Ventral Carotid Canal Dehiscence In A Kenyan Population: An Osteological Study

Talha Chaudhry[1], Khulud Nurani[1], Moses Obimbo[1], Kevin Ongeti[1], Philip Mwachaka[1]

[1]Department of Human Anatomy, University of Nairobi, Nairobi, Kenya

Corresponding author: Talha Chaudhry. Department of Human Anatomy, University of Nairobi. P.O. Box 50451 – 00200, Nairobi, Kenya. Email: talhahchaudhry99@gmail.com

ABSTRACT

Background: The ventral surface of the carotid canal has previously been reported to be incomplete. Knowledge of this is important in the prevention of iatrogenic injuries during skull base procedures involving the petrous internal carotid artery and in the repair of carotid canal stenosis and fractures. Data on the prevalence of ventral carotid canal dehiscence locally remains scarce. **Methods:** 98 dry-sexed skulls were used to check for the presence of ventral carotid canal dehiscence. Data was analyzed using SPSS (Version 25.0) and frequency tables generated. Chi-square tests were used to assess associations with respect to side and sex. A p-value of ≤ 0.05 was considered significant. **Results**: Ventral (exocranial) dehiscence was present in 19.4% of skulls, with male skulls more likely to be dehiscent ($p = 0.04$). Minor dehiscence in the form of fissures was observed in 12.2% (24/196 sides), while holes were observed in 1.5% (3/196 sides). The rarer major dehiscence was not observed in this study. Bilateral dehiscence was observed in 8.2% (19 skulls). **Conclusion**: The ventral carotid canal was incomplete in 19.4% of Kenyan skulls. Procedures around the skull base should be done with caution to avoid inadvertent hemorrhage and vasospasm of the petrous internal carotid artery.

Keywords: *Carotid canal*, *Petrous Internal Carotid Artery*, *Dehiscence*

INTRODUCTION

Ventral carotid canal dehiscence refers to the failure of fusion of the exocranial floor of the carotid canal (CC). The inferior surface of the CC is usually closed off by a thin plate of bone during the embryonic period. The ontogenesis of the canal in the embryonic period has been noted to be dependent on the underlying embryonic internal carotid artery (ICA) (1). It has been hypothesized that this dehiscence is a result of incomplete osseous development of the petrous carotid canal (2). This incompleteness may be major in cases of complete deficiency of the bone covering the ventral carotid canal, or minor in cases of partial closure or fissure-type defects (3).

Inadvertent injury to the petrous internal carotid artery due to unanticipated bony dehiscence of the carotid canal is a potentially catastrophic but avoidable complication of surgical approaches to the clivus, petrous apex, and the lateral sellar compartment (1). Given the degree of anatomic complexity and gravity of inadvertent injury to the neurovascular structures of the skull base, an intricate knowledge of both the typical and atypical morphology of the osseous structures is required, especially with the increasing use of endoscopic and microsurgical procedures at the skull base (2, 3). Dorsal and tympanic carotid canal dehiscence have been well documented (4); however, there is a paucity of data on the prevalence and types of ventral carotid canal dehiscence in the local setting.

A clear description of the variant anatomy of the floor of the CC in a Kenyan population would help to prevent iatrogenic injuries in microsurgical procedures within the CC, skull base surgeries, and the exposure of the petrous internal carotid artery. Therefore, this study aims to determine the prevalence and types of ventral CC dehiscence in an adult Kenyan population.

MATERIALS AND METHODS

Study Design

This study was a descriptive cross-sectional study carried out at the Osteology Department of the National Museums of Kenya. Approval for the use of cadaveric material for research is provided for in the Human Anatomy Act, Cap. 249 (1967), and the Human Tissues Act, Cap. 252 (1968) of the Laws of Kenya. The study was conducted in accordance with the ethical guidelines stated in the Declaration of Helsinki. Permission was sought from the Osteology Department of the National Museums of Kenya for the use of the premises for the data collection procedures. Skulls in the study were sexed and confirmed to be adult based on the presence of a mastoid process and dentition, as indicated by an anthropologist on the skull repository. Dry adult skulls of known sex with an intact skull base were used, as those of children have skull bases that are not completely ossified. Skulls with obvious signs of trauma to the skull base were excluded. Purposive sampling was used to select 98 skulls that satisfied the selection criteria, and thus 196 sides were studied.

Data Collection Procedures

The ventral aspect of the CC was inspected for completeness and integrity. If the bony canal was dehiscent, it was classified as major or minor based on the degree of canal closure failure, with major indicating complete absence of bone (2). Minor dehiscence was further classified into fissures or holes based on the shape of the bony defect (3).

Photography, Data Analysis and Presentation

A 12 MP (f/1.8, 26mm wide, 1/2.55", 1.4µm, dual pixel PDAF, OIS) phone camera was used to take the photographs. The independent variables included the sex and side of the skull, while the dependent variable was the presence or absence of dehiscence. Data was presented as frequencies, which were calculated using SPSS 25.0 (Chicago, Illinois). Chi-square tests were also used to assess whether the presence of dehiscence was dependent on the sex and side of the skull examined. A p-value of ≤ 0.05 was considered significant at a 95% confidence interval.

RESULTS

Of the 98 skulls examined, 67 (68.4%) were male and 31 (31.6%) were female. Of the 196 sides observed, ventral CC dehiscence was absent in 86.2% (169 sides). Ventral carotid canal dehiscence was present in 19.4% of skulls. Minor dehiscence in the form of holes and in the form of fissures were observed in 1.5% (3 sides) and 12.2% (24 sides) respectively. Major dehiscence was not observed in the current study.

An association was noted between the presence of ventral CC dehiscence and gender (p = 0.04), with male skulls more likely to be dehiscent. However, no significant association was found between the side of the skull examined and the presence of ventral CC dehiscence (p = 0.30). The laterality (side distribution) of ventral CC dehiscence is summarized in *Table 1* below.

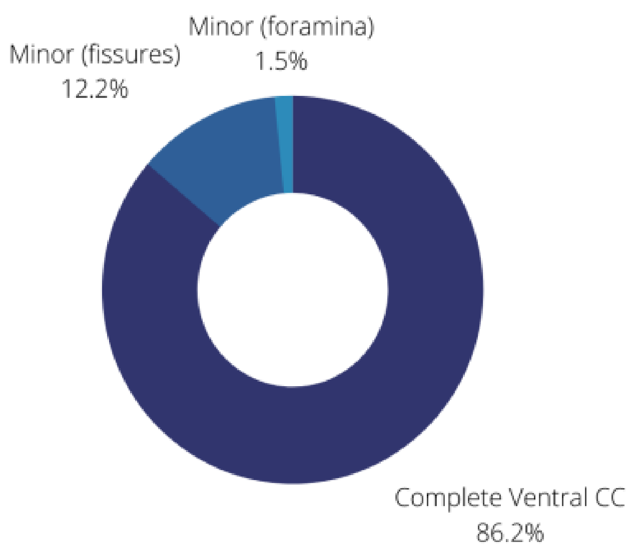

Figure 1: Pie chart indicating the prevalence of the types of ventral CC dehiscence in the 196 carotid canals studied.

Table 1: Laterality of ventral CC dehiscence

Morphology	**f (skulls)**	**%**
Intact ventral CC	79	80.6
Unilateral right dehiscence	3	3.1
Unilateral left dehiscence	8	8.2
Bilateral dehiscence	8	8.2

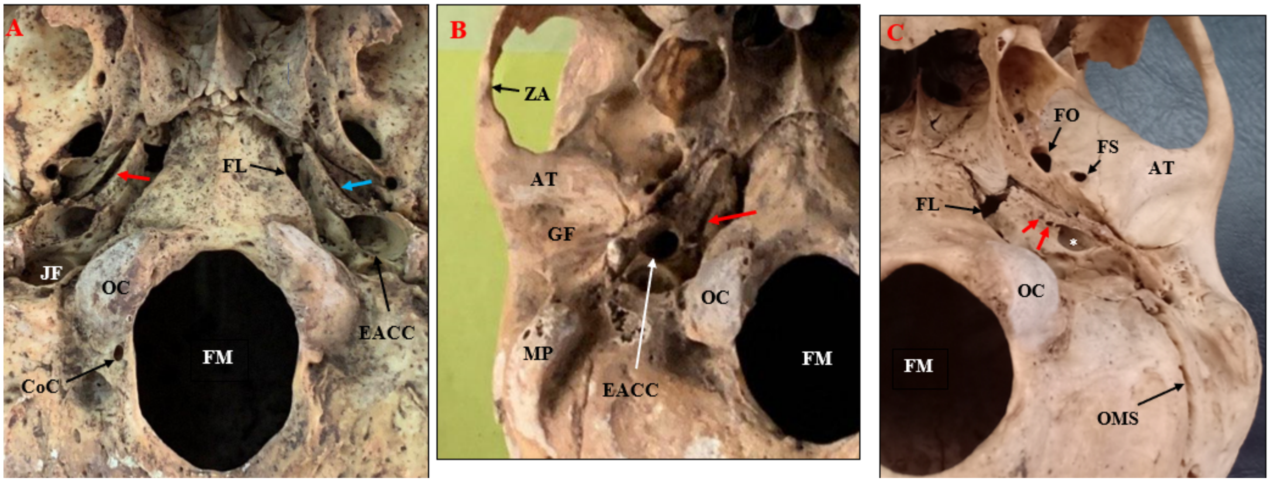

Figure 2A-C: Photographs illustrating the types of dehiscence noted. **A**: Bilateral ventral carotid canal dehiscence [right minor fissure-type dehiscence (red arrow) and left minor fissure-type dehiscence (blue arrow)]. **B**: Right minor fissure-type ventral carotid canal dehiscence (red arrow). **C:** Left minor holes-type ventral carotid canal dehiscence (red arrows). ***AT*** *– Articular tubercle;* ***CoC*** *– Condylar canal;* ***EACC*** *– External aperture of carotid canal;* ***FL*** *– Foramen lacerum;* ***FM*** *– Foramen magnum;* ***FO*** *– Foramen ovale;* ***FS*** *– Foramen spinosum;* ***GF*** *– Glenoid fossa;* ***JF*** *– Jugular foramen;* ***MP*** *– Mastoid process;* ***OC*** *– Occipital condyle;* ***OMS*** *– Occipitomastoid suture;* ***ZA*** *– Zygomatic arch*

DISCUSSION

Out of the 98 skulls examined, 19 (19.4%) displayed ventral CC dehiscence. Bilateral dehiscence was observed in 8 skulls, while unilateral right and unilateral left dehiscence were identified in 3 and 8 skulls, respectively. The prevalence of ventral CC dehiscence in the current study was higher than that observed in the British, Saudi, Spanish, and Turkish skulls (4-6). Vidya (2015) found no ventral dehiscence in an Indian population. This may have been due to the small sample size utilized in the study. The highest prevalence of ventral CC dehiscence was noted by Hearst et al. (2008) in a North American population (35.9%). Similar to previous studies, minor dehiscence was more prevalent (13.7%) compared to major dehiscence, which was not noted in the present study (2,3).

An association was noted between sex and the presence of ventral dehiscence (p = 0.04), with males being more likely to display ventrally dehiscent CCs. The basis for this remains unclear and warrants future investigation to elaborate on the exact mechanism for this finding. It could possibly be attributed to the higher prevalence of internal carotid artery hypoplasia noted among males (8). This may explain the higher rate of ventral carotid canal dehiscence, as the ontogenesis of the canal in the embryonic period has been noted to be dependent on the underlying embryonic internal carotid artery (1).

This failure of complete closure of the CC may be explained by a failure of ossification of the petrous apex during the embryonic period or may be due to an underlying ICA anomaly as the petrous apex develops secondary to the embryonic ICA (3). This may predispose the unprotected ICA to trauma from masses in the adnexa and to iatrogenic injury during skull base procedures.

Table 2: Comparison of prevalence of ventral CC dehiscence with other populations.

Authors	Population	Study Type	N	Ventral CC Dehiscence			
				Unilateral right	Unilateral left	Bilateral	Total
Calgüner et al., 1997	Turkish	DS	307	-	-	-	5 (1.6%)
Vázquez et al., 1999	Spanish	DS	538	2 (0.4%)		4 (0.7%)	6 (1.1%)
Hearst et al., 2008	North American	DS	198	68 (34.3%)	74 (37.4%)	26 (26.3%)	71 (35.9%)
Aoun et al., 2013	Saudi	DS	150	-	-	-	5 (3.3%)
Vidya, 2015	Indian	DS	20	-	-	-	0
Toll et al., 2018	British	CT	75	6 (8%)		3 (4%)	9 (12.0%)
Current study	Kenyan	DS	98	3 (3.1%)	8 (8.2%)	8 (8.2%)	19 (19.4%)

DS – Dry skulls, CT – Computed Tomography

ICA injury has been noted in about 3–8% of traditional skull base procedures (9). Surgeons should presume the presence of very thin bone over the ICA and should dissect the mucoperiosteum and the bone overlying the ICA with caution in cases requiring mobilization of the ICA (10). This knowledge would allow for increased familiarity with the anatomy of the CC, which should translate to safer dissection and minimize morbidity for patients.

Locally, skull base surgeons operating in the petrous apex or clival regions should expect to find ventral CC dehiscence in around 20% of patients and should therefore exercise caution to avoid inadvertent hemorrhage or vasospasm of the ICA. Preoperative imaging may also help reduce iatrogenic injury as dehiscence can be identified prior to surgery and steps taken to mitigate damage to the petrous ICA. Otologic surgeons should also exercise caution when performing Balloon Eustachian Tuboplasty (BET) as rupture of the ICA may result in cases of dehiscent CC adjacent to the bony Eustachian tube (4).

CONCLUSION

The ventral exocranial surface of the carotid canal is incomplete in approximately 20% of Kenyan skulls, with a slight predilection for the male sex. Skull base, otologic surgeons, and neurosurgeons operating around the region of the petrous apex should exercise great caution in order to avoid inadvertent hemorrhage and vasospasm of the petrous ICA during procedures.

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