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Research Article

MORPHOMETRICAL STUDY OF SACRAL HIATUS IN DRY HUMAN SACRA IN WEST INDIAN POPULATION

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ABSTRACT
The knowledge of the anatomy of sacral hiatus is important for successful caudal epidural anaesthesia used during various surgical procedures. The present study was conducted on 104 dry human adult sacral bones of unknown sex. These bones were subjected to qualitative and quantitative analysis. The measurements were taken with the help of Vernier callipers, a pair of dividers with steel measuring tape were subjected to statistical analysis. The results of qualitative study revealed that 84.6% sacra were made up of 5 vertebrae. The commonest shapes of sacral hiatus were inverted 'U' (46.2%) and inverted 'V' (24%). The level of apex of the hiatus was at S4 in 67.7% sacra. The most common level of the base of the hiatus was at S5 (95.8%). Sacral cornua were palpable (unilaterally and bilaterally) in only 55.2% sacra. The results of quantitative study revealed that the mean length and anteroposterior depth at the apex of the sacral hiatus were 24.73 ± 9.38 mm and 5.58 ± 1.66 mm respectively. The depth of the hiatus was more than 2mm in 99% sacra which suggested that the needle can be pushed with ease. The intercornual distance at the base of hiatus ranged from 6.48 to 29.20 mm. In 60.4% sacra, the distance between the caudal end of the median sacral crest and the apex of the sacral hiatus was more than 10mm which was not favourable for caudal epidural block. The distance between S2 and the apex ranged from 0 - 55.20 mm which may result in dural puncture. The triangle formed by right and left posterior superior iliac spines and the apex of the hiatus was found to be equilateral in nature and there was a positive significant correlation of the base with right and left margins of the triangle. The findings of the present study will be helpful to the clinicians and anaesthetics to locate the sacral hiatus for caudal epidural anaesthesia.

Key Words: *Sacrum, Sacral Hiatus and Caudal Epidural Block*

INTRODUCTION
Sacral approach to epidural space produces reliable and effective block of sacral nerves (Aggarwal *et al.*, 2009). The sacral hiatus gives immediate and easy access to the sacral epidural space at a level where most of the roots of the cauda equina are no longer inside the sacral canal, below the termination of the dural sac (Dalens, 2006). Anatomic variations in the sacral hiatus, may relate to failure of caudal epidural anaesthesia (Sekiguchi *et al.*, 2004). According to McLeod (2006) anatomical abnormalities of the sacrum include upward and downward displacement of the hiatus, pronounced narrowing or partial obliteration of the sacral canal, ossification of the sacrococcygeal membrane, absence of bony posterior wall of the sacral canal and variation in shape of the hiatus, ranging from long and narrow to broad. Caudal epidural anaesthesia has been used for many years and is the easiest and the safest approach to the epidural space. When correctly performed there is little danger of the spinal cord or dura being damaged. It is used to provide peri and post - operative analgesia in adults and children. It may be the sole anaesthetic for some procedures, or it may be combined with general anaesthesia (Vadodaria and Conn, 1998). The knowledge of the location of sacral hiatus is essential in the anaesthetic interventions required for variety of operations. The aim of the present study was to identify the anatomical landmarks for the localisation of sacral hiatus and to study various morphometric measurements and variations of the structures around the sacral hiatus in dry adult sacra in Western population.

MATERIALS AND METHODS
The present morphometrical study was done on dry human adult sacral bones of unknown sex and age in the state of Goa. Damaged or eroded sacra were excluded. The measurements were done on 104

sacra using a stainless steel Vernier calliper and a pair of dividers with steel measuring tape. The analysis was carried out in two parts:

Qualitative analysis

1. Sacral composition.
2. Shape of the hiatus.
3. Level of the apex of hiatus in relation to sacral vertebra.
4. Level of base of hiatus (tips of cornua) in relation to sacral and coccygeal vertebrae.
5. Palpable or impalpable sacral cornua: sacral cornua of less than 3mm were considered impalpable or absent.

All the 104 sacra were studied for sacral composition and shape of hiatus. Eight sacra had no sacral hiatus as there was complete agenesis of the dorsal wall in two sacra and complete closure of the dorsal wall in remaining six sacra, and were excluded from the remaining qualitative and quantitative analysis.

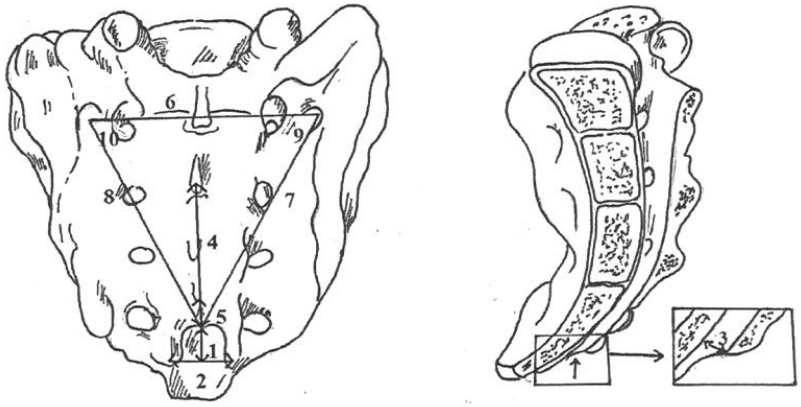

Figure 1: The measured parameters

Quantitative analysis (Figure 1)

1. Length of sacral hiatus – distance from the apex of hiatus to the midpoint of intercornual distance.
2. Intercornual distance – distance between inner surfaces of cornua.
3. Antero posterior diameter of sacral canal at the apex of the hiatus.
4. Median distance between the level of second sacral foramina and apex of sacral hiatus.
5. Distance between caudal end of median sacral crest and apex of sacral hiatus.
6. Transverse distance between right and left lateral sacral crests at the level of the first sacral foramina which represents the base of the triangle.
7. Distance between the right lateral sacral crest at the level of the first sacral foramina and the apex of the hiatus which represented the right margin of the triangle.
8. Distance between the left lateral sacral crest at the level of the first sacral foramina and the apex of the hiatus which represented the left margin of the triangle.
9. Angle between the lines formed by the 6^{th} and the 7^{th} parameters.
10. Angle between the lines formed by the 6^{th} and 8^{th} parameters.

Statistical analysis: All data were expressed as mean ± standard deviation and range. Analyses were performed using SPSS software. Relationship between the variables was analysed using the Karl Pearson correlation test. Base of the triangle was correlated with the right and the left margins of the triangle. Likewise, length of the sacral hiatus was correlated with the base, right and the left margins of the triangle. Results were substantiated with tables and scatter diagrams.

RESULTS AND DISCUSSION

The results of the present study indicate that the anatomical features and location of the sacral hiatus are highly variable. These variations can result in the failure of caudal epidural block.

In the present study, 88 (84%) sacra were made up of 5 segments, 8 (7.7%) showed sacralisation, 1 (1%) sacrum made up of only 4 segments and 7 (6.7%) sacra had cocygeal ankylosis (Table 1). Kumar *et al.,* (1992) on the other hand, reported sacra made up of 5 segments only in 69.80%, whereas, coccygeal ankylosis in 21.29%. Sacralisation was seen in 7.43% and sacra were made up of only 4 segments in 1.48%, which were similar to the present study.

Table 1: Sacral composition

Sacral composition	No (%)
5 vertebrae	88 (84%)
4 vertebrae	1 (1%)
Sacralisation	8 (7.7%)
Coccygeal ankylosis	7 (6.7%)

Inverted U and inverted V types are the most favourable shapes for caudal epidural block. In the present study the shapes of the sacral hiatus were variable, the commonest variety being inverted 'U' in 48 (46.2%) and inverted 'V' in 25 (24%) sacra. The figures in the present study were close to those reported by Nagar (2004) who observed inverted 'U' in 41.5% and inverted 'V' in 27% cases. Other shapes reported were irregular, M, bifid and dumb-bell which pose difficulty in needle insertion (Table 2). Aggarwal *et al.,* (2009) reported 'M' shaped sacral hiatus in 0.87% which was low when compared to the present study. In 8 sacra the sacral hiatus was absent due to complete agenesis of the dorsal wall and completely closed dorsal wall. Black (1949) in his study observed that in these cases the procedure was partially successful as the anaesthetic solution infiltrated the surrounding tissue instead of blocking the nerves resulting in failure of the block. Of 8 sacra which did not have sacral hiatus, coccygeal ankylosis was seen in 5 sacra. This was not reported by any other author previously.

Table 2: Shapes of sacral hiatus

Shape of sacral hiatus	No (%)
U	48 (46.2%)
V	25 (24%)
Irregular	10 (9.6%)
M	3 (2.9%)
Dumb-bell	7 (6.7%)
Bifid	3 (2.9%)
Closed	6 (5.8%)
Complete agenesis	2 (1.9%)

Newell (2008) states that the apex of the sacral hiatus is present commonly at the level of 4th sacral vertebra. Table 3 shows that in the present study, the apex of the sacral hiatus was seen most commonly at the level of 4th sacral vertebra in 65 (67.7%) sacra, which was almost similar to Sekiguchi *et al.,* (2004) in 60 (65%) sacra and Aggarwal *et al.,* (2009) in 78 (68.42%) and it was much higher in the study conducted by Kumar *et al.,* (1992) who reported an incidence of 76.23%. Nagar (2004) and Patel *et al.,* (2011) reported much lower incidence of 55.9% and 59.33% respectively. In the present study, the apex of the sacral hiatus was seen at the level of S3 in 27.1% and at S2 in 5.2% sacra. Sekiguchi *et al.,* (2004) reported the level of the apex of the sacral hiatus to be at S2 in 4% sacra which was almost close to the present study, but they found a lower incidence of 15% at S3. Nagar (2004) reported the level of the apex to be at S2 in 3.4% but reported 37.3% at S3 which was higher when compared to the present study. Most of the studies namely Kumar *et al.,* (1992) Nagar (2004), Sekiguchi *et al.,* (2004), Aggarwal *et al.,* (2009) and Patel *et al.,* (2011) also reported the level of the apex to be at S5, which was not reported in the present study.

Table 3: Level of apex and base of sacral hiatus in relation to sacral vertebrae

	S2 (%)	S3 (%)	S4 (%)	S5 (%)	Coccyx (%)
Level of apex of sacral hiatus	5 (5.2%)	26 (27.1%)	65 (67.7%)	-	-
Level of base of sacral hiatus	-	-	-	92 (95.8%)	4 (4.2%)

Level of the base of the sacral hiatus was seen at the level of the fifth sacral vertebra in 95.8% sacra in the present study (Table 3), which was much higher when compared to the incidence reported by other workers namely Kumar *et al.*, (1992), Nagar (2004) and Aggarwal *et al.*, (2009) who reported incidence of 83.17%, 72.6% and 61.40% respectively. In the present study the base of the sacral

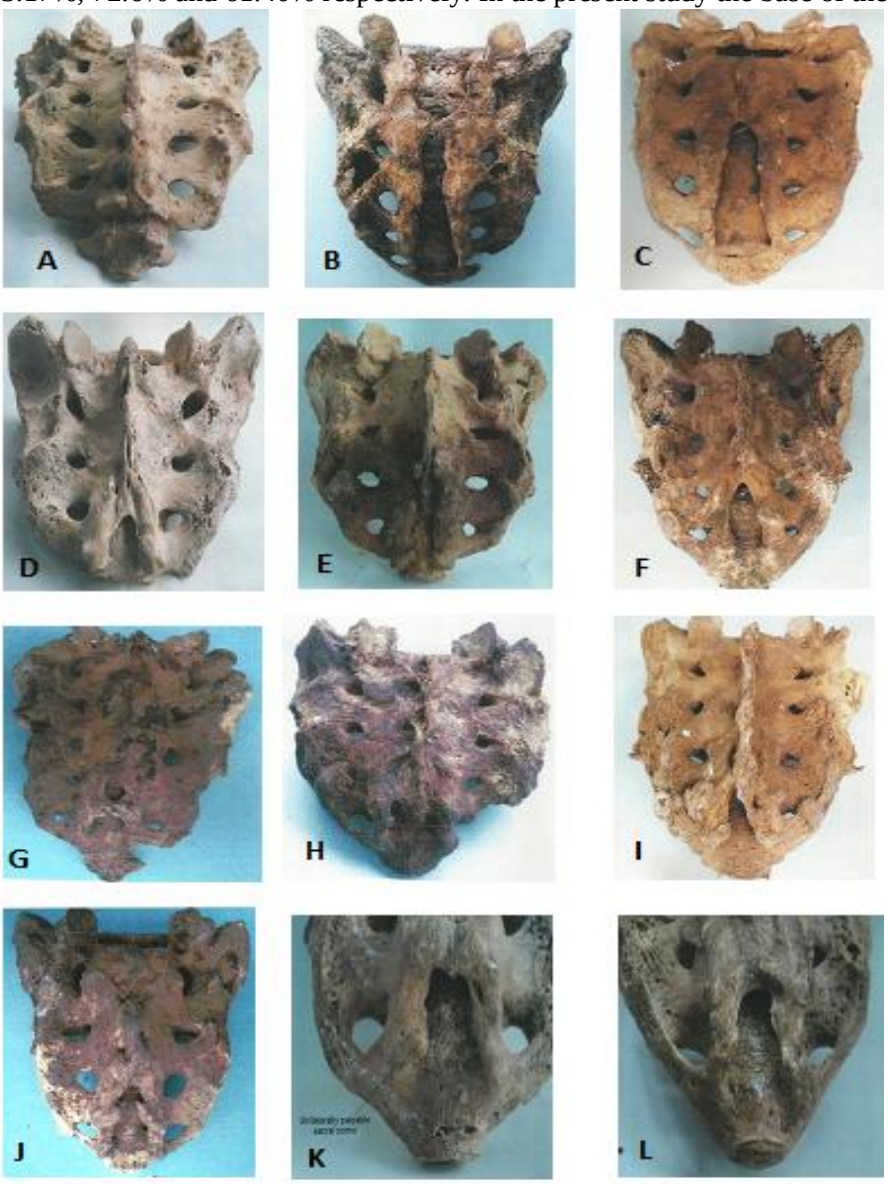

Figure 2: Picture showing sacral composition, various shapes and level of apex of sacral hiatus, and palpable and absence of sacral cornua: (A) Complete closure of the dorsal wall of sacral canal with coccygeal ankylosis, (B) Complete agenesis of the dorsal wall of sacral canal, (C) Sacrum showing sacralisation and apex of hiatus at S2, (D) Sacrum made up of four segments, (E) Inverted U shape hiatus, (F) Inverted V shape hiatus and apex at S3, (G) Bifid shape hiatus, (H) M shape hiatus, (I) Irregular shape hiatus, (J) Dumb-bell shape hiatus, (K) Unilaterally palpable sacral cornu, (L) Bilateral absence of sacral cornua

hiatus was seen at the level of coccyx in 4.2% cases, which was much lower when compared to the studies conducted by Kumar et al., (1992), Nagar (2004), Aggarwal et al., (2009) and Kumar et al., (2010) who reported the incidences of 14.35%, 16.3% 27.19% and 40% respectively. Some workers also reported the base of the sacral hiatus to be at S4 which was not reported in the present study.

Table 4: Sacral cornua

Sacral cornua	No (%)
Bilaterally palpable	36 (37.5%)
Unilaterally palpable	17 (17.7%)
Absent	43 (44.8%)

According to Aggarwal *et al.,* (2009) sacral cornua are the most commonly used landmark for identifying the sacral hiatus. Variations in the cornu ranging well defined projection to flattening may greatly affect its utility for locating sacral hiatus. In the present study sacral cornua were bilaterally palpable in 37.5%, unilaterally palpable in 17.7% and were impalpable bilaterally in 44.8% cases (Table 4). Sekiguchi *et al.,* (2004) reported incidence of 46% of prominent sacral cornua and 54% of absent sacral cornu.

Length of sacral hiatus decides the length of the needle to be used to give the block. In the present study, it varied from 7.92 to 59.22 mm with a mean distance of 24.73 ± 9.38 mm (Table 5). It was less than 10 mm in 1% sacra (Table 6). Nagar (2004) reported a range of 11 to 30 mm. It was less than 10 mm in 10% sacra, which was much higher when compared to the present study. Senoglu *et al.,* (2005) reported a mean distance of 32.9 ± 19.9 mm which ranged from 12 to 53 mm. The wide range in the length of the sacral hiatus in the present study can be explained by the fact that only 67.7% of sacra the apex was at S4 and in the remaining there was a defect of non union of 2nd and 3rd pair of sacral laminae.

Table 5: Showing descriptive statistics of the quantitative parameters

Parameter	Mean	Standard deviation	Range (mm)
Length of sacral hiatus	24.73	9.38	7.92 - 59.22
Intercornual distance	16.87	3.66	6.48 - 29.20
Antero posterior diameter of sacral canal at the apex of the hiatus.	5.58	1.66	1.98 - 9.92
Median distance between the level of second sacral foramina and apex of sacral hiatus.	32.16	12.96	0 - 55.20
Distance between caudal end of median sacral crest and apex of sacral hiatus.	11.76	5.75	2.06 - 26.62
Transverse distance between right and left lateral sacral crests at the level of the first sacral foramina which represents the base of the triangle	64.96	5.44	49.10 - 79.40
Distance between the right lateral sacral crest at the level of the first sacral foramina and the apex of the hiatus which represented the right margin of the triangle.	62.64	9.62	34.12 - 83.90
Distance between the left lateral sacral crest at the level of the first sacral foramina and the apex of the hiatus which represented the left margin of the triangle.	62.33	9.92	34.50 - 83.90
Angle between the right lateral crest at the level of first sacral foramina and apex of hiatus	57.26	6.73	26.98 - 65.53
Angle between the left lateral crest at the level of first sacral foramina and apex of hiatus	58.65	7.03	29.79 - 72.13

The present study reported intercornual distance ranging from 6.48 to 29.20 mm with an average distance of 16.87 ± 3.66 mm (Table 5). Senoglu *et al.,* (2005) reported a mean distance of 17.47 ± 3.22 mm ranging from 7 to 28 mm. These measurements were similar to the findings of the present study. Sekiguchi *et al.,* (2004) reported intercornual distance ranging from 2.2 to 18.4 mm, which was lower when compared to the present study. In the present study, this distance was less than 10 mm in only 2.1% sacra and in about 53.1% of sacra it was 15 to 20 mm, which was sufficient enough for the passage of the needle (Table 6). Aggarwal *et al.,* (2009) in their series found 21% sacra with distance less than 10 mm.

Depth of the sacral hiatus at apex is important as it should be sufficient enough to allow the entry of the caudal epidural needle into the sacral canal with ease. In the present study, it ranged from 1.98 to 9.92 mm with an average of 5.58 ± 1.66 mm (Table 5). Sekiguchi *et al.,* (2004) reported a mean distance of 6 ± 1.9 mm ranging from 1.9 to 11.4 mm. These findings were consistent with the present study. In the present study, anteroposterior diameter of the sacral canal at the apex of the hiatus was less than 2 mm in 1% sacra (Table 7). Sekiguchi *et al.,* (2004) reported that the diameter of the sacral canal was less than 2 mm in 1% of sacral bones, hence impeding the use of 22G needles for caudal epidural block. This was similar to the present study. Senoglu *et al.,* (2005) and Aggarwal *et al.,* (2009) in their series found diameter of less than 2 mm in 6.25% and 8.7% cases respectively. This was much higher when compared to the present study.

Table 6: Showing the incidence of length of sacral hiatus, intercornual distance and distance between caudal end of median sacral crest and apex of sacral hiatus

	Parameter		
Distance (mm)	**Length of sacral hiatus No (%)**	**Intercornual distance No (%)**	**Distance between caudal end of median sacral crest and apex of sacral hiatus No (%)**
0 - 4.9	-	-	12 (12.5%)
5 - 9.9	1 (1%)	2 (2.1%)	26 (27.1%)
10 - 14.9	8 (8.3%)	28 (29.2%)	27 (28.1%)
15 - 19.9	29 (30.2%)	51 (53.1%)	22 (22.9%)
20 - 24.9	17 (17.7%)	12 (12.48%)	7 (7.3%)
25 - 29.9	15 (15.6%)	3 (3.12%)	2 (2.1%)
30 and above	26 (27.1%)	-	-

Table 7: Showing incidence of AP diameter of the sacral canal at the apex of the hiatus

Parameter	**Distance (mm)**	**No (%)**
Antero posterior diameter of sacral canal at the apex of the hiatus.	0 - 1.9	1 (1%)
	2 - 3.9	10 (10.4%)
	4 - 5.9	49 (51%)
	6 - 7.9	29 (30.2%)
	8 and above	7 (7.3%)

Distance between apex of sacral hiatus and the level of S2 foramen is important because in adults duramater and arachnoid end at the level of the second sacral vertebra. Hence this distance decides the length of the needle that can be safely introduced into the canal. In the present study this distance ranged from 0 to 55.20 mm with a mean distance of 32.16 ± 12.96 mm (Table 5). Aggarwal *et al.,* 2009, reported a mean distance of 30.16 ± 14.07 mm ranging from 2 to 135 mm. In the present study, the lower limit reported was 0 mm as 5 sacra had the apex of the hiatus at S2 thus indicating danger of dural puncture. No other study reported similar finding.

According to Sekiguchi *et al.,* (2004) the median sacral crest can be used as an alternate bony landmark for reaching the sacral hiatus. Sacral hiatus is felt as a dimple when the median sacral is palpated towards caudal direction. In the present study distance between the caudal end of the median sacral crest and the apex of the sacral hiatus ranged from 2.06 to 26.62 mm with an average of 11.76 ± 5.75 mm (Table 5). The distance was more than 10 mm in 60.4% cases (Table 6). Aggarwal *et al.*, (2009) reported an average distance 12.35 mm ranging from 2 to 25.70 mm which was almost similar to the present study. Sekiguchi *et al.*, (2004), reported that in 49% cases, this distance was more than 10 mm and hence it cannot be used as a landmark.

Triangle formed between the two posterior superior iliac spines and the apex of the sacral hiatus had equilateral features in the present study and this can be used as an important landmark to locate the hiatus. The mean values of the three sides of the triangle i.e. base, right margin and the left margin were 64.96 ± 5.43 mm, 62.65 ± 9.62 mm and 62.33 ± 9.92 mm (Table 5). The average values of the angles between the margins of the triangle formed by the two lateral crests and the sacral hiatus were 57.26 ± 6.73^{o} on right and 58.64 ± 7.02^{o} on left, which also suggested that the triangle (Table 5).

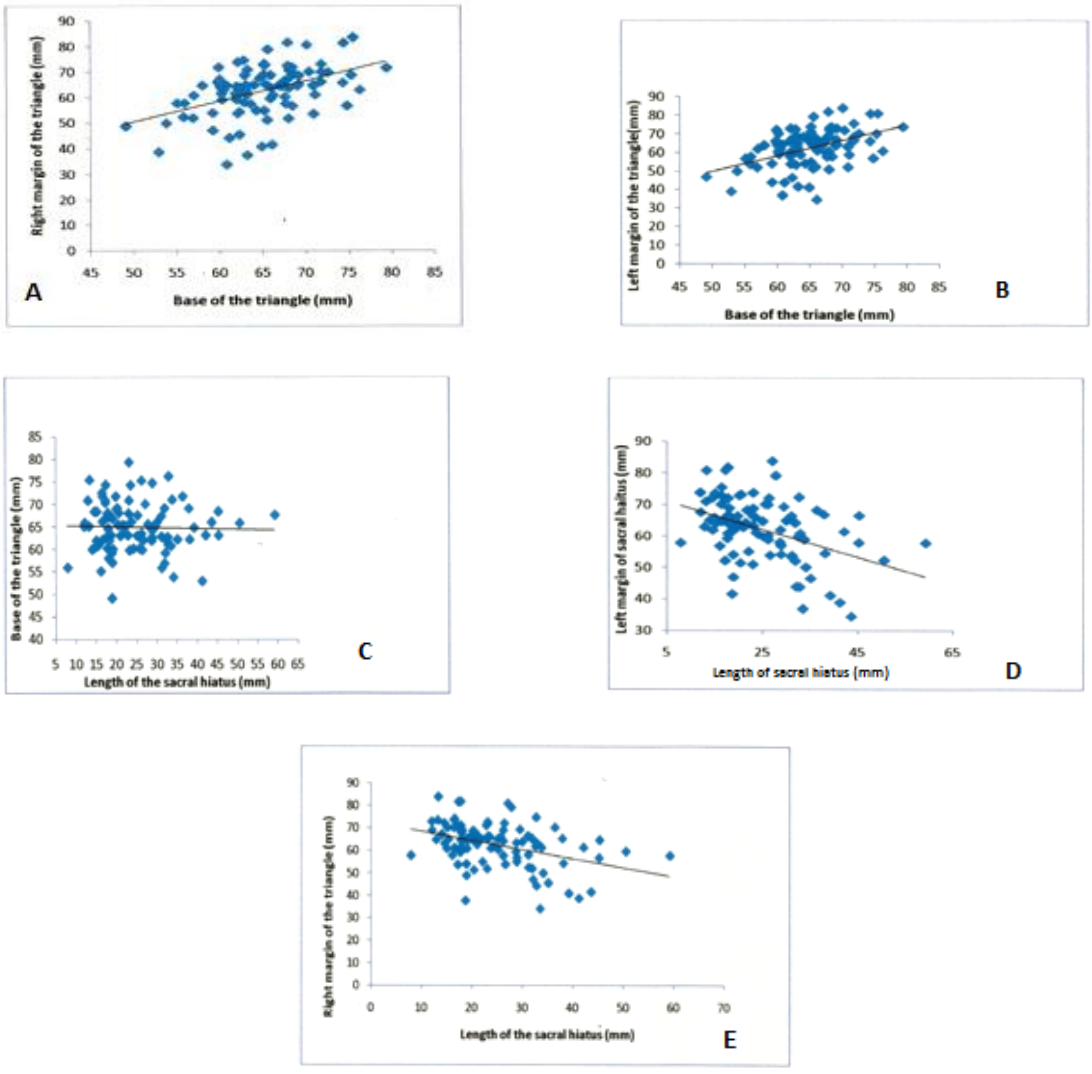

Figure 3: Scatter Diagrams
Diagram A and B are showing association of the bas of the triangle with the right and left margins base of the triangle with the right and left margins of the triangle respectively.
Diagrams C, D and E are showing association of the length of the sacral hiatus eith the base, left margin and right margin of the triangle respectively.

These values were nearly equal and hence formed an equilateral triangle. Senoglu *et al.,* (2005) reported the mean values of the three sides to be 66.51 ± 53.52 mm, 67.10 ± 9.95 mm and 67.53 ± 9.48 mm. The average values of the angles between the margins of the triangle formed by the two lateral crests and the sacral hiatus were 61.89 ± 4.81^{o} on right and 61.22 ± 4.79^{o} on left. These findings were similar to the present study. Aggarwal *et al.,* (2009) however reported the mean values of the three sides to be 50.96 ± 6.69 mm, 59.92 ± 8.84 mm and 59.99 ± 8.31 mm. They found equilateral triangle formation only in 45% cases. In remaining 55% cases, right and left sides were much shorter than the base. In the present study, Karl Pearsons correlation test and figure 3A and 3B showed moderate positive correlation between the base of the triangle and the right and the left margins of the triangle and it was statistically significant (r = 0.458 on right, r = 0.451 on left, p = 0.000, correlation is significant at the 0.01 level 2 tailed). The length of the sacral hiatus had a negative correlation with the base, right and left margin of the triangle (base: r = - 0.029, p = 0.777, insignificant correlation; left - 0.422, right - 0.394, p = 0.000, correlation significant at 0.01 level two tailed) (Figure 3C, 3D and 3E). Aggarwal *et al.,* (2009) reported strong positive statistical correlation between the base of the triangle and the margins of the triangle. However they found the length of the hiatus had a positive correlation with the base and margins of the triangle.

Conclusion

In the present study, the majority of sacra studied conformed towards a successful caudal epidural block, in terms of sacral composition, shape of the hiatus, level of the apex of the sacral hiatus, level of the base of the sacral hiatus, length of the sacral hiatus, intercornual distance, AP diameter of the sacral canal at the apex of the hiatus and the equilateral nature of the triangle formed between the two posterior superior iliac spines and the apex of the sacral hiatus. The two parameters that were not favourable towards performing successful caudal epidural block were study of sacral cornua and the distance between the caudal end of median sacral crest and the apex of the hiatus. This can be kept in mind while giving caudal epidural block in West Indian population. Ethnic differences may be the probable reason for the difference in the features and morphometrical measurements of the sacral hiatus as reported in different studies. To best of our knowledge, studies documented of this kind on dry human sacra of West Indian population are very few. The findings of the present study will be helpful to the anaesthetists and researchers as ready references to locate the sacral hiatus and to know the possible causes for the failure of caudal epidural block.

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