.61	47-10

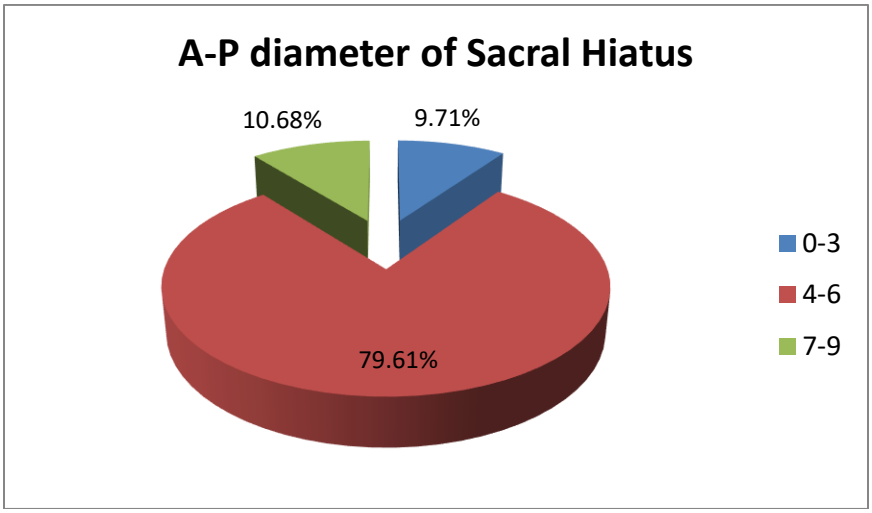
ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024



5. Anteroposterior diameter at the apex of sacral hiatus

Sr. no.	Range	No. of specimen	Percentage
1.	0-3	10	9.71
2.	4-6	82	79.61
3.	7-9	11	10.68

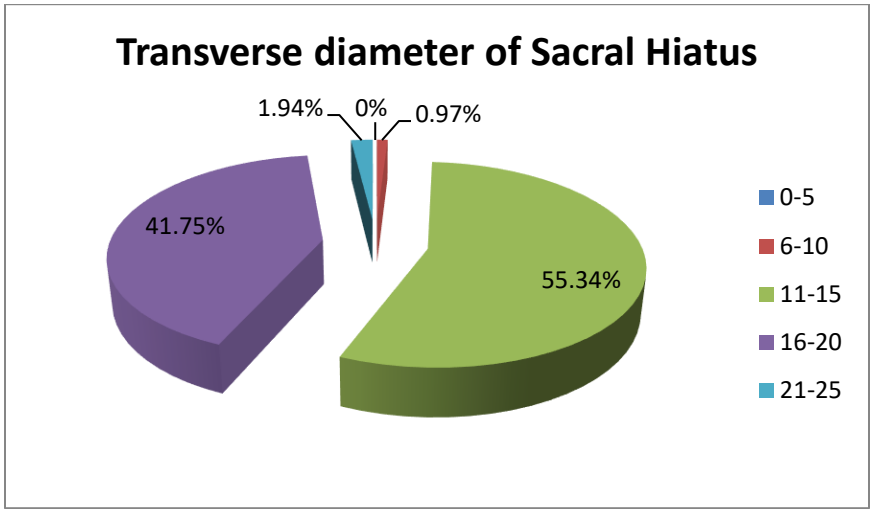
	Mean± SD (mm)	Range (mm)
Present study	5.19 ± 1.36	3-9



ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

6. Transverse diameter of sacral hiatus between inner aspects of inferior limit of sacral cornua (Transverse width of sacral hiatus at base) has been found in range of 11mm – 15 mm in about 55.34% cases

Range	No. of specimen	Percentage
	0	0
6-10	1	0.97
11-15	57	55.34
16-20	43	41.75
21-25	2	1.94



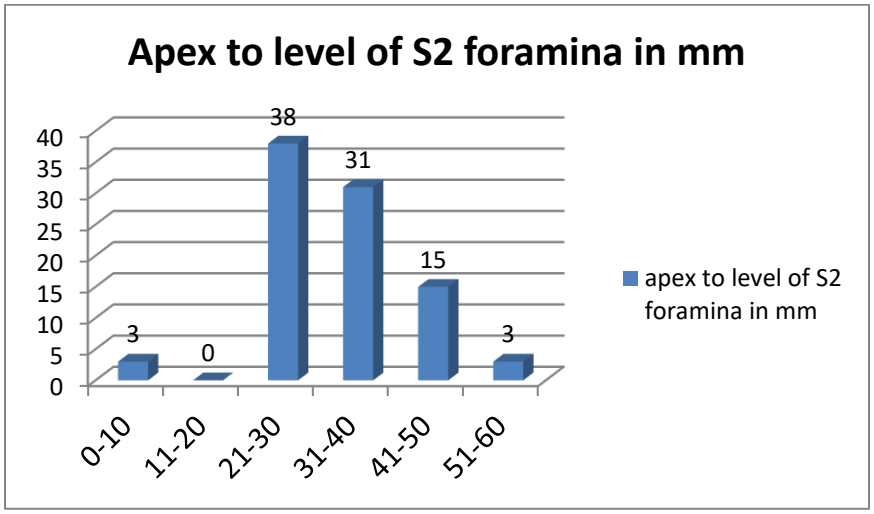
7. Transverse diameter of sacral hiatus between inner aspects of inferior limit of sacral cornua

	Mean ± SD (mm)	Range (mm)
Present study	15.40 ± 2.17	9-21

8. The distance of apex to the level of S2 foramina

Serial no.	Range	Specimen	Percentage
1.	0-10	3	2.91%
2.	11-20	13	12.62%
3.	21-30	38	36.89%
4.	31-40	31	30.11
5.	41-50	15	14.56%
6.	51-60	3	2.91%

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

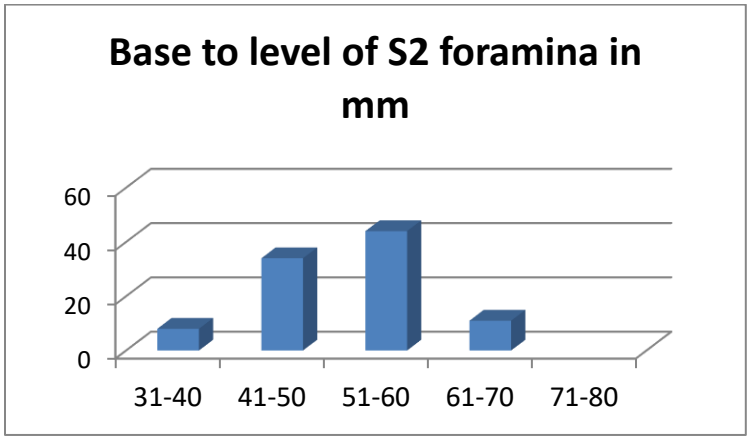


	Mean ± SD (mm)	Range (mm)
Present study	30.50 ± 10.26	6-54

9. In more than half of the cases distance of the apex to the level of S2 foramina was present between 21-40 mm.

10. The distance of base to the level of S2 foramina

Serial no.	Range	Specimen	Percentage
1.	31-40	8	7.77%
2.	41-50	34	33.01%
3.	51-60	44	42.72%
4.	61-70	11	10.68%
5.	71-80	6	5.82%

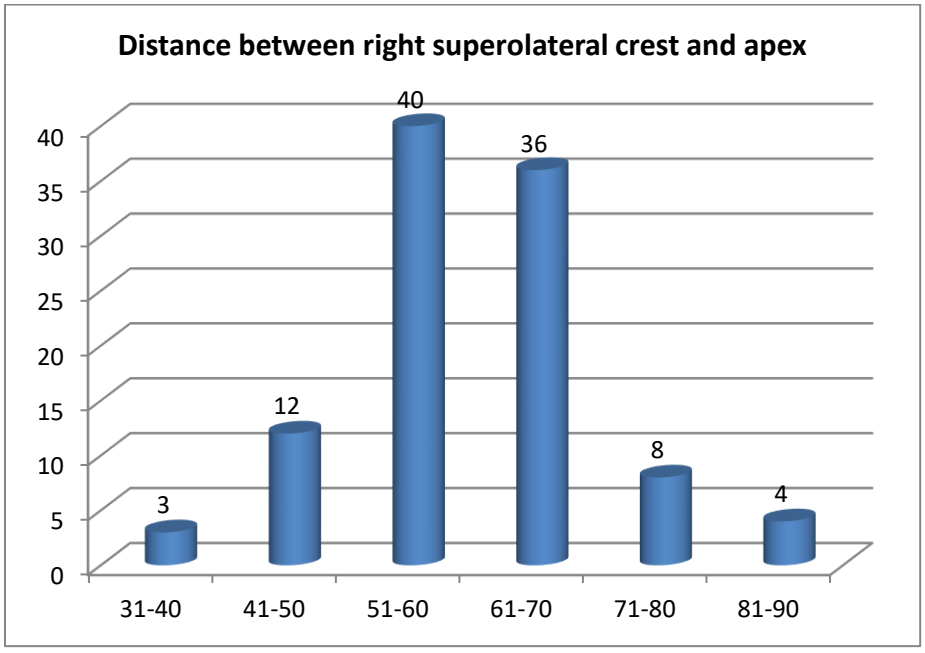


ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

	Mean ± SD (mm)	Range (mm)
Present study	52.93 ± 9.13	32-77

11. Distance between right superolateral sacral crest and apex

Serial no.	Range	Specimen	Percentage
1.	31-40	3	2.91%
2.	41-50	12	11.65%
3.	51-60	40	38.83%
4.	61-70	36	34.96%
5.	71-80	8	7.77%
6.	81-90	4	3.88%



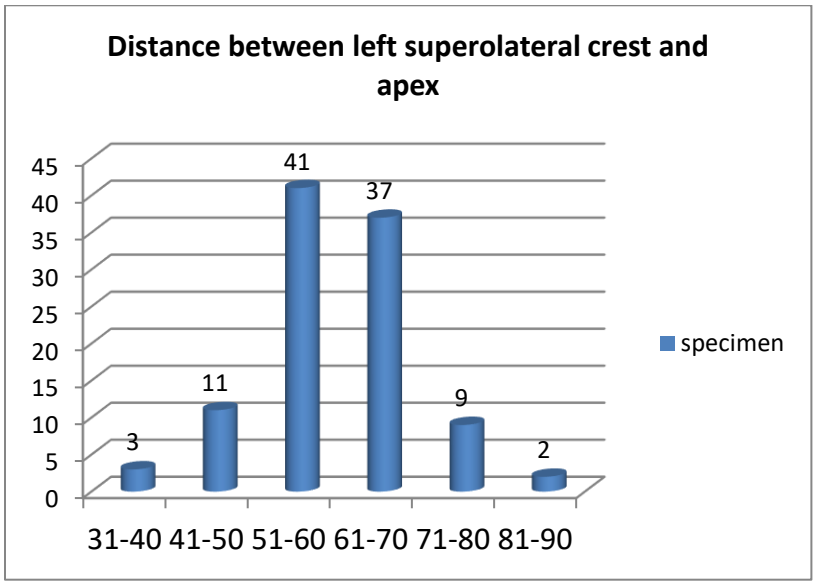
	Mean ± SD (mm)	Range (mm)
Present study	60.13 ± 9.73	35-84

12. Distance between left superolateral sacral crest and apex

Serial no.	Range	Specimen	Percentage
1.	31-40	3	2.91%
2.	41-50	11	10.68%
3.	51-60	41	39.81%
4.	61-70	37	35.92%
5.	71-80	9	8.79%

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

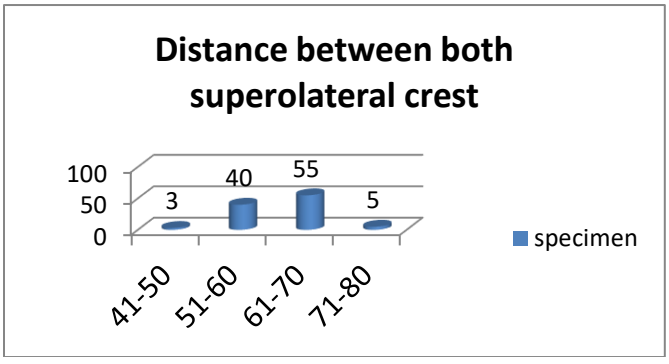
6.	81-90	2	1.94%



	Mean ± SD (mm)	Range (mm)
Present study	60.19 ± 9.58	35-84

13. Distance between right and left superolateral sacral crest

Serial no.	Range	Specimen	Percentage
1.	41-50	3	2.91%
2.	51-60	40	38.84%
3.	61-70	55	53.40%
4.	71-80	5	4.85%



	Mean ± SD (mm)	Range (mm)
Present	61.09 ± 5.92	44-74

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

study		

Discussion

This study is an attempt to know detailed morphometry including the variations of sacral hiatus. This study shall be useful for anesthetist, for caudal block in sacral hiatus in a variety of surgical procedures in adult and pediatric patients. The results of multiple parameters obtained are hereby discussed comparing similar parameters of other studies.

1. Shape of sacral hiatus

Our study proposes the obtained variations in the shape of sacral hiatus with an attempted classification. We observed complete agenesis of sacral hiatus in 2 sacra as also reported previously by Trotter et al. 1.85%, 1.49% by Kumar et al. and 1.5% by Nagar et al. Although this variation has been excluded in this study, Kumar V et al. have clinically correlated that patients with low back pain have higher percentage of deficient dorsal wall.

Sacral hiatus is usually triangular or inverted U shaped and is bounded laterally by sacral cornua. These shapes are preferable for a favorable CEB. In the present study we observed inverted U (46.60%) was the most common shape, which has been similar to findings by Nagar et al., MD Jawed et al., Seema et al. and Anmol Shinde et al., but Nadeem et al. reported higher value which was 56%, due to racial variation.

2nd most common shape was inverted V (36.89%). On the contrary, Kumar V et al. & Vandana et al. observed inverted V to be more common than inverted U. This may be because of deficient study sampling size.

Irregular shaped sacral hiatus was seen in 9.70% in present study which was similar to Md Jawed et al (8.87%) and Anmol Shinde et al (8.07%).

In present study dumbbell shape was seen in 3.88% of sacra which was similar to Md. Jawed et al. Nagar et al. and Seema et al., but Nadeem et al. observed higher incidence on the basis of different study population.

Bifid sacral hiatus was seen in 2.91% cases, very similar to Vandana et al. and Shinde et al.

Shape of sacral hiatus

Sl. no.	Study	Inverted U	Inverted V	Dumb Bell	Irregular	Bifid
1.	Nagar et. al. (2004)	41.5%	27%	13.3%	14.1%	1.5%
2.	Seema et al.(2013)	42.95%	27.51%	13.41%	16.10%	_
3.	Nadeem et al.(2014)	56%	14%	10%	16%	2%
4.	Md. Javed et al.(2016)	44.36%	35.85%	4.48%	8.87%	4.03%
5.	Vandana et al.(2016)	33.33%	33.33%	_	24.24%	3.03%
6.	Shinde et al. (2017)	46.33%	29.67%	10.33%	8.07%	3%

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

7.	**Present study**	**46.60%**	**36.89%**	**3.88%**	**9.70%**	**2.91%**

2. Level of apex

Standard text books state the apex of sacral hiatus to be present at the level of 4th sacral vertebra, which has been also documented in this study. in 64 sacra (62.13%), almost similar to Sekiguchi et al., Kamal Ahmm et al. and Ukoha U. et al, but was slightly less than reported by Nagar et al. Nadeem et al observed a lower value of 34%. due to racial variation.

Dona Saha et al. observed higher percentage of 74.36%, explained on the basis of different study populations having genetic constitutional variations.

All studies including the present, noted variations of location of apex from upper part of second sacral vertebra to lower part of fifth sacral vertebra. We document at the level of 3rd sacral vertebra (28.16%), 2nd sacral vertebra (2.91%) and 5th sacral vertebra (6.80%).

Apex of hiatus is an important guide mark for successful CEB. Chances of puncture of Dural sac during CEB has been reported to be common due to the presence of the apex at 2nd or 3rd sacral vertebra. Adequate precaution should be taken in cases of higher position of apex. while deciding length of the needle to be introduced into the canal.

Level of apex of sacral hiatus with respect to sacral vertebra

Sl. no.	Study	4th sacral vertebra	3rd sacral vertebra	2nd sacral vertebra	5th sacral vertebra
1.	Nagar et al. (2004)	55.90%	37.3%	3.4%	3.4%
2.	Sekiguchi et al.(2004)	65%	15%	4%	15%
3.	Ukoha U et al. (2014)	69.90%	20.50%	2.40%	4.80%
4.	Nadeem et al. (2014)	34%	62%	2%	2%
5.	Kamal ahmm et al. (2014)	60.20%	30.40%	4.70%	4.70%
6.	Dona saha et al. (2016)	74.36%	17.09%	1.71%	6.84%
7.	**Present study**	**62.13%**	**28.16%**	**2.91%**	**6.80%**

3. Level of base of sacral hiatus with respect to sacral vertebra

Base of sacral hiatus was seen most commonly at the level of 5th sacral vertebra (78.64%), similar to Nagar et al, Md. Jawed et al, Vandana et al. and A. Shinde et al.

Nadeem et al. reported lower incidence of 62% and Ukoha at el. observed higher incidence of 88%, due to racial variation.

Level of the base was also seen at the level of 4th sacral vertebra (8.74%) and coccyx (12.62%).

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

Level of base of sacral hiatus with respect to sacral vertebrae

Sl. no.	study	5th sacral vertebra	4th sacral vertebra	coccyx
1.	Nagar et al.(2004)	72.6%	11.1%	16.3%
2.	Nadeem et al.(2014)	62%	24%	14%
3.	Ukoha et al.(2014)	88%	2.40%	7.20%
4.	Md Jawed et al.(2016)	79.84%	12.10%	8.06%
5.	Vandana et al.(2016)	80.3%	13.63%	6.06%
6.	A. shinde et al.(2017)	77.03%	11.82%	11.15%
7.	**Present study**	**78.64%**	**8.74%**	**12.62%**

4. Length of sacral hiatus (in mm)

In present study length of sacral hiatus varied from 10mm to 47 mm, similar to Trotter et al, Trotter & Lanier et al., Vinod kumar et al., Nagar et al., Kamal Ahmm et al., Nadeem et al., Osunwoke et al. and Dona Saha et al.

Senoglu et al. found higher value of mean length (32.1 mm) of sacral hiatus. This discrepancy may be due to racial variation. Similarly, Vandana et al. also observed mean length of 33.71 mm, due to less study sample size.

A few sacra of 1.94% were found to have length of sacral hiatus in the range 0-10 mm, a point to be remembered for insertion of needles during CEB anesthesia. This figure was low as compared to 10.3% reported by Nagar et al.

Nagar et al. reported length of sacral hiatus was 11 mm to 30 mm in 65.8% of cases. In our study length of sacral hiatus was 11 mm to 30 mm in almost 80% of cases.

Length of sacral hiatus

Sl. no.	Study	Mean ± SD (mm)	Range (mm)
1.	Trotter et al.(1944)	22.5	66-0
2.	Trotter & Lanier et al.(1945)	24.8 in male 19.8 in female	
3.	Vinod kumar et al.(1992)	20 in males 18.9 in females	-
4.	Nagar et al.(2004)	22.8	-
5.	M Senoglu et al.(2005)	32.1	53-12
6.	Kalam ahmm et al.(2014)	26.38±12.02 in male 25.63±10.46 in female	- -
7.	Nadeem et al. (2014)	25.2	50-5
8.	Osunwoke et al. (2014)	23.65	-
9.	Dona saha et al. (2016)	20.21±7.73	54.00-8.80

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

10.	Vandana et al. (2016)	33.71±9.54	55.20-15.10
11.	**Present study**	**22.36±8.61**	**47-10**

5. Anteroposterior diameter of sacral hiatus at the level of apex

The anteroposterior diameter of sacral canal at apex of sacral hiatus is important as it should be sufficiently large to admit a needle or catheter during CEB anesthesia. Subcutaneous deposition of anesthetic drugs may occur due to variation in diameter.

The present study finds diameter ranging from 3 to 9 mm with a mean of 5.19 ±1.36 mm, similar to that reported by Nagar et al. Trotter et al, Lanier et al., Vinod Kumar et al. and Seikuguchi M et al.

In the present series anteroposterior diameter of sacral canal at apex of sacral hiatus was less than 3 mm in 9.71%, which was similar to the finding of MD. Jawed et al. (9.68%). Trotter et al. reported 5% cases with 0-2 mm diameter. 15.6% cases of Nagar et al. had value higher than present study.

Senoglue et al. and Dona Saha et al. reported lower incidences which were 6.25% and 6.84% respectively. Wide range of variations were seen probably because of different geographical study populations observed by different authors.

About 79.61% Sacra showed anteroposterior diameter between 4 and 6 mm. This was similar to findings reported by A. & A. Aggarwal et al., Nagar et al. and Dipali rani pal et al.

Anteroposterior diameter at the apex of sacral hiatus

Sl. No.	Study	Mean ± SD (mm)	Range
1.	Trotter et al. (1944)	5.3	-
2.	lanier et al. (1944)	6.1±0.2	-
3.	Vinod kumar et al.(1992)	4.8	-
4.	Nagar et al.(2004)	4.88	2-14
5.	Sekiguchi et al. (2004)	6±1.9	1.9-11.4
6.	Senoglu et al. (2005)	4.46±1.33	1-7
7.	A. &A. Agrawal et al.(2009)	5.03±1.57	1.9-10.40
8.	Deepali rani pal et al.(2012)	5.34±1.39	2-9
9.	Nadeem et al.(2014)	5.53	2-12
10.	Dona saha et al. (2016)	6.02±2.43	2-12.50
11.	MD. jawed et al. (2016)	5.39±1.96	2.1 -10.87

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

12.	**Present study**	**5.19±1.36**	**3-9**

6. Transverse diameter of sacral hiatus between inner aspects of inferior limit of sacral cornua

Present study shows transverse width varied from 9 mm to 21 mm with mean of 15.40±2.17 mm. Arithmetic mean was nearly similar to William FM et al., Trotter et al. and Senoglu et al; Lanier at el. Nadeem et al. reported higher value of this entity, whereas Nagar et al. and Sekiguchi et al. observed lower value. These results were attributed to racial diversity.

In more than half cases (55.34%) transverse width of sacral hiatus at base was in range of 11 mm – 15 mm, which was similar to study conducted by Nagar SK et al. They reported that more than half (54%) cases with value in range of 10mm – 15mm.

Transverse diameter of sacral hiatus between inner aspects of inferior limit of sacral cornua

Sl. No.	Study	Mean ± SD (mm)	Range (mm)
1.	Lanier at el. (1944)	19.3	-
2.	Trotter et al. (1945)	17	-
3.	Nagar et al. (2004)	10	3-19
4.	Sekiguchi et al. (2004)	10.2±o.35	2.2-18.4
5.	Senoglu et al. (2005)	17.47±3.2	7-28
6.	Nadeem et al.(2014)	19.5	3-25
7.	William FM et al. (2017)	15	10-25
8.	**Present study**	**15.40±2.17**	**9-21**

7. The distance of apex to the level of S2 foramina

An important part in Caudal epidural block 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' dura mater and arachnoid end at the level of second sacral vertebra. Thus, this distance decides the length of the needle that can be safely introduced into the canal. High level of sacral apex (S3) is a dangerous site in close relation to the level of Dura mater termination at S2.

The mean distance from apex to S2 in present study was 30.50 ±10.26 mm with a range of 6 to 54 mm. These findings were similar to studies by A. Aggrawal et al., Deepali et al., Clarista et al. and Vandana et al, but higher in cases reported by Senoglu et al. and Satish et al. Both worked on different geographical areas having genetic variations.

In more than half of the cases distance of the apex to the level of S2 foramina was present between 21- 40 mm.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

The distance of apex to the level of S2 foramina

Sl. No.	Study	Mean ± SD (mm)	Range (mm)
1.	Senoglu et al.(2005)	35.37±10.36	11-62
2.	A.Aggarwal et al. (2009)	30.16±14.17	2-135
3.	Deepali et al. (2012)	31.33±10.59	5.02-60.3
4.	Clarista et al. (2013)	32.16±12.96	0-55.20
5.	Satish m. Patel et al.(2016)	35.5±17.8	4-69
6.	Vandana et al. (2016)	32.97±13.42	10.10-76
7.	**Present study**	**30.50±10.26**	**6-54**

8. The distance of base to the level of S2 foramina

The mean distance from base of sacral hiatus to S2 vertebra in the present study was 52.93 ± 9.13 mm, with a range of 32 to 77 mm, coinciding with those of Pal et al., Neeta et al., Vandana et al. and William et al.

Senoglu et al. and Satish et al. reported higher values for this entity which were 65.23 mm and 72.16 respectively. Difference in observation can be possible because both studies were performed in different populations having genetic variations.

Sl. No.	Study	Mean ± SD (mm)	Range (mm)
1.	Senoglu et al. (2005)	65.25±9.39	39-85
2.	Pal et al. (2012)	54.88±7.92	37.03-79.8
3.	Neeta et al. (2014)	53.36±10.22	13.66-68.55
4.	Satish et al. (2016)	72.16±17	35-100
5.	Vandana et al. (2016)	59.70±11.04	5.0-84.20
6.	William et al. (2017)	56.83±6.96	40-80
7.	**Present study**	**52.93±9.13**	**32-77**

9. Distance between right superolateral sacral crest and apex

Apex of the sacral hiatus is difficult to palpate, especially in obese patients. The posterior superior iliac spine imposes on the upper part of lateral sacral crest and that point of overlapping on the lateral sacral crest was named by Senoglu N and colleagues as superolateral sacral crest and the line joining the two posterior superior iliac spines passes through the lower point of the 1st dorsal sacral foramina in most of the cases. So, in non-articulated pelvis this line was used to locate the position of posterior superior iliac spine on lateral sacral crest. This line formed the base of a triangle and the lines joining the apex of the sacral hiatus with the right & left posterior superior iliac spines or the superolateral sacral crests formed the other two arms of the triangle. The three arms of this triangle were measured in each sacrum. This triangle can be a practical guide to detect the sacral hiatus.

In this study right superolateral crest was considered as right margin, left superolateral crest was considered as left margin and distance between both superolateral crest was considered as base of inverted triangle.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

In our study distance between right superolateral sacral crest and apex varied between 35-84 mm. (Mean 60.13±9.73 mm), approximately in the range reported by Patel et al., A. Shinde et al, Vandana et al., Dona Saha et al. and A. A. Aggarwal et al. But less than that observed by M.S. Mustafa et al. and higher than observed by Mrudula et al.

Sl. No.	Study	Mean ± SD (mm)	Range (mm)
1.	Senoglu et al. (2005)	67.10±9.95	42.1-89
2.	A. Aggarwal H Kaur et al.(2009)	66.0±9.6	45.07-86.86
3.	A. Aggarwal et al.(2009)	59.92±8.48	36-78
4.	M.S. Mustafa et al.(2012)	75.0±10.3	-
5.	Patil. et al.(2012)	61.95±11.71	29-95
6.	Mrudula et al.(2013)	53.6	26-68
7.	Deepa et al.(2014)	69±14.49	56-94
8.	A. Shinde et al.(2015)	61.02	-
9.	Vandana et al.(2016)	63.16±9.07	39-85.30
10.	Dona Saha et al.(2016)	63.38±9.21	37.50-84.10
11.	Patel et al.(2016)	60.4±14.9	40-90
12.	**Present study**	**60.13±9.73**	**35-84**

10. Distance between left superolateral sacral crest and apex

This parameter considered as left margin of triangle. Mean length was 60.19 ± 9.58 mm, with a range between 35-84 mm. Finding was almost similar to Shinde et al., Vandana et al., Dona Saha et al. and A. A. Aggarwal et al. Deepa et al. found higher value for same entity, which may be due to less sample size used in their study.

Sl. No.	Study	Mean ± SD (mm)	Range (mm.)
1.	Senoglu et al. (2005)	67.53±9.48	46-88.1
2.	A. A.Aggarwal (2009)	59.99±8.31	37-76
3.	A. Aggarwal $ H.Kaur et al.(2009)	65.3±9.8	27-72
4.	M.S. Mustafa et al. (2012)	75.0±10.2	-
5.	Patil et al. (2012)	61.4±11.98	28-91
6.	Mrudula et al. (2013)	54.6	-
7.	Deepa et al. (2014)	71±17.77	55-104
8.	A.Shinde et al.(2015)	63.94	-
9.	Vandana et al. (2016)	62.53±9.03	44-83.40
10.	Patel et al. (2016)	53.2±10	38-75

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

11.	Dona Saha et al. (2016)	63.50±9.20	37.50-84.10
12.	**Present study**	**60.19±9.58**	**35-84**

11. Distance between right and left superolateral sacral crest

This parameter considered as base of the triangle. We found mean length was 61.09 ±5.92 mm. with maximum and minimum as 74 and 44 mm respectively. The finding was similar to that reported by Patil et al., Dona Saha et al.and Kumar et al. Wide range of variations were observed by A & A. Aggarwal (50.96 mm) and M. Mustafa (75.5mm).

Sl. No.	Study	Mean ± SD (mm)	Range (mm)
1.	Senoglu et al. (2005)	66.51±53.52	51-79.5
2.	A. A.Aggarwal(2009)	50.96±6.69	20-75
3.	A.Aggarwal $ H.Kaur et al.(2009)	70.1±7.8	86.86±51.95
4.	M.S. Mustafa et al. (2012)	75.5±10.3	-
5.	Patil et al. (2012)	60.61±6.71	43-78
6.	Mrudula et al. (2013)	56.5	51-66
7.	Deepa et al. (2014)	71±1.78	55-104
8.	A.Shinde et al.(2015)	64.5	-
9.	Vandana et al. (2016)	64.83±6.87	48.60-85.10
10.	Patel et al. (2016)	60.4±14.9	40-90
11.	Dona Saha et al. (2016)	62.38±6.19	46.68-89.1
12.	**Present study**	**61.09±5.92**	**44-74**

12. Concept of equilateral triangle

Many workers suggested the utility of equilateral triangle formed by two posterosuperior iliac spines and apex of hiatus for locating the hiatus, Senoglu et al. stressed upon its equilateral nature in all cases on the basis of nearly equal mean value of three sides. In our study, mean length for right margin of triangle was 60.13 mm, left margin was 60.19 mm and mean length for base of the triangle was 61.09 mm observed, approximately forming an equilateral triangle.

But when observed dimensions prove that all borders of triangle might not be necessarily similar in an individual specimen. Aggarwal et al. and Patil et al. reported an equilateral triangle in 45% and 23% cases respectively. Aggarwal et al. reported in 55% cases wherein right and left sides of the triangle were much shorter than the base as position of apex of hiatus. On the contrary, Bhattacharya et al. observed an isosceles triangle in general, but a complete equilateral triangle was found only in 16% cases.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

This study finds 9 specimens (8.74%) as complete equilateral triangle. Hence, the authors believed that the equilateral triangle is not sufficient to be fully relied upon for locating sacral hiatus in all the cases.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

Summary and conclusion

Identification of the caudal epidural space is not always possible even for experienced clinicians due to wide anatomical variation, relating to failure of CEB procedure. These conceptual variations are helpful especially for anesthetists, surgeons and gynecologists (spinal analgesia) while performing CEB.

Dry and undamaged and fully ossified human sacra (103 in number) were studied for matric and non-matric parameters. Normal shapes of sacral hiatus observed include inverted-U in 56.61% Sacra and inverted-V in 28.30% Sacra. A few abnormal shapes of sacral hiatus were also reported in significant percentages. The apex of sacral hiatus was found at the level S4 (71.70%) and S3 (20.75%). Base of sacral hiatus was most commonly located at S5 (81.13%). The mean length of sacral hiatus was 21.71 ± 8.76 mm. Mean antero-posterior diameter of sacral hiatus was 5.19±1.33 mm. Transverse diameter at the level of sacral cornua was 15.40±2.24 mm. Shallow sacral hiatus at apex, observed in significant percentage. These abnormalities can lead to failure of caudal anesthesia.

Concept of equilateral triangle was also not fully reliable among coastal Odisha population. Thus, for locating sacral hiatus, combination of landmarks rather than single landmark should be used. This study also described the possible anatomical causes of caudal block failure. This type of variations should be kept in mind before caudal block.

Conflict of interest

The authors have declared that no competing interests exist.

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Department of Anatomy, Government Medical College, Cuttack, Odisha

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 9, 2024

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