Morphological and Morphometric Analysis of Carotid Canal Apertures in the Nigerian Population

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Abstract

Background: The external opening of the carotid canal (EOCC), the entry point of the internal carotid artery into the skull, varies across populations. This study characterized the EOCC with the mastoid process (shortest distance from the EOCC to the tip of the mastoid process [SDTCC]), the foramen magnum (shortest distance from the EOCC to the foramen magnum [SDFM]), and the midline of the skull base (shortest distance from the EOCC to the midline of the base of the skull [SDMCC]) in the Nigerian population. **Materials and Methods:** Fifty skull base pictures were taken in the plumed position with a digital camera. Measurements were taken using Image J software, and Euclidean distances were calculated. The shapes of the EOCC were noted. Paleontological Statistics (PAST 3.0) was used to perform descriptive statistics. Paired t-test and Pearson correlation were used to compare bilateral values and the relationship between the parameters, respectively. **Results:** The length (right, 0.53 [standard deviation (SD)=2.5] mm; left, 10.99 [SD=2.84] mm) and width (right, 13.96 [SD=2.43] mm; left, 14.16 [SD=2.09] mm) of the EOCC were recorded. In contrast to the populations in South Africa, Serbia, and India, the length of the EOCC obtained from this study is shorter than the breadth. The length of SDFM (right, 41.04 mm; left, 44.13 mm), SDMCC (right, 58.4 mm; left, 57.97 mm), and SDTCC (right, 57.29 mm; left, 55.61 mm) was established among Nigerians. **Conclusion:** The Nigerian population showed EOCC of shorter length than the breadth compared to other populations, and the size of the skull is independent of the foramina size. These dimensions may provide information for procedures that affect the skull base.

Keywords: Carotid canal, Mastoid process, Morphometric, Morphology, Skull base, Nigerians

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Introduction

The external opening of the carotid canal (EOCC), the entry point of the internal carotid artery (ICA) into the human skull (1), is on the inferior surface of the petrous portion of the temporal bone, located posterolaterally to the foramen lacerum and anterolaterally to the jugular foramen (2). The internal carotid venous plexus and some perivascular tissues separate the ICA from the walls of the carotid canal. The ICA on gaining access through the EOCC runs inside the temporal bone and restricts surgical procedures for the transbasal approach to lesions in the frontal skull base and the transzygomatic approach to those in the middle skull base (3).

The knowledge of the regional anatomical relations of the bony and vascular structures of the skull base is crucial in many skull base surgical dissections used to gain access to the middle cranial and infratemporal fossae, including the transmastoid and transpetrosal approaches (4, 5).

The quantitative evaluation of the EOCC and its relationships with adjacent anatomic structures is critical for understanding associated and related skull base pathologies and surgical procedure planning (2). Such studies have been carried out in other populations, and variations in the length and breadth of the EOCC were recorded (1, 2, 6-8); hence, the readings for one population may not be appropriate for another. In the lesions that extend not only to the middle skull base but also to the infratemporal fossa, preservation of the ICA during surgery is important (9) and this can be achieved by knowing the morphometric characteristics of the EOCC peculiar to each population for surgical intervention.

Different populations have different EOCC sizes and shapes, which may affect surgical procedures. Oval-shaped EOCCs are more common in South African populations, according to a study (2), whereas round-shaped EOCCs are more common in Indian and Serbian populations (1, 6, 8). Knowledge of these differences is necessary in this age of medical tourism and intercontinental connectivity. These shapes are defined by the petrous process and cavernous sinus of the temporal bone forming the carotid canal through which the carotid artery passes toward the intracranial space; the petrous itself is pyramidal in shape (4). There is a dearth of information on the morphologic and morphometric features, location, and relationships of the carotid canal with other anatomical structures in a sample of the Nigerian population. It is necessary to relate the EOCC diameter with the skull base size. This will enhance the approaches to skull base imaging and surgery in the population.

Materials and Methods

This study was a descriptive cross-sectional analysis of some selected characteristics of the EOCC and its relationship with other significant anatomical structures at the base of the human skull (Figures 1 and 3) in the cadaveric laboratory of the Anatomy Department, University of Ibadan, Nigeria. Fifty human skulls of estimated ages 20–60 years of both genders were used for this study based on the sample availability that fulfilled the criteria of nil deformities, congenital anomalies, and fractures at the base of the skull.

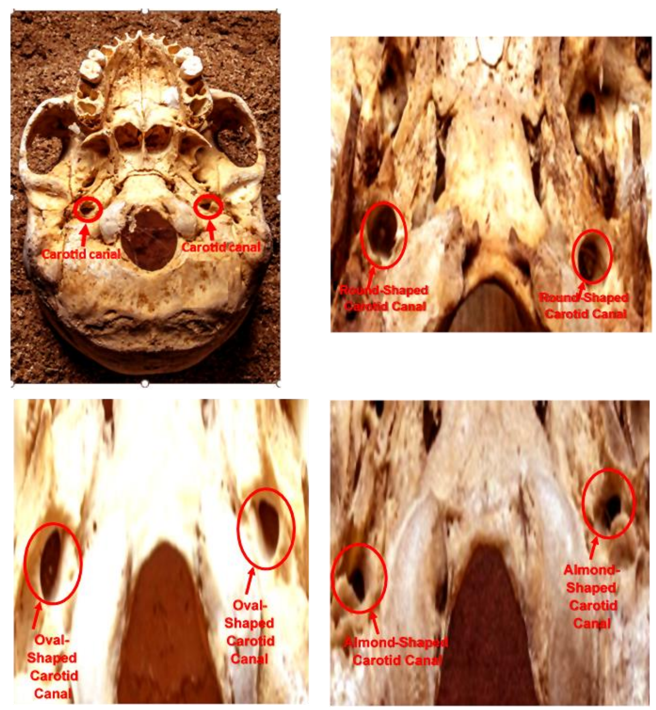

Figure 1. Showing carotid canal and the different morphological shapes of the canal.

The source of the skulls in our bone library was from maceration of dissected adult cadavers. This ensures that the skulls were adult skulls. Direct measurements of the bi-mastoid distance using a digital Vernier caliper were taken. A Canon EOS 500 digital camera, Canon USA, was used to take skull base pictures of the study subjects.

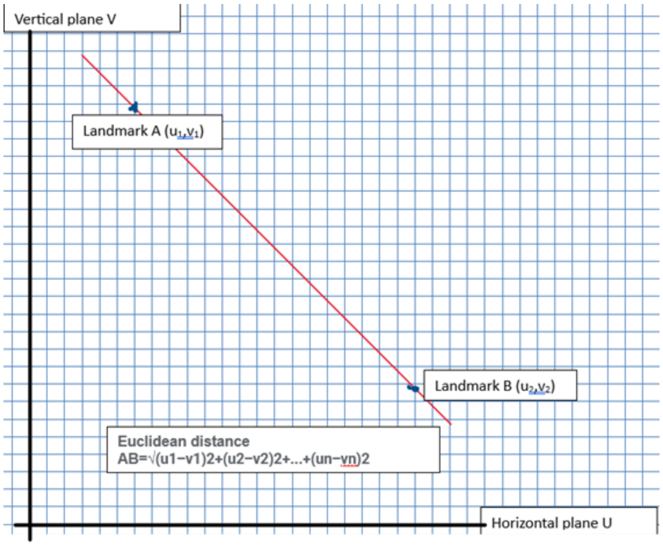

Figure 2. An illustration of Euclidean distance.

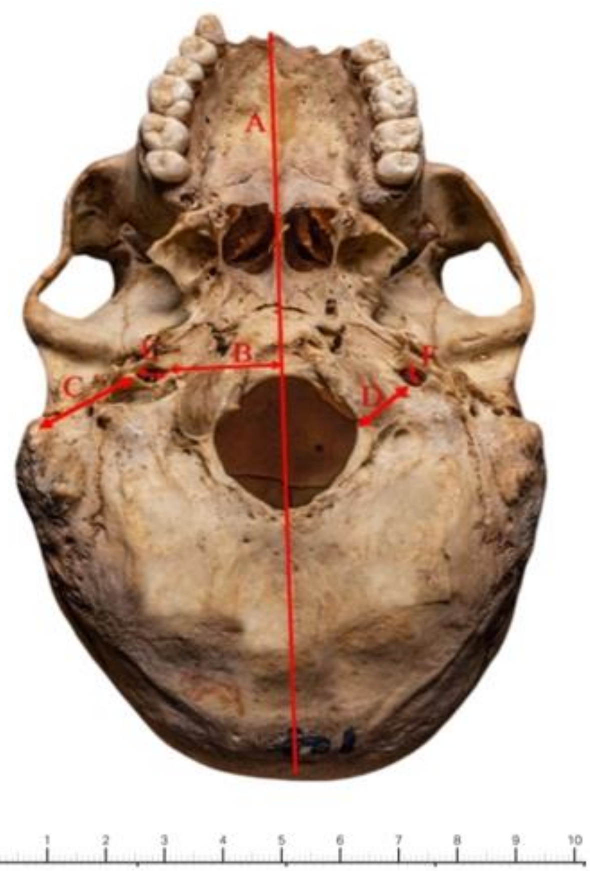

Figure 3. Measurements with scale bar.
A - Midline of the base of the skull, B – SDMCC, C – SDTCC, D – SDFM, E – TR, F – AP

Using Image J (10), assessments of anatomical positions on both sides were made and Euclidean distances were calculated (Figure 2).
The following parameters (Figure 3) were derived from the obtained photographs:

- Anteroposterior (AP) and transverse (TR) diameter of the EOCC.
- The shortest distance from the EOCC to the tip of the mastoid process (SDTCC).
- The shortest distance from the EOCC to the foramen magnum (SDFM).
- The shortest distance from the EOCC to the midline of the base of the skull (SDMCC).

To improve measurement accuracy, each measurement was taken three times by the same person and the average was recorded.
The ethical approval number for this study is UI/EC/23/0623. This was obtained from the UI/UCH Ethical Review Committee in the Institute for Advanced Medical Research and Training (IMRAT), University College Hospital, Ibadan.

Statistical analysis

The Paleontological Statistics was used to analyze the data. The mean (standard deviation [SD]) and range from the aforementioned measurements were calculated as descriptive statistics, and paired t-test was used to compare the right and left values. The correlation between the EOCC and other parameters was verified using Pearson's correlation. A statistical significance was considered if $p \leq 0.05$.

Results

The descriptive statistics of measurements from all the specimens were used to calculate the mean±SD, which was then used to represent the values for each parameter (Table 1).
As shown, there is no statistically significant difference between the right and left values of the length (AP) and width (TR) of the EOCC in all measured specimens, using the paired t-test at a 95% confidence level ($p \leq 0.05$). The shape of the EOCC was mostly round (48%) or oval-shaped (45%), while only 7% was almond-shaped with a pointed edge (Figure 1).

In addition, there were no statistically significant morphometric differences between the right and left sides in the dimensions of these important anatomical landmarks (Table 1): the distances from the foramen magnum to the CC (SDFM) (right, 41.04 mm; left, 44.13 mm), the midline to the CC (SDMCC) (right, 58.4 mm; left, 57.97 mm), and the tip of the mastoid process to the CC (SDTCC) (right, 57.29 mm; left, 55.61mm).

Table 1: Carotid Canal Parameters of the Skull of Nigerians in millimeter

Parameter	Right		Left		T-score	P-value
	X±SD	Min – Max	X±SD	Min – Max		
(AP) EOCC	10.53±2.5	4.4 – 16.82	10.99±2.84	5.1 - 18.61	0.858	0.393
(TR) EOCC	13.97±2.43	9.43 – 18.92	14.16±2.09	9.6 - 18.01	0.426	0.671
SDFM	41.04±8.8	28.46 – 70.83	44.131±8.801	29.7 - 65.96	1.866	0.065
SDMCC	58.40±5.81	48.54 – 71.56	57.967±6.34	41.52 - 73.35	0.352	0.726
SDTCC	57.29±7.75	40.8 – 74.37	55.61±8.03	40.7 - 72.1	1.052	0.295

(AP) EOCC: Anteroposterior (AP) diameter of the external opening of the carotid canal
(TR) EOCC: Transverse (TR) diameter of the external opening of the carotid canal
SDFM: The shortest distance from the EOCC to the foramen magnum (SDFM).
SDMCC: The shortest distance from the EOCC to the midline of the base of the skull (SDMCC).
SDTCC: The shortest distance from the EOCC to the tip of the mastoid process

Table 2: Results of Correlation between Bi-mastoid Distance and Skull Base Parameters

		Bimastoid Distance Correlation Coefficient
(AP) EOCC	L	0.003
	R	-0.032
(TR) EOCC	L	0.157
	R	0.117
SDFM	L	0.157
	R	0.025
SDMCC	L	0.255
	R	0.005
SDTCC	L	0.003
	R	0.164

(AP) EOCC: Anteroposterior (AP) diameter of the external opening of the carotid canal
(TR) EOCC: Transverse (TR) diameter of the external opening of the carotid canal
SDFM: The shortest distance from the EOCC to the foramen magnum (SDFM).
SDMCC: The shortest distance from the EOCC to the midline of the base of the skull (SDMCC).
SDTCC: The shortest distance from the EOCC to the tip of the mastoid process
L: Left
R: Right

There were weak positive and negative correlations between the bi-mastoid distance and the (AP) EOCC, (TR) EOCC, SDFM, SDMCC, and SDTCC (Table 2).

Discussion

In this study, the shape of the EOCC was predominantly oval (48%), similar to the findings observed in a sample of the South African population (2). However, a round shape (43%) was also common among the Nigerian population comparable with the findings among Indian and Serbian populations (Table 3). The correlation of the size of the EOCC and other parameters with respect to the bi-mastoid distance revealed weak positive and negative correlations, indicating that the diameters of the foramina at the base of the skull are independent of the size of the base of the skull.

The preservation of the ICA during surgery can be achieved by increasing the EOCC diameter laterally to gain substantial operative space during surgery (3). This approach is more advantageous in the Nigerian population, considering that the breadth of the EOCC is longer than the length. The right and left sides of the human skull differ in several aspects, in spite of the fact that it appears to be symmetrical on cursory observations. According to Naidoo et al. (2), the left side of the EOCC is typically longer than the right side. This is, however, contrary to the findings of our study, wherein there was no statistically significant difference in the length and width of the EOCC between sides. This concurs with other findings (1, 11). This non-significant asymmetry of many right and left features at the base of the skull is a commonly observable phenomenon (12).

Table 3: Comparison of EOCC Dimensions in Different Populations

EACC	**Sex**	**Population**	**No. of specimens**	**length (AP diameter)**		**Width (ML diameter)**		**Shape**		
				Right side	**left side**	**Right side**	**Left side**	**Round**	**Oval**	**Almond**
Ahmed *et al*.(2015)		Indian	100 skulls	6.79	6.28	5.54	5.27			
Aoun et al. (2013	Male	Saudi Arabian	75 skulls	7.96±0.89	6.77±0.8	5.7±0.69	5.58±0.67			
	Female		75 skulls	7.0±0.65	6.77±0.6	5.0±0.5	4.86±0.44			
Berlis *et al*. (1992)	CT	German	60 skulls	7.91±1.13		5.88±0.64				
	Skulls			7.81±1.16		5.69±0.35				
Naidoo *et al*. (2017)	Male	South African	47 skulls	5.41		7.52		28.40%	49.40%	22.20%
	Female		34 skulls							
Somesh *et al*. (2014)		Indian	82 skulls	8.13±0.99	8.16±1.00	6.31±0.64	6.19±0.80	52.14%	30.67%	17.17%
Shaikh *et al*. (2014)	Male	Indian	181 skulls	7.62±1.05	7.51±0.88	5.33±0.8	5.46±0.8			
	Female			7.2±1.05	7.26±1.03	5.3±1.23	5.25±0.81			
Tewari *et al*. (2018)		South Indian	68 skulls	7.76±0.88	7.89±0.88	5.81±0.71	6.32±0.80	51.18%	29.13%	18.89%
Pupovac *et al*. (2020)		Serbian	24 skulls+36 temporal bones	7.31±1.01	7.71±1.06	5.82±0.78	6.20±1.04	53.57%	29.76%	15.47%
Our study		Nigerian	50 skulls	10.53±2.5	10.99±2.84	13.97±2.43	14.16±2.09	43%	46%	11%

In this study sample, the EOCC has a longer AP and wider TR, in contrast to the data range provided in the earlier studies, where the average length of the EOCC for adults was 3.20–10.5 mm and the width was 4.0–8.5 mm (6, 8, 13). In addition, it is noteworthy that the TR diameters were greater than the AP diameters in contrast to what is observable among other populations (1, 2, 6-8, 14). The use of sample groups with different geographic characteristics, such as race and region, may be the cause of this discrepancy (2, 14). Table 3 displays a comparison of our findings with those from earlier studies.

The morphometric analysis of both sides of SDFM, SDMCC, and SDTCC showed no statistically significant differences. This finding agrees with other works (7, 14). When compared to other studies (2, 11), the SDFM, the SDMCC, and the SDTCC are at higher values. These differences are important for surgeons working on the base of the skull to note. The disparity pattern is likely due to differing study methodologies and other distinctive qualities such as racial and ethnic identity. This comparison is important when considering medical tourism for the treatment of skull base cases between locations.

Study limitations

This is only a cadaveric study which may not reflect the findings on live humans. The number of skulls assessed might have been larger but for some procurement constraints. The sampling method of convenience may not be adequate enough as a representative population sample. Also, variables like ethnicity and origin of the skulls may influence the study findings. These limitations should be borne in mind in the translational application of the findings.

Conclusion

In this study, the length of the EOCC is shorter than the breadth, contrary to the findings in other populations, and the size of the skull is independent of the foramina size in the Nigerian population. The consideration of these dimensions may provide information for neurosurgical procedures that affect the base of the skull

Recommendation

Further work may need to be undertaken to expand this study to the same population using live imaging of the skull and cross-sectional sampling technique of adults between ages 20–60 years.

Author contributions

MA led in conceptualization, methodology, project administration, supervision, validation and in writing, reviewing & editing of the original draft. All authors contributed equally to formal analysis, investigation and software.

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