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Original Article

A STUDY OF MORPHOLOGY, MORPHOMETRY, SYMMETRY AND DEVELOPMENT OF EXTERNAL OPENING OF CAROTID CANAL WITH COMPARISON IN MALE, FEMALE AND FOETUS

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ABSTRACT

Introduction: The Carotid Canal is an important structure at the base of skull as it conveys the internal carotid artery, along with a sympathetic nerve plexus and a venous plexus. Previous researches done on carotid canal suggest that abnormalities to this canal, such as fractures of carotid canal and carotid sympathetic plexus schwannoma have their effect on the internal carotid artery and the structures passing through it. Cases of absence of carotid canal have also been reported, which causes variations of the internal carotid artery. Attempt has been made in this study to give a detailed view of the 'external opening of carotid canal' (EOCC) which is the gateway of the carotid canal at the skull base. This study shall be useful for Surgeons, Radiologists, Anatomists, Forensic Experts, Anthropologists, etc.

Aim: This study aims at measuring the various dimensions of the external openings of the carotid canal pair present at the base of skull, and to observe the age changes, sexual dimorphism, and symmetry of the external opening of the carotid canal from the analysis of these measurements.

Materials and methods: Total 235 dry skulls that included 181 adolescent to adult skulls of known age and sex (age ranging from 13 years up to old age skulls of 60 years or above) and 54 foetal skulls were studied for this purpose. The longest & shortest diameter of each carotid canal, was measured using a screw adjusted compass and a Vernier Calliper. Their distance from pharyngeal tubercle and from the X axis and Y axis was measured.

Observations and Results: In the present study, it was observed that external opening of each carotid canal was unique in its morphology and morphometry. The dimensions of external opening of carotid canal progressively increased from foetal age to 25 years of age, however after 25 years of age, it did not show any age change within same sex, but it showed age changes when adolescent female skulls of age less than 25 years were compared with adult male skulls of age above 25 years. It was also observed that the external opening of carotid canal showed sexual dimorphism when compared within same age group (that is, between adolescent male and female skulls below 25 years age, and between adult male and female skulls above 25 years age. Further it was also observed that EOCC did not show any asymmetry in foetal age, however it showed asymmetry in female skulls below age 25 years (adolescent).

KEY WORDS: External opening of carotid canal, Dimensions, Morphology, Morphometry, Symmetry, Age changes, Sexual Dimorphism, Variations.

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INTRODUCTION

The external opening of Carotid Canal (EOCC) continues as the carotid canal stretching up to Foramen Lacerum (FL) anteromedially. The EOCC is sometimes separated from jugular foramen by only a thin plate of bone.

The Internal Carotid Artery (ICA) along with the sympathetic carotid plexus of nerves and a venous plexus enters the EOCC, ascend in the carotid canal, and turns anteromedially to reach the posterior wall of the FL [1,2,3]. As the EOCC transmits the above mentioned important structures, this study of EOCC will thus be of great help. Previous researchers who have studied the carotid canal, suggest that the anomalies of the carotid canal cause their effect on the ICA these anomalies can occur due to genetic defect, due to diseases or due to accidental traumas. This study, involves the assessment of morphometry, morphology, symmetry, sexual dimorphism and age changes in the pair of EOCC in different skulls ranging from foetal to old age and of male and female sex.

Aim: There are three aims of this study;

1. To study the age changes in EOCC from foetal to adult age.

2. To find out whether there is any sexual dimorphism present in the EOCC.

To analyse the symmetry of the pair of EOCC in each skull.

MATERIALS AND METHODS

Total 235 dry skulls (including adult and foetal) were studied for this purpose. The skulls studied were categorised into five groups. First group included foetal skulls and it was labelled as 'A' group. Second and third group consisted of skulls of known sex and of age between 13 years to 25 years. The second group was labelled as 'B-f' for female skulls of age 13 to 25 years, and the third group was labelled as 'B-m' for male skulls of age 13 to 25 years. The fourth and fifth groups consisted of skull of known sex and of age 25 years and above (including old age skulls). The fourth group was labelled as C-f for female skulls of age 25 years and above, and the fifth group was labelled as C-m for male skulls of age 25 years & above. The dimensions of each EOCC were measured by using a screw adjustable pair of compass. The reading on the compass was then measured by a Vernier Calliper. The readings were taken twice and the average was taken as final reading. The base of each skull (norma basalis) studied, was photographed for reference by using a digital camera. The readings taken were tabulated and analysed statistically. Statistical calculations were done with the help of statistical software, the 'two tailed' Two-sample 't test' for independent and correlated samples was used for this study, and a significance level more than 95% ($p<0.05$) was considered significant.

At First, the longest diameter (LD) and shortest diameter (SD) of Right & left EOCC present in each was measured. For determining the symmetry in a given pair of EOCC, the distance of each EOCC from midline was measured. For this purpose, X and Y axis was marked on the skull. The X axis was parallel to the coronal line, it passed through the pharyngeal tubercle (PT) and extended up to the posterior wall of mandibular fossa on either sides. Depending upon the age, size and shape of the skull, the X-axis either passed anteriorly to the EOCC, touched the EOCC tangently, or passed through it. In cases where the X-axis passed through the EOCC, the values of the measurements were taken as negative (i.e. in minus). The Y axis coincided with the midsagittal line, it crossed the X axis, perpendicularly at the PT. It passed from the middle of basi-occiput, extending posteriorly up to the external occipital crest (passing through Foramen Magnum as an imaginary line, it is marked out in the foramen magnum by placing a thread of calibre 0.01mm congruently along the Y-axis), and anteriorly up to the centre of vomero-vaginal canal. The distance of each EOCC, was measured from the Y Axis, the X Axis and the PT, and the measurements were labelled as 'DY', 'DX' and 'DPT' respectively. These measurements were used to locate the exact position of the EOCC with respect to X and Y axis and midpoint, and thus to know the symmetry of each EOCC.

The orientation of the LD of EOCC with respect to the Y Axis was different for each EOCC. Sometimes the LD was almost parallel to the Y-axis, and sometimes it was almost perpendicular to the Y-axis. To know this pattern, the angle of LD with Y-axis was measured for each EOCC and compared in foetus and adults and in males and females. The measurements were statistically analysed, readings are enlisted in tables given below.

OBSERVATIONS AND RESULTS

Part 1: The first part of the observation contains the group wise tabulation of all the morphometric and morphological dimensions of each EOCC studied. The mean, minimum value, maximum value, variance and standard deviation of all the measurements of each group are enlisted as below. Separate tables are used for left and right EOCC of each group.

Table 1.1: Left EOCC

Group A	LD	SD	DY	DX	DPT	Angle
Mean	0.257	0.176	0.939	0.26	0.983	51.4
Minimum	0.072	0.045	0.241	0	0.273	18
Maximum	0.639	0.348	2.28	1.712	2.3	69.5
Std. Dev	0.125	0.087	0.415	0.259	0.428	17.92

Table 1.2: Right EOCC

Group A	LD	SD	DY	DX	DPT	Angle
Mean	0.237	0.178	0.929	0.208	0.979	53.7
Minimum	0.069	0.061	0.256	0	0.271	20
Maximum	0.594	0.451	1.91	0.674	1.91	88
Std. Dev	0.12	0.093	0.386	0.138	0.939	18.83

Table 1.3: Left EOCC

Group B-f	LD	SD	DY	DX	DPT	Angle
Mean	0.698	0.508	2.431	0.022	2.449	68.8
Minimum	0.516	0.392	1.932	-1.145	1.932	47
Maximum	0.819	0.64	2.831	0.5	2.886	89
Std. Dev	0.069	0.062	0.261	0.322	0.256	10.05

Table 1.4: Right EOCC

Group B-f	LD	SD	DY	DX	DPT	Angle
Mean	0.7	0.542	2.375	0.041	2.406	66.5
Minimum	0.471	0.415	2.044	-0.64	2.044	31
Maximum	0.843	0.639	2.819	0.583	2.819	86
Std. Dev	0.089	0.061	0.224	0.291	0.231	13.35

Table 1.5: Left EOCC

Group B-m	LD	SD	DY	DX	DPT	Angle
Mean	0.747	0.523	2.502	-0.034	2.461	67.9
Minimum	0.493	0.3	1.679	-0.538	0.243	36.5
Maximum	1.031	0.715	3.516	0.46	3.46	95
Std. Dev	0.118	0.086	0.367	0.242	0.469	12.42

Table 1.6: Right EOCC

Group B-m	LD	SD	DY	DX	DPT	Angle
Mean	0.745	0.527	2.43	-0.007	2.447	72.1
Minimum	0.538	0.4	1.743	-0.507	1.743	43
Maximum	0.957	0.651	3.198	0.451	3.203	93
Std. Dev	0.098	0.064	0.257	0.232	0.335	10.34

Table 1.7: Left EOCC

Group C-f	LD	SD	DY	DX	DPT	Angle
Mean	0.726	0.525	2.429	0.002	2.468	72
Minimum	0.358	0.3	2.011	-0.5	2.022	52.4
Maximum	0.932	0.683	3.112	0.561	3.2	90
Std. Dev	0.103	0.081	0.262	0.261	0.281	9.82

Table 1.8: Right EOCC

Group C-f	LD	SD	DY	DX	DPT	Angle
Mean	0.72	0.53	2.368	0.026	2.41	74.7
Minimum	0.46	0.37	1.752	-0.3	1.763	50
Maximum	1.044	1.1	3.325	0.448	3.325	95
Std. Dev	0.105	0.123	0.283	0.199	0.279	10.99

Table 1.9: Left EOCC

Group C-m	LD	SD	DY	DX	DPT	Angle
Mean	0.751	0.546	2.474	0.017	2.488	70.8
Minimum	0.549	0.336	0.741	-0.527	0.741	45
Maximum	1.077	0.7	3.516	1.213	3.1	95
Std. Dev	0.088	0.08	0.308	0.276	0.304	8.68

Table 1.10: Right EOCC

Group C-m	LD	SD	DY	DX	DPT	Angle
Mean	0.762	0.533	2.431	-0.075	2.471	69.6
Minimum	0.549	0.347	1.9	-4	1.954	48
Maximum	1.033	0.718	3.28	1.257	3.3	93
Std. Dev	0.105	0.08	0.261	0.542	0.259	10.63

Photo 1: Adult skull Showing the right and left EOCC, Y-AXIS, X-AXIS, PT and the line showing the angle of LD with Y-axis (Note: the Y & X Axis are marked on the actual Skull by a pencil, the dotted white line passing through Foramen magnum indicates the continuation of Y axis as an imaginary line through the foramen magnum.)

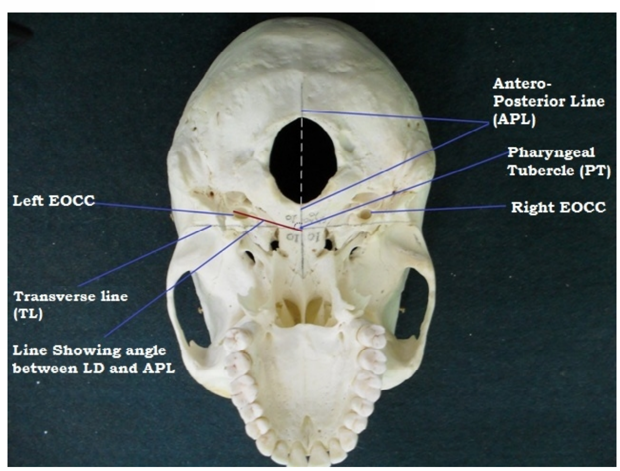
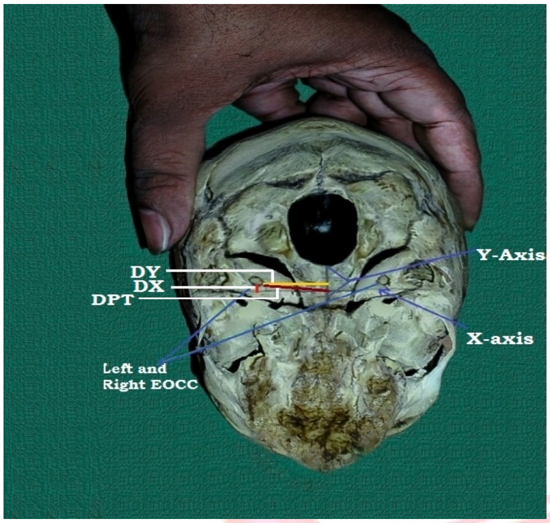


Photo 2: Foetal Skull Showing the right and left EOCC. Y-AXIS, X-AXIS, DY (Yellow line), DX (small Orange line) and DPT (Red Line).



Part 2: This part of the observations shows the comparison of one group with other. This was done to observe the age changes and sexual dimorphism in the EOCC from foetal to adult age. Here the EOCC of one side is compared with the EOCC of same side in different groups as shown below.

Table 2.1: Left . LD

LD		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	**<0.01**
B-m	C-f	>0.05
B-f	B-m	**<0.05**
C-f	C-m	**<0.05**

Table 2.2: Right. LD

LD		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	**<0.01**
B-m	C-f	>0.05
B-f	B-m	**<0.05**
C-f	C-m	**<0.05**

Table 2.3: Left. SD

SD		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	**<0.05**
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.4: Right. SD

SD		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.5: Lt. DY

DY		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	**<0.05**

Table 2.6: Rt. DY

DY		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	**<0.05**

Table 2.7: Lt. DX

DX		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.8: Rt. DX

DX		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.9: Lt. DPT

Angle		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.10: Rt. DPT

DPT		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.11: Lt. Angle

DPT		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	>0.05
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	>0.05
C-f	C-m	>0.05

Table 2.12: Rt. Angle

Angle		p
A	B-f	**<0.01**
A	B-m	**<0.01**
A	C-f	**<0.01**
A	C-m	**<0.01**
B-f	C-f	**<0.05**
B-m	C-m	>0.05
B-f	C-m	>0.05
B-m	C-f	>0.05
B-f	B-m	**<0.05**
C-f	C-m	**<0.05**

Part 3: In this part the symmetry of the EOCC was studied, and for this purpose the left EOCC was compared with the right EOCC, within the same group only. The observations were tabulated as below;

Table 3.1: Lt. LD *Vs* Rt. LD

Group	A	B-f	B-m	C-f	C-m
p	>0.05	>0.05	>0.05	>0.05	>0.05

Table 3.2: Lt. SD *Vs* Rt. SD

Group	A	B-f	B-m	C-f	C-m
p	>0.05	**<0.05**	>0.05	>0.05	>0.05

Table 3.3: Lt. DY *Vs* Rt.DY

Group	A	B-f	B-m	C-f	C-m
p	>0.05	>0.05	>0.05	>0.05	>0.05

Table 3.4: Lt. DX *Vs* Rt. DX

Group	A	B-f	B-m	C-f	C-m
p	>0.05	>0.05	>0.05	>0.05	>0.05

Table 3.5: Lt. DPT *Vs* Rt. DPT

Group	A	B-f	B-m	C-f	C-m
p	>0.05	>0.05	>0.05	>0.05	>0.05

Table 3.6: Lt. Angle *Vs* Rt. Angle

Group	A	B-f	B-m	C-f	C-m
p	>0.05	>0.05	>0.05	>0.05	>0.05

The observations were done in three parts as explained below;

Part 1: in the first part, the mean, maximum and minimum values were calculated. It was seen that the standard deviation was comparatively more in A group skulls (Table 1.1 and 1.10).

Part 2: In the second part the age changes and the sexual dimorphism in the EOCC was observed. The tables shown above were divided into three partitions for this purpose, as explained below.

1. The first partition has a plain line, here the skulls of younger age groups were compared to the older age groups of same sex. So while A group skulls were compared with all the other groups, the adolescent males and females skulls of B-m and B-f group were compared to adult males and females of C-m and C-f group respectively to see the age changes in these groups. The results obtained are explained below;

a. Comparing the group A skulls with the other group skulls showed highly significant increase in the dimensions of other groups over A group. Hence it was observed that the dimensions of EOCC significantly increases from foetal to adult age (table 2.1 to 2.12).

b. Comparing the adolescent B-m and B-f group skulls with the Adult C-m and C-f group skulls however, did not show any significant increase in dimensions of EOCC (table 2.1 to 2.12), except for angle between LD & Y axis of Rt. side which shows significant increase in C-f group over B-f group. (Table 2.12)

2. The Second partition is shown in dotted lines, here the adolescent skulls of one sex were compared to the adult skulls of opposite sex. The B-m and B-f group skulls were compared with the C-f and C-m group respectively to see the age changes and sexual dimorphism in these groups. The results observed are as below;

a. When the B-f group was compared to the C-m group, the C-m group showed statistically significant increase in the LD and SD over B-f group. While increase in the dimension of LD was highly significant ($p<0.01$) in both right and left EOCC (Table 2.1 and 2.2), the increase in the dimension of SD was statistically significant ($p<0.05$) in only left EOCC(table 2.3). Rest of the dimensions did not show statistically significant increase. (table 2.1 to 2.12).

b. The comparison between B-m group and C-f group, it did not show any age change or sexual dimorphism (table 2.1 to 2.12).

3. The third partition is shown by double lines and here the skulls of same age but opposite sex were compared with each other.

a. When the B-m group was compared with the B-f group, the B-m group showed statistically significant increase in LD of both right and left EOCC and the Angle of the right side EOCC (table 2.1, 2.2 and 2.12). Other dimensions did not show significant difference (table 2.3 to 2.11).

b. When C-m group was compared with the C-f group, the C-m Group showed statistically significant increase in LD and DY of both right and left EOCC and in the Angle of only the right EOCC (table 2.1, 2.2, 2.5, 2.6 and 2.12).

Part 3: In this part the symmetry in the pair of EOCC was observed, so the comparison was done between right and left side within same groups. The results observed are as follows;

a. The comparison of dimensions left EOCC with right EOCC did not statistically significant asymmetry in all the dimensions in A group, B-m group, C-f group and C-m group (table 3.1 to 3.6).

b. However, the B-m group showed statistically significant asymmetry in SD, with the dimension of right SD being larger than left SD (table 3.2)

DISCUSSION

The EOCC is a prominent and important feature at the base of human skull, as it transmits the ICA [1,2]. Previous researchers have shown in their study that the change in any dimension of the carotid canal, can cause its effect on the ICA and so the brain. A table of comparison of the present study with previous researchers is given below:

Table 4: Showing comparison of the present study with previous researchers.

Author		LD Left	LD Right	SD Left	SD Right	DY Left	DY Right	DX Left	DX Right
A. Berlis et al [6]		0.79 ±1.13(CT)		0.59 ±0.64 (CT)		-	-	-	-
		0.78 ±1.16 (Skull)		0.57 ±0.35(Skull)					
E. Calguner et al [8]	Males	6.50 ± 1.46	6.82 ± 1.56	4.60 ± 1.05	4.86 ± 2.34	2.56±3.60	2.57 ±2.88	-	-
	Females	6.30 ± 1.05	6.68 ± 1.18	4.33 ± 0.91	4.59 ± 0.87	2.50 ±3.59	2.49± 2.45	-	-
Namita A. Sharma et al [14]		0.7		0.54		2.53	2.49	-	-
Mohamed Abo Aoun et al. [16]	Males	0.68 ±0.8	0.8 ±0.89	0.56 ±0.67	0.57 ±0.69	2.82 ±1.97	2.88 ±2.15	-	-
	Females	0.68 ±0.6	0.7 ±0.65	0.49 ±0.44	0.5 ±0.5	2.6 ±1.5	2.64 ±1.4	-	-
M.S.Somesh et al [17]		0.81 ±0.99	0.82 ±1.00	0.63 ±0.64	0.62 ±0.80	2.49 ±0.25	2.54 ±0.25	-	-
Present study	Foetal	0.26 ±0.13	0.24 ±0.12	0.18 ±0.42	0.18 ±0.09	0.94 ±0.09	0.93 ±0.37	0.26 ±0.26	0.21 ±0.14
	Adolescent male	0.75 ±0.12	0.75 ±0.1	0.52 ±0.09	0.53 ±0.06	2.50 ±0.37	2.43 ±0.26	-0.03 ±0.24	-0.01 ±0.23
	Adolescent female	0.7 ±0.07	0.7 ±0.09	0.51 ±0.06	0.54 ±0.06	2.43 ±0.26	2.38 ±0.22	0.02 ±0.32	0.04 ±0.29
	Adult Male	0.75 ±0.09	0.76 ±0.11	0.55 ±0.08	0.53 ±0.08	2.47 ±0.31	2.43 ±0.26	0.02 ±0.28	-0.08 ±0.54
	Adult Female	0.73 ±0.10	0.72 ±0.11	0.53 ±0.08	0.53 ±0.12	2.43 ±0.26	2.38 ±0.28	0.002 ±0.26	0.03 ±0.2

In the present study the EOCC was observed in 54 foetal skulls and 8 of these foetal skulls were of 4 to 7 months (IUL) foetus. It was seen here that the CC starts developing in the early embryonic life. The CC was not well formed in these skulls, but it could still be made out as a cartilage covered continuous canal from the EOCC to the FL, as the petrous part of temporal bone has cartilaginous ossification [1,3,4]. As the size (age) of the skull advanced, the canal showed gradual ossification of the cartilage cover around the then present ICA, which would start its course till then. The ICA gives branches within the CC in foetal age, which reaches the middle ear and the surrounding area. This causes dehiscence in the CC [1]. However till the foetus is born, these branches are not required and disappear. This completes the formation of a continuous canal and closes the dehiscence. This process of formation of the CC can be compared to the development of naso-lacrimal canal during facial development. The study of ICA and the carotid canal in neonatal and paediatric group was performed by J. Lang et al [5], who have mentioned the measurement of the length of entire carotid canal and its distance from various bony prominences of the skull base; they also mention the non existence of sex difference and asymmetry in the skulls they studied. The present study shows similar results as the sex differentiation could not be made out in the foetal group, moreover it was found that the EOCC in foetal skulls does not show statistically significant asymmetry in the dimensions as well as distance from X and Y axis (coronal and midsaggital lines respectively) (table 3.1-3.6).

The measurements obtained for the dimensions of EOCC in adolescent male group in the present study are near to the measurements obtained by A. Berlis et al [6] observed in dry skulls. While the measurements of EOCC for distance from midline (mid saggital line/plane) is closer to the measurements by Namita A Sharma et al [14]. In case of adolescent female the measurements of dimensions are near to the measurements of EOCC of female skulls by Mohamed Abu Aoun et al [16], and the measurements of distance from midline are near to the measurements by M. S. Somesh et al [17]. In the present study, sexual dimorphism is seen between the adolescent male and female group which is similar to the findings of Mohamed Abu Aoun et al [16] and of Ruta N. Ramteerthakar and B. N. Umberji [15]. In the present study the adolescent female group showed asymmetry in case of shortest diameter which is in contrast with the previous findings of Lang et al [5], Calguner et al [8], Mohamed Abu Aoun et al [16], and M. S. Somesh et al [17]. This may be because the female (and the male) skulls were not grouped in adolescent and adult group in the previous studies.

The measurements for the dimensions of EOCC in adult male skulls in the present study are comparable to the findings of A. Berlis et al [6] observed in dry skulls, whereas the measurements for dimensions of EOCC in female in the present study are comparable to Namita A. Sharma et al [14]. The present study the comparison of dimensions of EOCC between adult male and adult female skulls showed statistically significant sexual dimorphism, which is similar to the findings by Ruta N. Ramteerthakar et al [15], and Mohamed Abu Aoun et al [16]. However the comparison of distance of EOCC from Y axis (mid-saggital line) in adult male and female also showed sexual dimorphism on both left and right side in the present study which is in contrast to the previous findings of Calguner et al [8], Namita A. Sharma et al [14], Mohamed Abu Aoun et al [16]. This may be because the skulls were not categorised into adolescent and adult groups in previous studies. Also the fact to be noted is the skulls studied in this study and in previous studies, were from different regions of the world on different races, which can be the reason of the contrasting findings.

It was further observed that both the adult male skulls and the female skulls do not show any significant asymmetry in the EOCC of left and right side, that is, in case of dimensions of EOCC as well as in the distance from X axis and Y axis (coronal and mid-saggital lines respectively), which is similar to the findings of Calguner et al [8], Mohamaed Abu Aoun et al [16], and M. S. Somesh et al [17].

T. E. Mayer, H. Brueckmann et al (1997) [7] have found that the carotid canal was asymmetric in one fifth of the patients with unilateral aural atresia, slightly rotated or elevated in relation to the hypoplastic base of the skull ($P<0.05$).

Furthermore, John D. Roll, Martin A. Urban, et al (2003) [9] reported cases of a 5 year boy and a 10 year old girl, where the EOCC was Hypoplastic. In the present study there was no hypoplastic carotid canal seen.

Gerald York, Daniel Barboriak et al (2004) [10] have identified 21 carotid canal fractures in 17 patients. They found that the presence of a carotid canal fracture had a sensitivity of 60% and specificity of 67% for detection of injury to the ICA passing through that canal.

Metin Orakdögen, Zafer Berkman et al (2007) [11] reported a rare case of agenesis of the left internal carotid artery in a 43-year-old woman. The left carotid canal was absent in this case. In yet another study conducted by Namita A Sharma and Rajendra S. Garud (2011) [14] on 50 dry skulls, a skull having bilateral absence of canal was observed. In this skull right sided carotid canal was completely absent whereas on left side it was represented by a very narrow blind fossa. In the present study however, no skull was found having absence of carotid canal.

Arata Watanabe, Tomohiro Omata et al (2010) [12] studied the CT scans of 60 Japanese patients and found that the normal diameter in adults was 5.27 ± 0.62 mm (mean ± SD). The mean diameter of the bony carotid canal was

3.31 ± 0.44 mm in 11 adult patients with adult-onset moyamoya disease.

Carotid Canal Sympathetic Plexus Schwannoma was reported in two cases, one of a 27 year old female and another of a 68 year old male by J.D. Hamilton, F. DeMonte, L. E. Ginsberg (2011) [15]. Many a times dehiscence have been observed in carotid canal, which made way for aberrant branches of ICA.

In their study, Arata Watanabe, et al (2010) [18] have quoted that the bony carotid canal developed rapidly before approximately 2 years of age. After fusion of the bony suture, the bony carotid canal developed slowly.

CONCLUSION

This study was done in three parts, from the observations it was concluded that the EOCC shows statistically significant increase in the measurements of its dimensions from foetal to adolescent age but the dimensions do not significantly increase once the EOCC reaches adolescent age (although there may be increase in the angle of its longest diameter with the mid saggital line). However, the EOCC shows sexual dimorphism when compared between adolescent female and adult male. It was observed that the EOCC shows sexual dimorphism within adolescent males and females and this sexual dimorphism increases in the adult males and females. Further it was observed that, although the asymmetry in EOCC is insignificant, the EOCC may be significantly asymmetrical in adolescent females. This knowledge about the various morphometric dimensions of EOCC, the information about its precise distance from X and Y axis of the skull base, and the awareness of its symmetry is very essential for the surgeons, neurosurgeons, radiologists etc to perform various skull base surgeries carotid angiograms, etc and also for recent advanced surgeries like biopsy of brainstem lesions etc for various clinical procedures. This information is also very important for the clinical anatomists and forensic experts.

Conflicts of Interests: None

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