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Research Article

Morphological and Morphometric study of carotid canal in Indian Population

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Abstract

Aim: To study the morphological details and analyse the morphometry of the External Aperture of carotid canal (AECC) in the base of dry human skulls of mainly Indian population.

Methods: 82 dry adult human skulls of unknown sex and of South Indian origin were obtained and variations in appearance of AECC were observed. The length and width of the AECC of both sides were determined using vernier calipers and area (A) was calculated and analyzed. Also measurements were made between certain chosen landmarks on both the sides and analyzed.

Results: The values for the right side were 8.12 ± 0.99 mm, 6.31 ± 0.64mm and 40.61 ± 7.79 mm^2 and for the left side the values were 8.15 ± 1.00 mm, 6.19 ± 0.80 mm and 40.032 ± 8.10 mm^2 respectively, for the mean length, width and area of the AECC. Also, the shape of AECC was typically round in most of the skulls studied (51.83%).

Conclusion: By analyzing the length, width and area of AECC on both the sides, there was no statistical difference and the values were comparable with the studies done in the past.

Keywords: Carotid canal, Morphology, Morphometry, Skull, Sphenoid

1. Introduction

The carotid canal or canalis caroticus (CC) is a large, almost circular foramen through the petrous part of the temporal bone or os temporale and it transmits the large vessel internal carotid artery (ICA) or arteria carotis interna (ACI) with accompanying plexuses of veins and some autonomic nerves. The external aperture of the carotid canal or apertura externa canalis carotici (AECC) is found on the lower surface of the pars petrous of the os temporale, postero-lateral to the foramen lacerum and antero – lateral to the jugular foramen.[1,2]

Beginning from the AECC, the carotid canal runs upward for a distance of 1 cm and then bending on itself at almost a right angle, the canal turns forward and medially, directed up to the apex of the petrous part of the temporal bone for about 2-3 cm and comes to an end, forming the internal aperture of the carotid canal or apertura interna canalis carotici (AICC). This opening is found in front of the foramen lacerum and the internal carotid artery enters the cranial cavity intracranially. The arteria carotis interna is separated from the CC walls by perivascular tissues and the plexus venous caroticus internus.[3]

Basilar cranial fractures have been associated with injury to the carotid artery and vascular complications are more frequently observed when there is involvement of the carotid canal. Fracture through the petrous segment of the carotid canal is associated with a relatively high incidence of internal carotid injury and patients suffer more severe head injuries.[4]

Agenesis, aplasia, or hypoplasia of the internal carotid artery (ICA), are rare congenital developmental anomalies, occurring in less than 0.01% of the population.[5,6,7] However, agenesis of internal carotid artery is usually asymptomatic and is often detected as an incidental finding or after a cerebrovascular event, such as subarachnoid haemorrhage after rupture of a coincidental aneurysm or cerebral infarct.[8,9] This is commonly seen unilateral, however bilateral absence have been reported.[10,11] Also, the estimated prevalence of cerebral aneurysms in association with absence of ICA is 24% to 34% in the general population and recognition of this anomaly becomes important in cases of thromboembolic disease.[5] Though the exact cause of these developmental anomalies is not known, evaluation of the skull base for the presence or absence of the carotid canal may be required for distinguishing aplasia from agenesis, as presence of the ICA (or its precursor) is a prerequisite for development of the carotid canal at five to six weeks of gestation and this bony carotid canal development represents internal carotid artery (ICA) development which may stop with the beginning of ICA stenosis[12] and hypoplastic bony carotid canal can be seen in patients with adult onset moyamoya disease.[13]

Measurements of the adult skull base have been performed by only a few investigators.[14,15,16,17] Prenatal study of CC demonstrated that, it transmits the ACI within its internal curvature and the antero-inferior wall of the CC is occasionally missing, just like the auditory tube, which is not a closed tube.[18] Some previous researchers have studied the AICC,[19] while some have also measured the adult CC size together with angular measurements of its internal bend[14]. Imaging techniques such as computerized tomography (CT) and magnetic resonance tomography (MRT) have revealed many normal and pathological findings of the foramina of the skull. Microsurgery is being employed for aneurysms, clival tumours etc and therefore, precise knowledge of the skull base anatomy has become vital.[17]

In one of our recent studies concerning the assessment of skull asymmetries, the importance of skull base foramina measurements has become apparent.[20] The present study was planned to inform neurosurgeons and neuroradiologists about the comparative measurements of skull base. The 'CC' was chosen as the landmark since it is the most vital and the most easily visualized structure on MRT angiography and digital subtraction angiography (DSA). So with reference to ICA and their associated anomalies, we intent to give population specific details of the carotid canal which would assist neurosurgeons to improve different surgical approaches to the petrous part of the internal carotid artery.

2. Materials and Methods

The materials for the present study included 82 dry adult human skulls of unknown sex and of Indian origin obtained from Bone bank of the Department of Anatomy, Srinivas Institute of Medical sciences, Karnataka state, India. The external aperture of the carotid canal or apertura externa canalis carotici (AECC) is found on the lower surface of the pars petrous of the os temporale, postero-lateral to the foramen lacerum and antero – lateral to the jugular foramen. Patency was confirmed by inserting a probe through each. Skulls in poor conditions or skulls with partly damaged surroundings of the foramen ovale were not considered.

The antero-posterior diameter (Length) or "L" & perpendicular to this, transverse diameter (width) or "W" of the AECC of both sides are determined using Digital vernier callipers with a precision of 0.1 mm. Each dimension was measured thrice and the mean figure recorded. The data collected was checked for errors prior to analysis. From these obtained values area "A" of the external aperture of the carotid canal was calculated using the formula: $(\pi \times L \times B) / 4$ or $(3.142 \times L \times B) / 4$.[21]

Also, in the present study mean values (Mean ± Standard Deviation) for other parameters like, distance from the medial end of AECC to mid-sagittal plane (A), distance from the lateral end of AECC to mid-sagittal plane (B) & distance from the lateral end of AECC to posterior end of the root of the zygoma (C), on both sides were obtained in millimetres.[22]

Data analysis of the obtained values was analysed statistically using SPSS software version11.5 for windows. The mean and standard deviation (SD) of each dimension were computed. Right and left differences were analysed. A comparison was made of the means of the dimensions using the Student's t-test and p value less than 0.05 was considered statistically significant.

In various studies, the horizontal part of the carotid canal was named 'pars petrosa ascendens' and the second transverse portion 'pars petrosa transversalis'. Formal names of these parts could not be found in Nomina Anatomica.[15] Since our measurements were performed extracranially, measurements of the pars petrosa ascendens and pars petrosa transversalis were not included.

3. Results

3.1 Morphology of AECC

The external aperture of the carotid canal or apertura externa canalis carotici (AECC) is found on the lower surface of the pars petrous of the os temporale, postero-lateral to the foramen lacerum and antero – lateral to the jugular foramen. The present study was conducted on a total of 164 sides in 82 dry adult skulls and various shapes of carotid canal were observed. The shape of the carotid canal was typically round in 85 sides (Fig.1, arrow; Table-1; 43 right, 42 left), oval in 50 sides (Fig 2, arrow; Table-1; 22 right, 28 left) and almond shape in 28 sides (Fig.3, arrow; Table-1; 17 right, 11 left) . Also, the carotid canal was absent in 1 skull on left side only (Fig 4, arrow).

Fig1. Photograph of adult human skull showing Round shaped carotid canal

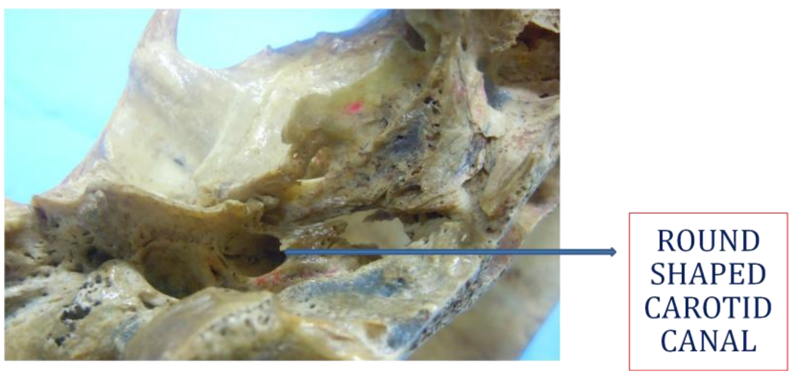


Table 1: Variations in the appearance of external aperture of the carotid canal

Shape	Right (n= 82)	Left(n= 81)	Total(n= 163)
Round	43 (52.43%)	42 (51.85%)	85 (52.14%)
Oval	22 (26.82%)	28 (34.56%)	50 (30.67%)
Almond	17 (20.73%)	11(13.58%)	28 (17.17%)

Fig 2: Photograph of adult human skull showing Oval shaped carotid canal

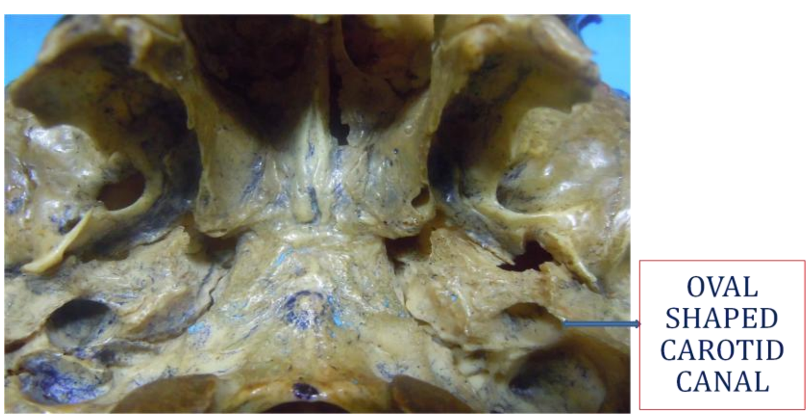


Fig 3: Photograph of Adult human skull showing almond shaped carotid canal

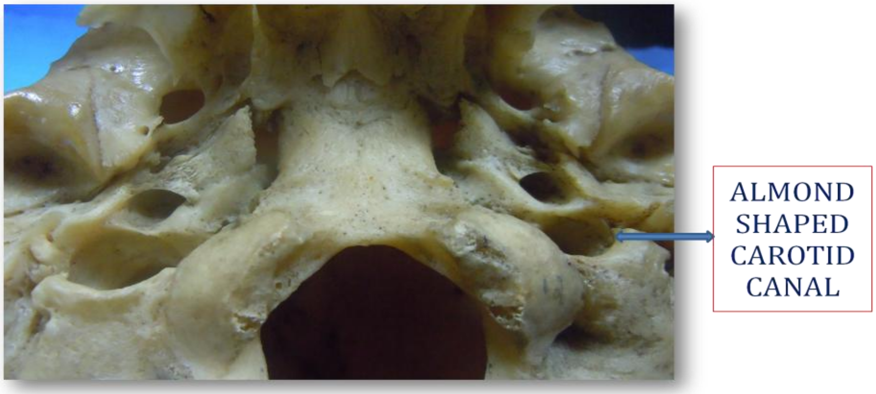
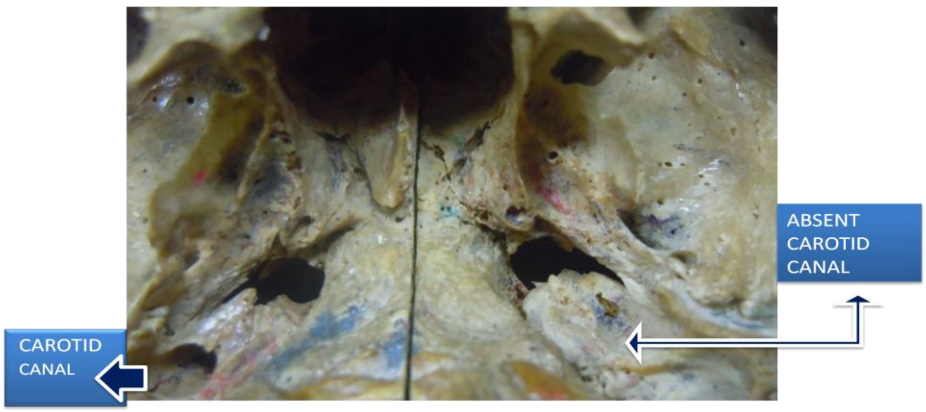


Fig 4: Photograph of adult human skull showing absent carotid canal on left side.



Also typically round shaped external aperture of the carotid canal was observed in 21 sides bilaterally & bilateral oval shape was observed in 11 sides and the incidence of round, oval and almond shaped carotid canal observed in our study were 52.14%, 30.67% and 17.17% respectively (Table 1).

3.2 Morphometry of AECC

The maximum antero-posterior diameter (length) of AECC on right and left sides of skull with its frequency distribution is noted (Table 2). The values range from 6 to 10 mm on the right side & 6.5 to 10.5 mm on the left side respectively. Likewise, the maximum transverse diameter (width) of AECC of both sides with its frequency distribution is also noted. On the right side, the range is from 5 to 8mm, while on the left side values ranges from 5 to 8.5mm respectively (Table 3). Maximum and minimum lengths observed were 10.0 mm, 6.0 mm and 10.5 mm, 6.5 mm on right and left sides respectively (Table 2) and similarly, maximum and minimum transverse diameters observed were 8.0 mm, 5.0 mm, and 8.5 mm, 5.0 mm on right and left sides respectively (Table 3).

Table 2: Antero-posterior Diameter (Length) Of Carotid canal (mm)

Antero-posterior diameter (mm)	Frequency Distribution	
	Right	Left
6	03	00
6.5	00	04
7	12	08
7.5	12	14
8	17	16
8.5	14	19
9	11	08
9.5	10	08
10	03	04
10.5	00	01

Table 3: Transverse Diameter (Width) of Carotid canal (mm)

Transverse diameter(mm)	Frequency	
	Right	Left
5	02	08
5.5	10	16
6	33	29
6.5	17	09
7	11	11
7.5	06	05
8	03	03
8.5	00	01

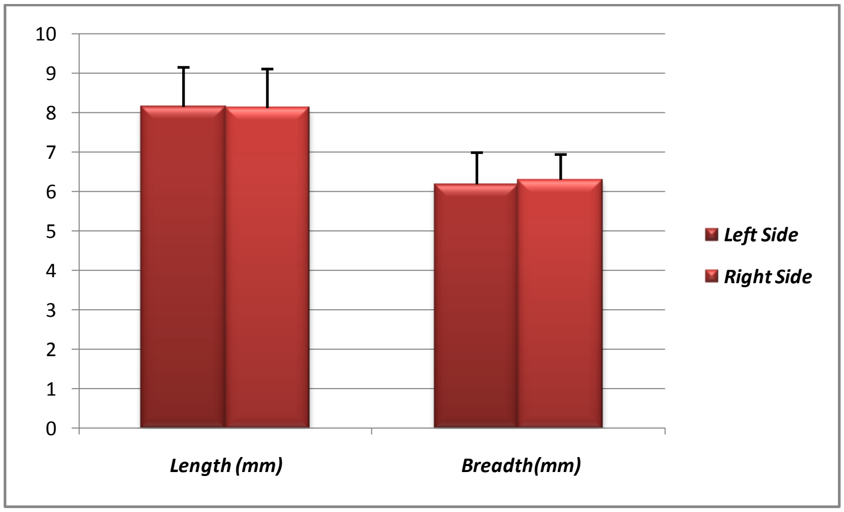
Mean of the antero-posterior & transverse diameters were obtained in millimetres (Mean ± Standard Deviation). In the present study the mean antero-posterior diameter of the AECC was 8.12 ± 0.99 mm on right side and 8.15 ± 1.00 mm on left side (Table 4; Fig 5a) and the difference between the mean length of right and left sides were not statistically significant (Table 4).

Table 4: Mean, Standard deviations (SD), t and P values for AECC – Side comparative results.

Parameters	Right Side (N = 82)	Left Side (N = 81)		
	Mean ± SD	Mean ± SD (mm)	t	p
Length{(L) in mm}	8.128 ± 0.990	8.158 ± 1.002	0.196	0 .845
Breadth{(B) in mm}	6.310 ± 0.641	6.195 ± 0.804	1.020	0. 309
Area {(A) in mm^2}	40.613 ± 7.793	40.032 ± 8.100	0.469	0.640

$P \leq 0.05$ is considered as significant value

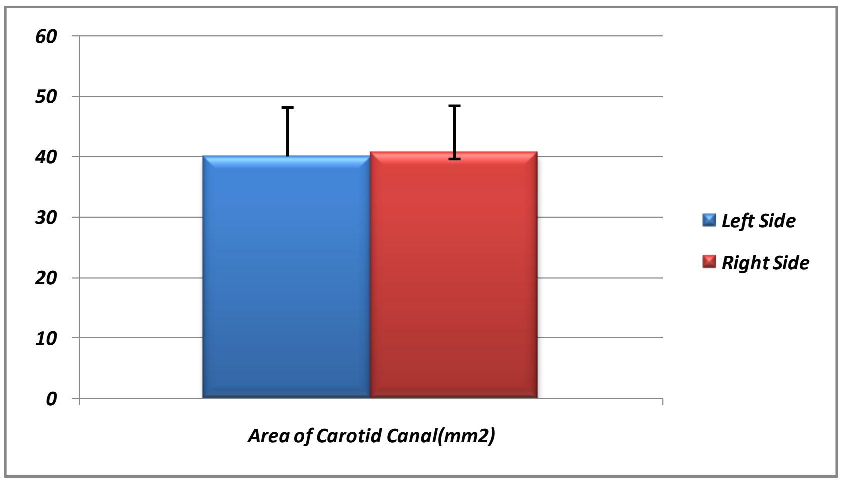
Fig 5a: Bar diagram showing Length {(L) (in mm)}, Breadth {(B) (in mm)} of Carotid Canal on both sides of skull.



The values are expressed as Mean± SD.

Also the mean transverse diameters of AECC on right and left side were 6.31 ± 0.64mm and 6.19 ± 0.80 mm respectively. These values were analysed statistically and there was no significant difference between the values obtained on the both sides. The mean area (A) of the AECC on the right was 40.61 ± 7.79 mm^2 and that on the left side was 40.032 ± 8.10 mm^2 (Table 4; Fig 5b) and there was no statistically significant difference between them (Table 4).

Fig 5b: Bar diagram showing Area {(A) (in mm^2)} of Carotid Canal on both sides of skull



The values are expressed as Mean± SD.

Also the values for other parameters like, the distance from the medial end of AECC to mid-sagittal plane (A), distance from the lateral end of AECC to mid-sagittal plane (B) & distance from the lateral end of AECC to posterior end of the root of the zygoma (C), on both sides were obtained in millimetres.[22] These values were 25.4 ± 0.25 & 24.9 ± 0.25 on right and left sides for parameter A, 32.0 ± 0.274 & 31.7 ± 0.23 on right and left sides for parameter B and 30.9 ± 0.22 & 30.7 ± 0.20 on right and left sides for parameter C respectively (Table 5).

Table 5: Mean & Standard deviations (SD) for AECC parameters (mm)

Parameters	Right Side (N = 82)	Left Side (N = 81)
	Mean ± SD	Mean ± SD (mm)
A	25.42 ± 0.250	24.97 ± 0.250
B	32.04 ± 0.274	31.78 ± 0.238
C	30.96 ± 0.229	30.78 ± 0.205

A=Distance from medial end of the AECC to mid –sagittal plane
B=Distance from lateral end of the AECC to mid –sagittal plane
C=Distance between the Lateral end of the AECC & Posterior end of the root of the zygoma
$P \leq 0.05$ is considered as significant value.

4. Discussion

The internal carotid artery originates in the common carotid artery in the neck and ascends toward the brain. It has cervical, petrous, cavernous, and cerebral portions. The internal carotid artery enters the carotid canal in the petrous portion of the temporal bone and that the cavernous port of the internal carotid artery lies within the cavernous sinus.

Congenital absence of one or both internal carotid arteries (ICA) has a high association with circle of Willis aneurysm formation and since the carotid canals in the skull base form secondary to the presence of the embryonic ICA, absence or hypoplasia of a carotid canal on a computed tomographic (CT) scan through the skull base should suggest a congenital ICA abnormality and prompt a search for associated intracranial vascular abnormalities even in a young or asymptomatic patient.[12]

So this study was conducted to provide information on the bilateral morphological differences in the vascular opening for the internal carotid artery i.e., carotid canal, in the floor of the skull. In relevance to ICA, carotid canal measurements and their importance have been estimated by various authors previously with intent to improve different surgical approaches to the petrous part of the internal carotid artery.[23, 24]

The bony carotid canal developed rapidly before approximately 2 years of age and after fusion of the bony suture, the bony carotid canal developed slowly.[15] Also, the bilateral absence of the anteroinferior wall of CC was reported for the first time in 1896.[18] The absent or deficient inferior wall of CC is an important variation that can give rise to complications through skull base surgery.[15-17,25] Previous studies have reported absence of inferior wall of CC, which was only one among 325 cases,[26] while in another study, 5 cases of deficient inferior wall was found among 307 skulls.[22] In such cases, the ACI is found in a sulcus and in one case, this sulcus was not 'S' shaped but placed straight, near the corpus of the ossphenoidale.[14,15] However in the present study, the inferior wall of carotid canal was deficient in 1 skull on left side only.

In the present study, the maximum antero-posterior diameter (length) of the apertura externa canalis carotici (AECC) was 10.5 mm and the minimum antero-posterior diameter (length) was 6 mm. Likewise, the maximum and minimum transverse diameter (width) of AECC was 8.5 mm and 5mm respectively. Also, the mean antero-posterior diameter of AECC was 8.13 ± 0.99 mm and 8.16 ± 1.00 mm (mean ± SD) on right and left side, where as the mean transverse diameter of AECC in right and left side was 6.31 ± 0.41mm and 6.20 ± 0.80 mm respectively.

The carotid canal measurements are noted in the previous studies like Arata *et al*[13].,and the transverse diameter in normal Japanese adults was 5.27 ± 0.62 mm (mean ± SD), whereas it was less (3.31 ± 0.44 mm) in the patients with adult-onset moyamoya disease with ICA stenosis. Also Calguner *et al*[22]., obtained measurements of carotid canals from 307 dry skulls including 177 adult male and 130 adult females skulls respectively and the values of the mean antero-posterior diameter of the carotid canal were 6.82 ± 1.56 and 6.50 ±1.46 (Mean ± SEM) in right and left sides of male skull where as in case of female skulls, these values were 6.68 ± 1.18 and 6.30 ± 1.05 (Mean ± SEM) respectively. Also, the mean transverse diameter on right and left side of male skulls were 4.86 ± 2.34 and 4.60 ± 1.05 (Mean ± SEM) and in case of females these values were 4.59 ± 0.87 and 4.33 ± 0.91 (Mean ± SEM) respectively. In another study by Lang and Schreiber,[16] the mean antero-posterior diameter of the carotid canal were 5.08 ± 0.20 and 5.20 ± 0.34 (Mean ± SEM) in right and left sides of the skulls respectively. However, in both these previous studies the measurements of the antero-posterior (long) diameter and transverse (short) diameter of apertura interna canalis carotici (AICC) or the internal aperture of the carotid canal was taken where as in the present study the values of external aperture of the carotid canal or apertura externa canalis carotici (AECC) are noted which have not been noted in any previous studies.

The mean area of apertura externa canalis carotici (AECC) calculated in the present study was 40.61 ± 7.79 mm^2 and 40.03 ± 8.10 mm^2 on right and left sides respectively and in a previous study, the mean combined area of AECC in adult male skulls was 57.14 mm^2 & 44.46 mm^2in case of female skulls[21].

Also, in the present study mean values (Mean ± Standard Deviation) for other parameters like, distance from the medial end of AECC to mid-sagittal plane (A), distance from the lateral end of AECC to mid-sagittal plane (B) & distance from the lateral end of AECC to posterior end of the root of the zygoma (C), on both sides were obtained in millimetres. These values were 25.4 ± 0.25 & 24.9 ± 0.25 on right and left sides for parameter A, 32.0 ± 0.274 & 31.7 ± 0.23 on right and left sides for parameter B and 30.9 ± 0.22 & 30.7 ± 0.20 on right and left sides for parameter C respectively. In a previous study by Calguner *et al*[22]., the values of the distance from the medial end of AECC to mid-sagittal plane (A) is 25.01 ±3.59 & 24.92± 2.45 in left and right sides for females and 25.63±3.60 and 25.67 ± 2.88 in left and right sides for males. Also in other study by Lang et al.,[15] these values were 20.50 ± 0.50 and 24.25 ± 0.75 in left and right sides respectively. Similarly the distance from the lateral end of AECC to mid-sagittal plane (B) is 30.41± 2.96 & 30.47± 2.70 in left and right sides for females and 31.53± 2.99 & 31.33 ± 2.64 in left and right sides for males[22] and in another study, these values were 28.25± 0.75 & 32.25 ± 0.75 in left and right sides respectively.[15]

5. Conclusion

From the present study we could see that the shape of AECC was typically round in 52.14% (85 in 163 sides) and absent in left side of one skull only (1 in 164 sides). By analyzing the length, width and area of AECC on both the sides, there was no statistical differences and the values were comparable with the studies done in the past.The knowledge of the anatomical features and information about the precise distance of the carotid canal from various landmarks encountered throughout skull base surgery, is very vital for the surgeons and neurosurgeons performing various skull base surgeries ranging from carotid angiograms, hematomas, Aneurysms etc and also for recent advances like biopsy of brainstem lesions etc for various clinical interventional procedures.

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