ORIGINAL ARTICLE

Optic canal dimensions in a Nigerian cohort: Implications for neurosurgery and radiology

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Abstract

Background: The variant morphometry of the optic canal is important to neurosurgeons, radiologists and ophthalmologists in the diagnosis and management of skull base and intracanalicular lesions. *Aim and Objectives*: This study delved into the anatomical details of the optic canal morphometry, emphasizing its importance in neurosurgical and radiological practices. *Materials and methods:* Utilizing Computed Tomography (CT) images from a Nigerian Teaching Hospital, we retrospectively assessed the dimensions of the optic canal in 300 adult patients (160 males and 140 females). Rigorous ethical clearance was obtained, and image analysis included measurements of height, width, length of medial and lateral walls, and aperture diameters. Statistical analyses were conducted using SPSS software, examining variations based on age, gender, and side. *Results:* The left canal demonstrated a wider width, while the right exhibited a longer lateral wall ($p < 0.05$). Gender differences were noted in orbital and cranial aperture sizes. Age-group comparisons revealed significant differences in wall lengths and aperture diameters. The optic canal dimensions showed weak positive correlations with age ($p < 0.05$). *Conclusion:* This study contributes vital CT measurements of the optic canal, serving as a foundational reference for ophthalmologists, neurosurgeons, and radiologists. The population-specific findings emphasize the optic canal's significance in clinical practice, particularly in the context of surgical interventions and diagnostic precision.

Key words: Optic Canal, Dimensions, Surgery, Computed Tomography

Introduction

The passageway linking the orbit to the middle cranial fossa is referred to as the optic canal, nestled within the sphenoid bone and bounded by the anterior clinoid process laterally and the body of sphenoid medially [1-3]. The anterior and posterior roots of the lesser wings of sphenoid bone constitute the superior and inferior boundaries of the optic canal [3]. Within this canal, the optic nerve, enclosed in meninges, along with the ophthalmic artery and its periarterial sympathetic plexus, find passage [2, 4-6]. Originating as a cartilaginous foramen, the optic canal undergoes ossification and canalization in tandem with the normal embryonic development of the optic strut [2]. After complete ossification, the optic canal retains its size in adulthood, presenting as a cylindrical structure with a narrower anterior diameter [4, 7-8].

Given the heightened susceptibility of the intra-cranial portion of the ophthalmic artery and optic nerve to injuries and various disease conditions, a profound understanding of the optic canal becomes important for accurate diagnosis and prevention of intraoperative neurovascular injuries [3, 6]. The morphometry of the optic canal plays a pivotal role in both radiological diagnosis and surgical management of lesions within the middle cranial fossa, including the parasellar region [2-3]. Surgical access to lesions around the orbital apex and the regions encompassing the lesser and greater wing of the sphenoid, such as optic neuropathies, angiomas, meningiomas, pneumosinus, and neuromas, is often achieved through the intracranial part of the optic canal or the superior orbital fissure [2-4, 6].

During procedures targeting ophthalmic and superior hypophyseal aneurysms, as well as tumors around the parasellar region, removal of bones encircling the optic canal, including the anterior clinoid process and the lesser wing of sphenoid, is a common practice [2-3]. This emphasises the necessity for surgeons to be aware of the normal morphometry of the optic canal and its neuro-arterial relations to ensure successful intracanalicular procedures [2-3]. As a central osseous structure, the optic canal is a critical landmark during neurosurgical procedures [3]. Head injuries with trauma around the optic canal may lead to optic nerve injuries and subsequent visual defects, highlighting the vital role of understanding the anatomy of this canal in optic nerve decompression following trauma [3]. The dimensions of the optic canal exhibit variations across different populations, a phenomenon attributed to gender, race, and geographical disparities [2-4, 9-10]. Inconsistent growth and postnatal alteration of the optic strut contribute to the diverse shapes, size and asymmetries observed in the optic canal among individuals and populations [2]. These morphological variations hold significant implications for anatomists, ophthalmologists, neurosurgeons, and radiologists, enhancing the precision of diagnosis and management of patients with intracanalicular and skull base lesions [2-3]. The current advances in endoscopic endonasal decompression of the optic nerve as well as other approaches including transfrontal craniotomy, and orbitotomy have emphasized the need for precise population specific morphometric details of the optic canal [11-12].

The increased popularity of advanced imaging techniques in the recent years has facilitated the detection of abnormalities at the cranial base [2]. Furthermore, Computed Tomography (CT) provides an accurate depiction of the complex cranial base and the orbital apex, enabling the identification of minute anatomical alterations due to normal variants, trauma, or pathology [3, 9]. Radiological evaluation of the optic canal becomes indispensable in orbital imaging, given its deep location, narrow diameter, significant adjacent structures and the thin bone enveloping it [9]. Therefore, this study was designed to evaluate the morphometry of the optic canal using CT images of adult patients in a Nigerian Teaching Hospital.

Material and Methods

In this cross-sectional study, the dimensions of the optic canals were retrospectively assessed using apparently normal brain CT images sourced from the radiological database of a tertiary care hospital in Delta State Nigeria. Ethical clearance (HREC/PAN/2023/010/0542) was obtained for the retrieval of images from the Picture Archiving and Communication System (PACS). The images, acquired in 5 mm axial slices, originated from a Toshiba Aquillon 64 slice multi-detector CT scanner manufactured in Japan (2009). The acquisition parameters included a scan voltage of 120kV, a current of 300mAs, and a Field of View (FOV) of

250 mm. The imaging indications comprised suspected craniofacial fractures, intracranial bleeds, and tumors.

Three hundred CT images of apparently normal brains were purposively selected, encompassing 160 males and 140 females aged above 20 years. Exclusion criteria involved images from patients below 20 years, those with poor quality or suboptimal images due to metal and motion artifacts, sinus disease, orbital and skull base tumors, craniofacial fractures, congenital anomalies, and evidence of prior orbital or cranial fossae surgery.

The images were scrutinized on a designated computer desktop using a bone algorithm. The bilateral optic canals were identified on both coronal and axial slices. Measurements of the canal, performed using a digital caliper calibrated in millimeters, included the height (maximum vertical diameter) and width (maximum transverse diameter) on coronal reconstructed slices (Figure 1). The length of the medial and lateral walls and the diameter of the orbital and cranial apertures were measured on axial slices (Figures 2 and 3) [3]. The medial wall was delineated as the medial

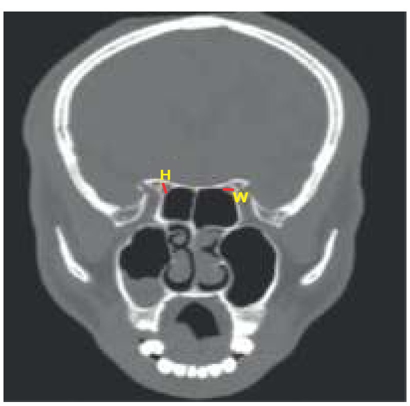

Figure 1: Coronal CT image showing the measurement of the height (H) and width (W) of the optic canal

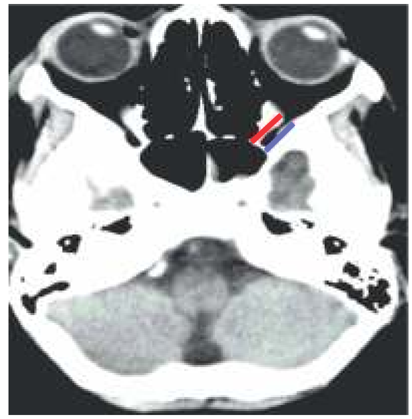

Figure 2: Axial CT slice showing the measurement of the length of the medial wall (red), length of the lateral wall (blue)

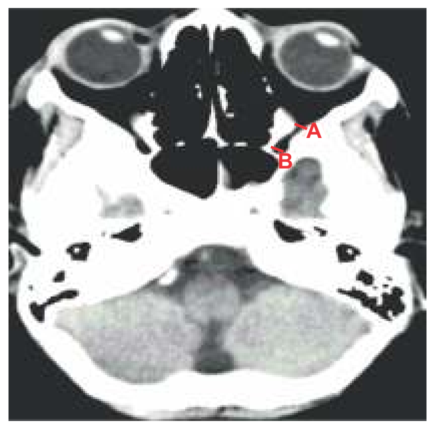

Figure 3: Axial CT slice showing the measurement of the diameter of the orbital (A) and cranial (B) apertures of the optic canal.

border of the posterior ethmoid sinus and sphenoid sinus, while the lateral wall was defined as the orbital margin of the anterior clinoid process [4]. To minimize interobserver bias, a single researcher conducted all measurements in triplicate, recording the average values. Data were classified based on age and gender and subsequently analyzed using IBM Statistical Package for the Social Sciences (SPSS) software Version 23 (New York, USA).

Gender and side comparisons employed independent and paired t-tests, respectively.

Differences in mean measurements across various age groups were assessed using Analysis of Variance (ANOVA). The association between variables and age was investigated through the Pearson's correlation test, with a significance threshold set at p-value < 0.05.

Results

The data under examination in this study comprised a total of 300 cranial CT images, with 160 males (53.3%) and 140 females (46.7%). The mean age of the studied population was 47.23 ± 2.12 years, ranging from 20 to 88 years. The majority of the population fell within the 50-60 years age group (28%), while the 80-90 years age group had the least frequency (1.67%). A detailed distribution of the population based on age and gender is presented in Table 1. Table 2 displays the mean measurements of the right and left optic canal variables. The width of the left optic canal was significantly larger than that of the right, while the right optic canal exhibited a longer lateral wall than the left ($p < 0.05$). Table 3 summarizes the mean variables in each gender group, revealing that the orbital and cranial apertures were significantly larger in males than females bilaterally ($p < 0.05$). However, no other variables showed significant gender differences ($p > 0.05$). The comparison of optic canal variables across different 10-year age groups is presented in Table 4.

Significant differences were observed in the lengths of the medial and lateral walls, as well as the diameter of the orbital and cranial apertures among age-groups. Table 5 indicates that the height and width of the optic canal did not exhibit statistically significant correlations with age, whereas all other variables showed a significant weak positive correlation with age ($p < 0.05$). The metric variables of the optic canal from various studies are documented and summarized in Table 6.

Table 1: Age and gender wise distribution of patients

Age groups (years)	Total population N (%)	MalesN (%)	Females N (%)
20-30	21 (7%)	11 (6.88%)	10 (7.14%)
31-40	58 (19.33%)	23 (14.38%)	35 (25%)
41-50	62 (20.67%)	41 (25.63%)	21 (15%)
51-60	84 (28%)	37 (23.12%)	47 (33.57%)
61-70	62 (20.67%)	41 (25.63%)	21 (15%)
71-80	8 (2.67%)	4 (2.5%)	4 (2.86%)
81-90	5 (1.67%)	4 (2.5%)	1 (0.71%)
Total	300 (100%)	160 (100%)	140 (100%)

Table 2: Descriptive statistics of all variables in the studied population.

Optic canal variables	Side	Minimum (mm)	Maximum (mm)	Mean ± SD (mm)	*p*
Height	**Right**	2.8	5.9	4.30 ± 0.48	0.058
	Left	3.2	6.2	4.34 ± 0.49	
Width	**Right**	3.1	7.9	4.83 ± 0.53	0.040*
	Left	3.7	6.3	4.88 ± 0.55	
Lateral wall length	**Right**	2.2	11.5	7.63 ± 1.43	0.007*
	Left	2.5	10.2	7.47 ± 1.42	
Medial wall length	**Right**	2.8	15.4	8.03 ± 1.53	0.291
	Left	3.4	17.9	7.95 ± 1.60	
Orbital aperture diameter	**Right**	1.3	3.7	2.44 ± 0.48	0.942
	Left	1.5	3.7	2.44 ± 0.48	
Cranial aperture diameter	**Right**	1.5	3.7	2.56 ± 0.42	0.090
	Left	1.1	3.7	2.53 ± 0.45	

Table 3: Gender differences in the measurements of the optic canal

Optic canal variables (mm)	Side	Males	Females	*p*
Height	**Right**	4.31 ± 0.48	4.29 ± 0.49	0.741
	Left	4.37 ± 0.51	4.30 ± 0.47	0.190
Width	**Right**	4.84 ± 0.53	4.80 ± 0.54	0.535
	Left	4.87 ± 0.56	4.89 ± 0.53	0.693
Lateral wall length	**Right**	7.70 ± 1.46	7.55 ± 1.39	0.360
	Left	7.53 ± 1.45	7.41 ± 1.39	0.484
Medial wall length	**Right**	8.15 ± 1.69	7.90 ± 1.30	0.151
	Left	8.02 ± 1.60	7.88 ± 1.60	0.440
Orbital aperture diameter	**Right**	2.51 ± 0.50	2.36 ± 0.45	0.008*
	Left	2.51 ± 0.51	2.36 ± 0.44	0.009*
Cranial aperture diameter	**Right**	2.61 ± 0.42	2.50 ± 0.42	0.015*
	Left	2.60 ± 0.47	2.45 ± 0.42	0.004*

Table 4: Difference in the mean variables of optic canal within different age groups

Optic canal variables (mm)	Side	20-30 years	31-40 years	41-50 years	51-60 years	61-70 years	71-80 years	81-90 years	*p*
Height	**Left**	4.30 ± 0.36	4.28 ± 0.46	4.32 ± 0.45	4.37 ± 0.59	4.37 ± 0.50	4.51 ± 0.22	4.16 ± 0.24	0.776
	Right	4.17 ± 0.54	4.22 ± 0.50	4.32 ± 0.46	4.34 ± 0.49	4.31 ± 0.465	4.53 ± 0.55	4.24 ± 0.15	0.467
Width	**Left**	4.82 ± 0.50	4.87 ± 0.50	4.82 ± 0.59	4.94 ± 0.60	4.87 ± 0.54	4.99 ± 0.21	4.80 ± 0.27	0.863
	Right	4.68 ± 0.53	4.75 ± 0.52	4.87 ± 0.51	4.87 ± 0.54	4.79 ± 0.57	5.18 ± 0.37	4.98 ± 0.25	0.247
Lateral wall length	**Left**	6.57 ± 1.66	7.22 ± 1.05	7.54 ± 1.19	7.54 ± 1.55	7.67 ± 1.45	7.96 ± 2.22	8.92 ± 0.71	0.006*
	Right	6.77 ± 1.72	7.43 ± 1.18	7.82 ± 1.24	7.62 ± 1.51	7.89 ± 1.49	7.55 ± 1.78	8.46 ± 0.22	0.031*
Medial wall length	**Left**	7.20 ± 1.35	7.52 ± 1.39	8.16 ± 1.59	7.99 ± 1.79	8.10 ± 1.28	8.53 ± 2.63	8.84 ± 0.33	0.003*
	Right	7.17 ± 1.52	7.79 ± 1.25	8.25 ± 1.71	7.97 ± 1.45	8.36 ± 1.60	8.11 ± 1.72	8.68 ± 0.18	0.038*
Orbital aperture diameter	**Left**	2.02 ± 0.35	2.16 ± 0.36	2.43 ± 0.33	2.58 ± 0.48	2.58 ± 0.54	2.76 ± 0.43	3.08 ± 0.38	0.001*
	Right	2.01 ± 0.41	2.21 ± 0.36	2.42 ± 0.31	2.55 ± 0.48	2.59 ± 0.56	2.68 ± 0.62	2.96 ± 0.36	0.001*
Cranial aperture diameter	**Left**	2.20 ± 0.29	2.31 ± 0.42	2.54 ± 0.35	2.64 ± 0.47	2.69 ± 0.47	2.56 ± 0.57	2.54 ± 0.24	0.001*
	Right	2.19 ± 0.04	2.40 ± 0.34	2.56 ± 0.29	2.63 ± 0.41	2.72 ± 0.51	2.64 ± 0.61	2.58 ± 0.11	0.001*

Table 5: Correlation between the optic canal variables and age

Optic Canal Variables (mm)	Side	Pearson's coefficient Coefficient	*p*
Height	**Right**	0.099	0.888
	Left	0.063	0.279
Width	**Right**	0.101	0.079
	Left	0.034	0.561
Lateral wall length	**Right**	0.162	0.005*
	Left	0.215	0.001*
Medial wall length	**Right**	0.162	0.005*
	Left	0.205	0.001*
Orbital aperture diameter	**Right**	0.384	0.001*
	Left	0.426	0.001*
Cranial aperture diameter	**Right**	0.308	0.001*
	Left	0.308	0.001*

Table 6: Comparison of the optic canal variables in different populations

Authors	Jiang *et al.,* (2015) [9]		Kalthur *et al.,* (2015) [4]		Ajay *et al.,* (2017) [2]		Zhang *et al.,* (2019) [10]		Khatun *et al.,* (2022) [3]		Current Study	
Country	China		India		India		USA		India		Nigeria	
Modality	CT		CT		CT		CT		CT		CT	
N	100		107		30		335		110		300	
Side	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Height (mm)					3.74	3.85	5.55	5.67	4.03	3.89	4.30	4.34
Width (mm)					5.82	5.73	3.33	3.24	4.07	3.87	4.83	4.88
Lateral wall Length (mm)	7.7	7.7	9.31	9.08			5.55	5.67	8.20	8.01	7.63	7.47
Medial wall length (mm)	11.9	11.9	11.10	10.16					9.21	9.01	8.03	7.95
Orbital aperture Diameter (mm)	5.13	5.18	2.9	2.9							2.44	2.44
Cranial apertureDiameter (mm)	7.33	7.37	4.68	4.51							2.56	2.53

Discussion

The mean height of the optic canal measured 4.30 mm and 4.34 mm on the right and left sides, respectively. Although higher than the findings documented by Ajay *et al.,* (2017) and Khatun *et al.,* (2022) [2, 3], these measurements were lower than those reported by Zhang *et al.,* (2019) [10]. Regarding the mean width, the optic canal measured 4.83 mm and 4.88 mm on the right and left sides, respectively. These values were higher than those reported by Khatun *et al.,* (2022) and Zhang *et al.,* (2019) [3, 10], but lower than the findings noted by Ajay *et al.,* (2017) [2].

This study observed shorter lateral and medial walls of the optic canal compared to findings documented by Khatun *et al.,* (2022), Kalthur *et al.,* (2015) and Jiang *et al.,* (2015) [3, 4, 9]. Conversely, Zhang *et al.,* (2019), reported a shorter lateral wall length compared to the findings in this study [10].

The mean diameter of the orbital and cranial aperture of this study measured 2.44 mm and 2.56 mm on the right side and 2.44 mm and 2.53 on the left side, respectively. These were smaller compared to findings reported by Kalthur *et al.,* (2015) and Jiang *et al.,* (2015) [4, 9].

The discrepancies in the morphometric parameters of the optic canal are attributed to population, regional, geographical, and racial differences [2, 3]. Moreover, variations in the modality, such as dry skull and CT images, different sample sizes and gender distribution, could also contribute to the observed differences [11]. Khantun *et al.,* (2022) noted significant differences between the optic canal variables measured on CT and those measured directly on the skull bones [3]. The dissimilarities observed from the CT studies could possibly be due to the use of different CT scanner models, associated software, and acquisition protocols at different imaging centers. Moreover, the reformatted slices used to measure each parameter could be responsible for the differences [2, 9-10]. The variations highlight the need for population-specific reference values to aid in proper diagnosis and surgical management of disease conditions associated with the optic canal.

Consistent with Sthapak *et al.,* (2023) and Kalthur *et al.,* (2015), our study reported significantly larger diameters of the orbital and cranial apertures of the optic canal in males than females ($p < 0.05$) [4, 11]. Khantun *et al.,* (2022) and Kalthur *et al.,* (2015) reported larger optic canal height, width, and length of the medial and lateral walls in males than in females [3, 4]. These gender differences may be due to variations is sex hormones, where higher testosterone in males contributes to larger bone size and larger skull features compared to females [13-14]. This is in concurrence with previous studies where the size of some foramina of the cranial base were larger in males than in females [15-16].

Smaller diameters of the optic canal in females may predispose to obstruction of the subarachnoid space and dysfunction or discontinuity of cerebrospinal fluid flow especially in patients with normal tension glaucoma and papilledema. Consequently, this may be responsible for rapid disease progression in females [11]. According to Ajay *et al.,* (2017), a narrow optic foramen is associated with optic nerve compression, subsequent optic neuropathy and atrophy and gradual loss of vision, presenting with reduced visual acuity, afferent pupillary defects, and visual field defects [2]. Initial clinical presentation of optic neuropathy overlaps with glaucoma, optic neuritis, maculopathy and cataract.

The width of the left optic canal and the length of the right optic canal's lateral wall were larger than corresponding variable of the contralateral canal. Kalthur *et al.,* (2015) and Zhang *et al.,* (2019) reported significantly larger measurements of the right than the left optic canal [4, 10]. On the contrary, Ajay *et al.,* (2017), Khatun *et al.,* (2022) and Sthapak *et al.,* (2023) did not observe any asymmetry in the optic canal variables [2, 3, 11]. According to Ratajczak *et al.,* (2021) asymmetry could be a result of left cerebral dominance in majority of the population and this is responsible for larger anatomical structures on the right side [17]. Asymmetry of skull base structures had previously been associated with genetic factors, epigenetic influences, and person's handedness [13-14]. Asymmetry of the optic canal with larger dimensions of the right compared to the left optic canal is common in patients with glaucoma and papilloedema [10].

The length of the lateral and medial walls, as well as the diameter of the orbital and cranial apertures, showed significant differences in various age-groups. Furthermore, these parameters exhibited a positive association with age. This could be associated with the increase in the diameter of the axons of the optic nerve and the thickness of the dura mater with age [18].

The prevalence of fractures of the sphenoid bone in Nigeria ranges from 35% to 46% among the adult population [19]. The findings of this study are important to neurosurgeons, ophthalmologists and radiologists for the proper diagnosis of pathologies related to the optic canal and to promote the preservation of its neurovascular contents during intracanalicular and subfrontal procedures [4]. The diameter of the optic canal apertures showed significant association with gender and age, providing valuable information that may be used to estimate the size of endoscopic instruments for the required surgery. The strength of the study is its reproducible protocol, providing a foundation for future research with a larger sample size to validate and expand upon our findings. The study is limited by the fact that it did not delve into some important aspects of endoscopic surgeries such as the neurovascular relations of the optic canal or its proximity to adjacent landmarks like the tuberculum sellae or tip of the nasal bone.

Recommendations

For future investigations, it is advised to employ a larger sample size gathered from diverse radiology centers. Additionally, utilizing a more sensitive magnetic resonance imaging protocol can enhance the precision of measurements. Evaluating the optic canal's distance from adjacent landmarks, including the tuberculum sellae and tip of the nasal bone, through radiological means is suggested. Further exploration into the accuracy of determining optic canal dimensions based on age and gender is warranted.

Conclusion

The study provides crucial CT measurements of the optic canal, offering fundamental baseline data for ophthalmologists, neurosurgeons and radiologists in their clinical practice.

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