VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 76, No. 2, pp. 289–294
DOI: 10.5603/FM.a2016.0060

ISSN 0015–5659
www.fm.viamedica.pl

An anatomical investigation of the carotid canal

N. Naidoo[1], L. Lazarus[2], N.O. Ajayi[2], K.S. Satyapal[2]

[1]*College of Medicine, Mohammed Bin Rashid University of Medicine and Health Sciences, Dubai Healthcare City, Dubai, United Arab Emirates*
[2]*Department of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, College of Health Sciences, University of KwaZulu-Natal, Westville Campus, Durban, South Africa*

[Received: 9 July 2014; Accepted: 20 November 2014]

Background: *The carotid canal (CC) located in the petrous temporal bone transmits the internal carotid artery, internal carotid venous plexus and sympathetic nerve plexus from the neck into the cranial cavity. It is an accessible passage into the cranial cavity and is considered an important anatomical landmark for neurosurgeons. The aim of this study was to investigate the topographical, morphometric and morphological parameters of the CC.*

Materials and methods: *An examination of the CC and related adjacent structures in 81 dry skull specimens was performed. Distribution of sample by sex was 34 females and 47 males, and by race 77 African and 4 Caucasian. The mean age was 50 years (range: 14–100 years).*

Results: *The external opening of the CC was found to be round-shaped, oval-shaped and tear-drop-shaped in 28.4%, 49.4% and 22.2% of the specimens, respectively. (1) Mean diameters [mm]: (a) medio-lateral 7.52 mm and (b) antero-posterior 5.41mm. Statistically significant difference in the vertical diameter was recorded in the race groups and laterality of the samples. (2) Mean distances [mm] between: (a) medial margins of external opening of CC was 50.03 mm, (b) lateral margins of external opening of CC was 62.73 mm and (c) external openings of CC and foramen lacerum was 15.6 mm. There was a statistically significant correlation between race and location of the opening of external CC in relation to foramen lacerum (viz. postero-lateral, lateral and diagonal, and lateral).*

Conclusions: *The present study corroborated previous reports on the CC; however, the tear-drop shaped external CC opening was a unique finding. The knowledge of the reference measurements pertaining to the CC and its relationship to adjacent structures may postulate a suitable surgical "safe-zone" range within the CC area.* (Folia Morphol 2017; 76, 2: 289–294)

Key words: carotid canal, morphometry, morphology, topography

INTRODUCTION

The carotid canal (CC) is located within the middle cranial fossa at the apex of the petrous temporal bone [23, 24]. It is delimited by the posterior margin of the greater wing of the sphenoid bone anteriorly and the basilar aspect of occipital bone posteromedially [24]. Teufel [26] and Berlis et al. [4] divided the CC into three characteristic parts, viz. ascending petrous, transverse petrous and ascending cavernous. The internal and external apertures, which constitute the CC, are situated in relation to other foramina, grooves and impressions containing a number of neurovascular and labyrinthine structures in close proximity [11].

Address for correspondence: Prof. K.S. Satyapal, Department of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, College of Health Sciences, University of KwaZulu-Natal, Private Bag X54001, Durban, 4000, South Africa, tel: +27 31 260 7110; + 27 83 777 8780, fax: +27 31 260 7890, e-mail: satyapalk@ukzn.ac.za

The internal opening of the CC is situated diagonal and lateral to the foramen lacerum [18, 24]. Although the jugular foramen and CC are situated in the posterior and middle cranial fossae, respectively, the former is found posterior to the internal opening of the CC [15, 24]. The external opening of the CC lies anterior to the jugular foramen and is bound by the external opening of the foramen lacerum antero-medially [5, 15, 18, 23].

The CC transmits the internal carotid artery (ICA) which is the major arterial supply to the brain and other deeper regions of the head such as the eye, accessory organs and the nose [14, 18, 25]. The CC also transmits the sympathetic nerve plexus and the internal carotid venous plexus, a venous network around the ICA connecting with the cavernous sinus and the internal jugular vein [9, 24].

Although skull-base anatomy is regarded as the central determinant of sex in forensic medicine, the role of foramina as neurovascular routes is especially important in the surgical environment [4, 7, 8]. According to York et al. [30], ICA injury has been recorded to occur in about 1% of patients who suffer severe blunt trauma to the head. Furthermore, patients with CC fractures appeared to present with a greater prevalence of injury to the ICA as opposed to those with other skull-base fractures [20, 30].

Since hypoplastic carotid canals are considered to be indicative of Moyamoya disease, early detection of such changes may prevent ICA stenosis and subsequent stenosis of the carotid canal itself [17].

In addition, there appears to be a lack in the provision of cranio-metric and cranio-morphologic parameters of the CC as stated by a number of authors [6, 12, 13, 22, 23]. Due to the infiltration of the contents of the CC during inflammatory and pathological processes of adjacent structures, there is much emphasis on the clinical need of the appreciation of the topographical relationship between of the CC and these adjacent structures [1, 28]. Since the knowledge of the normal and variant anatomy of the CC may be of significance in micro-surgical procedures, the purpose of this study was to determine the topographical, morphometric and morphologic parameters of the CC and related structures.

MATERIALS AND METHODS

The sample series comprised of 81 randomly selected dry human skulls obtained from the osteology bank of the Department of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, University of KwaZulu-Natal. The distribution of the sample series by sex was 34 females and 47 males. Racial distribution was 77 African and 4 Caucasian, while the mean age was 50 years (range: 14–100 years). Ethical clearance was obtained from the University's Ethic Committee (Ethics number: BE035/14). The morphology of the CC was documented and morphometric measurements were done with the aid of a digital calliper (Mitutoyo Digimatic Calliper, Model No. CD-8" C). Each morphometric parameter was evaluated three times in order to minimise intra-observer errors.

All skulls with distortion of the macro- and/or micro-anatomy, i.e. congenital malformations, temporal fractures and otosclerosis were excluded. The levels of significance with regard to laterality and certain demographic factors such age, sex and race, was determined. The data obtained was analysed using SPSS version 21.0 (SPSS Inc., Chicago, Illinois, USA). A p value of < 0.05 was considered to be statistically significant. Since age was also considered a continuous variable, the Pearson Product Moment Correlation Coefficient (r) values describing the strength and direction of the respective correlations with age were also determined (strength: < 0.5 = weak, > 0.5 = strong; direction: + [positive] or – [negative]).

RESULTS

Morphology

The external opening of the CC was observed to be round, oval-shaped and tear-drop-shaped in 28.4%, 49.4% and 22.2% of specimens, respectively (Fig. 1A–C). The CC was directed infero-medially and inferiorly in 77.8% and 22.2% of cases, respectively (Table 1). In addition, the comparison of the direction of the CC between right and left sides yielded a p value of 0.000 which was characteristic of the predominant infero-medial direction on the left side (Table 1).

Relations

The external opening of the CC in relation to the foramen lacerum was postero-lateral in 93.8%, lateral and diagonal in 3.1% and lateral in 3.1% of specimens, respectively (Table 1). The internal opening of the CC in relation to the foramen lacerum was situated lateral in 40.7%, lateral and diagonal in 48.8%, postero-lateral and diagonal in 9.3% and postero-lateral in 1.2% of specimens, respectively (Table 1). There was a significant correlation between race and the position of the external CC in relation to

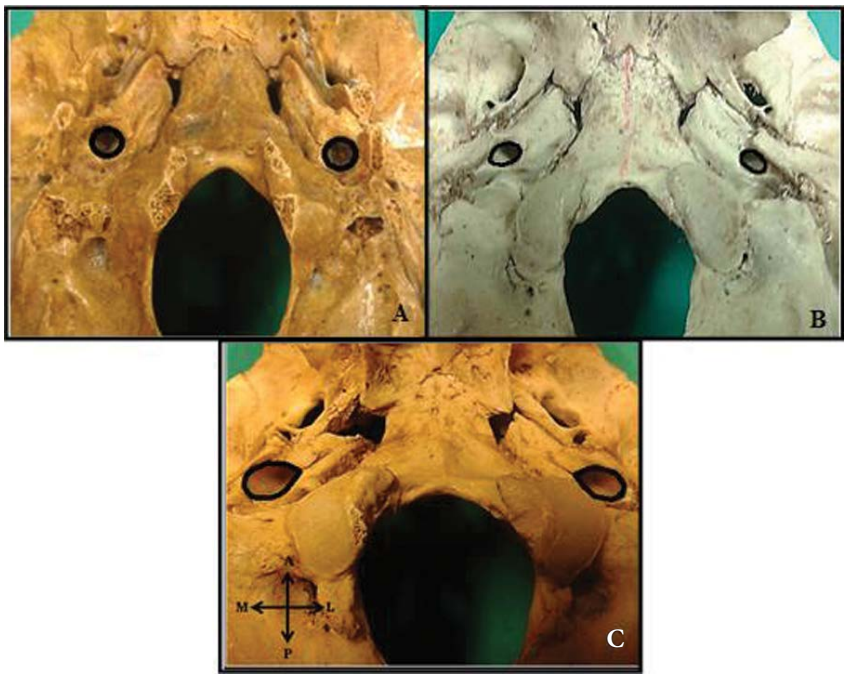

Figure 1. Shape of external opening of carotid canal; **A.** Round; **B.** Oval; **C.** Tear-drop; A — anterior; L — lateral; M — medial; P — posterior.

the foramen lacerum (p = 0.001) (Table 1). This was reflective of the high frequency in the postero-lateral position of the external CC in relation to the foramen lacerum (93.8%) predominantly observed within the African race group.

The relation of the external opening of the CC to the jugular foramen was observed to be antero-medial in 12.3%, antero-lateral in 11.7% and anterior in 75.9% (Table 1). The internal opening of the CC was found to be anterior, antero-medial and antero-lateral to the jugular foramen in 71.6%, 13.6% and 14.8% of specimens, respectively (Table 1).

Morphometry

The mean distance between the medial margins of the external CC was 50.03 mm, the lateral margins of external CC was 62.73 mm, the external openings of the CC and the foramen lacerum was 15.58 mm, and external margins of the CC and the summit of mastoid process was 27.94 mm. The medio-lateral

Table 1. Morphology and relations of the carotid canal

Morphology and relations		Shape of external carotid canal	Direction of external carotid canal	Position of carotid canal in relation to foramen lacerum		Position of carotid canal in relation to jugular foramen	
				External	Internal	External	Internal
		Round (28.4%); oval-shaped (49.4%); tear-drop shaped (22.2%)	Infero-medial (77.8%); inferior (22.2%)	Postero-lateral (93.8%); lateral and diagonal (3.1%); lateral (3.1%)	Lateral (40.7%); lateral and diagonal (48.8%); postero-lateral and diagonal (9.3%); postero-lateral (1.2%)	Antero-medial (12.3%); antero-lateral (11.7%); anterior (75.9%)	Anterior (71.6%); antero-medial (13.6%); antero-lateral (14.8%)
p	Side	0.775	0.000*	0.808	0.374	0.643	0.101
	Sex	0.304	0.115	0.595	0.219	0.938	0.430
	Race	0.710	0.498	0.001*	0.233	0.189	0.997
	Age	0.534	0.922	0.056	0.729	0.173	0.663
r	Age	–0.049	0.008	–0.150	–0.027	0.034	–0.108

*Significant p value

Table 2. Morphometric parameters of the carotid canal

Morphometric parameters		Distance between [mm]				Diameter [mm]	
		Medial margins of external carotid canal	Lateral margins of external carotid canal	External openings of carotid canal and foramen lacerum	External margins of carotid canal and summit of mastoid process	Medio--lateral	Antero--posterior
Mean values		50.03	62.73	15.58	27.94	7.52	5.41
p	Side	–	–	0.355	0.192	0.177	0.000*
	Sex	0.696	0.328	0.416	0.347	0.470	0.228
	Race	0.117	0.098	0.636	0.503	0.266	0.034*
	Age	0.934	0.655	0.019*	0.064	0.888	0.748
r	Age	–0.009	–0.049	–0.184	0.146	–0.011	–0.025

*Significant p value

diameter was 7.52 mm, while the antero-posterior diameter was 5.41 mm (Table 2). There was a statistically significant difference between the antero-posterior diameter on both sides ($p = 0.000$) and race groups ($p = 0.034$) (Table 2). The antero-posterior diameter was thus marginally longer on the left side in the Caucasian population. Furthermore, the comparison of age and the distance between the external openings of the CC and foramen lacerum yielded a p value of 0.019 (Table 2).

DISCUSSION

The skull is regarded as the most valuable and common skeletal part for the determination of sex of unclaimed bodies in the medico-legal industry [7, 19]. Asymmetry regarding the base of the skull and the respective canals and foramina is considered to be the "variant-normal" [2]. It may be indicative of underlying congenital, acquired or hereditary diseases [21]. Despite the apparent symmetric nature of the skull-base, there appears to be distinct differences between the right and left sides [21]. In light of the reported asymmetry index of 66% and the constant central and variant lateral skull-base regions, it is plausible that the CC is subjected to both morphological and morphometric differences [16, 21, 27].

The external opening of the CC was found to be rounded, oval-shaped and tear-drop-shaped in 28.4%, 49.4% and 22.2% of cases in the present study, respectively. Aoun et al. [2] and Somesh et al. [23] reported the presence of round and oval-shaped external openings of the CC; however, the tear-drop-shaped opening observed in the present study has not been reported in the previous literature. In addition, Aoun et al. [2] reported that there is variation in the direction of the external opening of the CC between right and left sides. This was also corroborated by the present study as a statistically significant difference was found in the direction of the CC between right and left sides. It is postulated that the left side generally presents with an infero-medially directed CC.

This study identified the internal opening of the CC to be situated lateral, lateral and diagonal, postero-lateral and diagonal, and postero-lateral to the foramen lacerum. The foramen lacerum was postero-laterally related to the external aperture of the CC in 93.8% of the specimens which corroborated the findings of Standring [24], Netter [18] and Somesh et al. [23]. Furthermore, the external opening of the CC appeared lateral and diagonal, and lateral to the foramen lacerum, both of which were not reported in the literature reviewed. A statistically significant relationship between race and the position of the external opening of the CC in relation to the foramen lacerum was recorded ($p = 0.001$). As a result, it is proposed that the postero-lateral position of the external CC in relation to the foramen lacerum is a characteristic topographical feature of the African race group.

Standring [24] and Moore et al. [15] described that the internal opening of the CC was located anterior to the jugular foramen; this was found in 71.6% of cases in the present study. Moore et al. [15] found the external opening of the CC to lie just anterior to that of the jugular foramen. However, the CC was also noted to be located antero-medial and antero-lateral to the jugular foramen in this study, the former of which was reported by Somesh et al. [23].

The medio-lateral diameter of the CC in the current study was 7.52 mm which was greater than that recorded by Yamamoto et al. [29] (5.00 mm), Berlis et al. [4] (5.69 mm) and Arata et al. [3] (5.27 mm). Although the antero-posterior diameter

of the CC (5.41 mm) appeared to be larger than that reported by Lang and Schreiber [12] (5.14 mm) and Yamamoto et al. [29] (4.9 mm), Berlis et al. [4], Calguner et al. [6] and Somesh et al. [23] recorded relatively increased values of 7.81 mm, 6.75 mm and 8.14 mm, respectively. Subsequently, the results of the current study suggest that the antero-posterior diameter is typically longer on the left side. In the computed tomographic study conducted by Motoshima et al. [17], patients with Moyamoya disease presented with distinctively narrowed CCs than those of the control/asymptomatic group. As a result, the diameter of the CC is ultimately dependent on the embryological development of the ICA [10, 23]. During weeks 3 and 4 of embryonic development, the ICA arises from the arteries of the third aortic arch and the distal segment of the dorsal aorta [10]. Since the base of the skull only develops during week 5, the prior development of the internal carotid artery will determine the morphometric and morphological presence of the CC [10]. Despite the rare occurrence of ICA hypoplasia or agenesis, it may often result in the formation of collateral circulations and subsequent intracranial haemorrhage [10].

In the present study the mean distance of 27.94 mm recorded between the external margins of the CC and the summit of mastoid process was comparatively less than that reported by Cicekcibasi et al. [8] (31.08 mm). Despite the fact that the comparison of age and the distance between the external openings of the CC and foramen lacerum yielded a statistically significant p value of 0.019, the r value of –0.184 indicated a negative weak correlation (Table 2).

Although Motoshima et al. [17] discussed the unknown adverse effects of laterality and certain demographic factors on the dimensions and morphology of the CC, it may be postulated that the statistically significant differences regarding race, age and laterality yielded in this study are reflective of asymmetry, variation and/or possible underlying pathology.

CONCLUSIONS

The topographical relationships of the CC to the adjacent structures examined in this study may be of importance for accurate examination during imaging of the cranial base. Morphometric and morphological data on the CC may be of great significance to the field of forensic pathology for the determination of sex and race of unknown or unclaimed human remains. Anatomic knowledge of the CC topography and morphometry may be indispensable to the anatomist, radiologist, neurosurgeon and otorhinolaryngologist with regard to the surgical approach as this may lead to the development of refined procedures.

REFERENCES

1. Ahmed MM. A comparative study of right and left sided foramen ovale, jugular foramen and carotid canal. Karnataka. 2011: 1–11.
2. Aoun MA, Nasr AY, Aziz AMA. Morphometric study of the carotid canal. Life Science J. 2013.; 10(3): 2559–2562.
3. Arata W, Tomohiro O, Hidehito K, et al. Bony carotid canal hypoplasia in patients with moyamoya disease. J Neurosurg Pediatr. 2010; 5(6): 591–594, doi: 10.3171/2010.3.PEDS09417, indexed in Pubmed: 20515332.
4. Berlis A, Putz R, Schumacher M. Direct and CT measurements of canals and foramina of the skull base. Br J Radiol. 1992; 65(776): 653–661, doi: 10.1259/0007-1285-65-776-653, indexed in Pubmed: 1393389.
5. Berkoviz BK, Moxham BJ. Textbook of head and neck anatomy. Wolfe Medical Publications, London 1988.
6. Calgüner E, Turgut HB, Gözil R, et al. Measurements of the carotid canal in skulls from Anatolia. Acta Anat (Basel). 1997; 158(2): 130–132, indexed in Pubmed: 9311422.
7. Chimmalgi M, Kulkarni Y, Sant SM. Sexing of Skull by New Metrical Parameters in Western India. J Anat Society of Indian. 2007; 56(1).
8. Cicekcibasi AE, Murshed KA, Ziylan T, et al. A morphometric evaluation of some important bony landmarks on the skull base related to sexes. Turkish J Medical Science. 2004; 34: 37–42.
9. Faiz O, Moffat D. Anatomy at a Glance 2002. Blackwell Science Ltd, United Kingdom 2002.
10. Farhat W, Ahdab R, Hosseini H. Congenital agenesis of internal carotid artery with ipsilateral Horner presenting as focal neurological symptoms. Vasc Health Risk Manag. 2011; 7: 37–40, doi: 10.2147/VHRM.S16642, indexed in Pubmed: 21339912.
11. Hassanein E, Geneidi E, Taha M. The Cochlear-Carotid Interval: Preoperative Assessment for Cochlear Implant. Mediterrean J Otology. 2008; 4: 19–23.
12. Lang J, Schafhauser O, Hoffmann S. Uber die postnatale Entwicklung der transbasalen Schadelpoforten: Canalis caroticus, Foramen jugulare, Canalis hypoglossalis, Canalis condylaris und Foramen magnum. Anat Anz. 1983; 153(4): 315–357.
13. Lang J, Schrieber T. Uber form undlage des Foramen jugulare (Fossa jugularis), des Canalis caroticus und des Foramen stylomastoideum sowie deren postnatale Lagaveranderungen. Hals-Nasen-Ohrenheilkunde. 1983; 31: 80–87.
14. Mohr H, Nazer MB, Campos D. Calcification of the left carotid artery and its implications: a case report in human. J Morphol Sci. 2010; 27(1): 32–34.
15. Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy. 6th Ed. Lippincott Williams & Wilkin, USA 2010: 971–974.

16. Moss ML, Greenberg SN. Functional cranial analysis of the human maxillary bone: I, Basal bone. Angle Orthod. 1967; 37(3): 151–164, doi: 10.1043/0003-3219(1967)037<0151:FCAOTH>2.0.CO;2, indexed in Pubmed: 19919211.
17. Motoshima S, Noguchi T, Kawashima M, et al. Narrowed petrous carotid canal detection for the early diagnosis of moyamoya disease. Fukuoka Igaku Zasshi. 2012; 103(10): 206–214, indexed in Pubmed: 23327089.
18. Netter FH. Atlas of Human Anatomy. 5th Ed. Saunders Elsevier, USA 2011.
19. Ramteerthakar RN, Umarji BN. A study of carotid canals for identification of sex. Medico-Legal Update. 2012; 12(1): 110–111.
20. Resnick DK, Subach BR, Marion DW. The significance of carotid canal involvement in basilar cranial fracture. Neurosurgery. 1997; 40(6): 1177–1181, indexed in Pubmed: 9179890.
21. Russo P, Smith R. Asymmetry of human skull base during growth. Int J Morphol. 2011; 29(3): 1028–1032, doi: 10.4067/s0717-95022011000300062.
22. Rutz J. Masse und Verlaufe der SchadelkanaJe: Canalis caroticus, Canalis condylaris, Foramen mastoideum, 'Emissarium occipitale' sowie Form und Grosse der Lingula sphenoidalis. Med Diss, Wiirzburg 1975.
23. Somesh MS, Sridevi HB, Murlimanju BV, et al. Morphological and morphometric study of carotid canal in Indian population. Int J Biomechanical Res. 2014; 5(7): 455–460.
24. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. Elsevier Ltd, Spain 2008: 830–845.
25. Swartz JD, Bazarnic M, Naidich TP, et al. Aberrant internal carotid artery lying within the middle ear. Neuroradiology. 1985; 27(4): 322–326, doi: 10.1007/bf00339565.
26. Teufel J. Einbau der Arteria carotis interna in den Canalis caroticus unter Berucksichtigung des transversalen Venenabflusses. Morphologisches Jahrbuch. 1964; 106: 188–274.
27. Vinkka H, Koski K. Variability of the craniofacial skeleton. II. Comparison between two age groups. Am J Orthod. 1975; 67(1): 34–43, indexed in Pubmed: 803025.
28. Wysocki J. Topographical anatomy and morphometry of the temporal bone of the macaque. Folia Morphol. 2009; 68(1): 13–22, indexed in Pubmed: 19384825.
29. Yamamoto M, Jimbo M, Ide M. X-ray CT study of the carotid canal. International Atomic Energy Agency. 1987; 9(6): 659–664.
30. York G, Barboriak D, Petrella J, et al. Association of internal carotid artery injury with carotid canal fractures in patients with head trauma. AJR Am J Roentgenol. 2005; 184(5): 1672–1678, doi: 10.2214/ajr.184.5.01841672, indexed in Pubmed: 15855137.