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Evaluation of optic canal anatomy and symmetry using CT

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ABSTRACT

Objective We aim to describe the anatomy and symmetry patterns of the optic canal in patients having undergone maxillofacial CT imaging.

Methods In this retrospective chart review, we included all patients who received sinus and maxillofacial CT at the University of North Carolina hospitals between 2008 and 2016, without facial or cranial fractures or other medical conditions that would affect optic canal size. We measured the length of ≥75% enclosed canal, minimum cross-sectional area and minimum diameter bilaterally using iNtuition TeraRecon (Durham, North Carolina) and compared bilateral symmetry using a 20 % difference threshold. Each parameter above was compared among white, black, non-white and non-black patients.

Results Of 335 patients, the mean canal length was 5.61±2.22 mm. The mean minimum area was 11.84±3.11 mm^2. The mean minimum diameter was 3.28±0.55 mm. A total of 39.4% (132/335) of patients had asymmetric canal lengths, 18.8% (63/335) had asymmetric minimum areas, and 12.5% (42/335) had asymmetric minimum diameters. No differences were found between racial groups. The right optic canal was larger than the left (right: 12.12 mm vs left: 11.55 mm, $p<0.0001$).

Conclusion Optic canal asymmetry is not uncommon. It may affect risk of papilloedema severity, explain cases of unilateral or asymmetric papilloedema and possibly asymmetric glaucoma.

Key messages

What is already known about this subject?

- Anatomic studies have been performed detailing estimates of human optic canal anatomy. The optic canal may serve as a bottleneck for cerebrospinal fluid flow, which in turn may influence certain ophthalmic diseases.

What are the new findings?

- By using three-dimensional reconstruction techniques, we are best able to identify the most restrictive regions of the human optic canal. By doing so, we have identified anatomic averages for patient groups in our population. The frequency of optic canal asymmetry was identified for the first time.

How might these results change the focus of research or clinical practice?

- Future studies involving diseases that are influenced by cerebrospinal fluid, such as glaucoma, idiopathic intracranial hypertension and space flight-associated neuroocular syndrome, will have a methodology for optic canal size determination and a comparative group to base diseased and non-diseased anatomical differences.

INTRODUCTION

The optic canal is the narrowest point of the optic nerve subarachnoid space.[1]

As a watershed region for cerebrospinal fluid (CSF) flow, it has become a landmark of interest in ocular pathologies that involve the translaminar pressure difference (TLPD), including glaucoma and papilloedema from increased intracranial pressure (ICP) or space flight-associated neuro-ocular syndrome (SANS).[2–4] The TLPD is determined by the difference between intraocular pressure (IOP) and the CSF pressure in the subarachnoid space surrounding the optic nerve. A high TLPD as a result of the imbalance between IOP and CSF pressure has been implicated in glaucoma pathogenesis.[5–7] As the optic nerve traverses the optic canal, the size of the canal, intracanalicular dural–pial adhesions and resultant patent subarachnoid space limits the flow of CSF, which may subsequently affect the TLPD.[5–7]

While there have been prior studies regarding the anatomy of the optic canal, most have focused on the size of the cranial versus the orbital foramen of the canal as well as the length of the canal walls. Given that each optic canal wall tends to be of different length, there are portions of the optic nerve that may only have one or two sides bordered by an osseous wall while traversing the canal. However, Poiseuille's law for pressure differential produced by laminar flow within a tube indicates that only the length and cross-section of the enclosed tube are important. Furthermore, the narrowest portion of the canal that provides the most impediment to CSF flow tends to be in the middle of the canal,[8] whereas the existing literature has largely focused on the area of the optic and cranial exit points of the canal.

Given the potential implication of optic canal size in pathology, it is important to establish a baseline for the parameters of the optic canal in the general population. Furthermore, some studies have noted asymmetry of the optic canal in patients with asymmetrical degrees of glaucoma and papilloedema and posit that the former may be causing the latter, though it is unknown how much asymmetry is present in the general population.[2 3 9] In this study, we use three-dimensional reconstructions from maxillafacial and sinus CT to find the length of enclosed optic canal and minimum area and to discern the prevalence of optic canal asymmetry in a general population.

MATERIALS AND METHODS

Participants

In this retrospective study, sinus CT scans from patients who presented to University of North Carolina hospitals from 1 July 2008 to 7 November 2016 for any reason were reviewed. Of these, subjects with facial or cranial fractures or surgeries, fibrous dysplasia, Paget's disease, acromegaly and other conditions likely to affect optic canal size were excluded. Scans with slice thickness above 0.75 mm were excluded. All protocols adhered to guidelines from the Declaration of Helsinki.

Patient and public involvement

As this was a retrospective study that used only deidentified data following extraction of requisite information, patients were not involved beyond that described in this study.

Data collection

Prior to image analysis, demographic data including number of patients, gender, race and ethnicity were collected. All images were analysed using iNtuition TeraRecon (Durham, North Carolina). For each optic canal, the midline throughout the course of the canal on the transverse plane was established by setting points along the midline, and using the TeraRecon software, we subsequently established a midline by manually placing reference points to delineate the canal anatomy (figure 1A). The midline was then corrected on the sagittal plane (figure 1B). The cross-section of the canal perpendicular to the midline was viewed on each slice anterior to posterior until a cross-section showing an estimated 75% osseous enclosure was reached, which was established as point A (figure 1C). The use of 75% as the threshold was arbitrarily determined. Continuing from anterior to posterior, the last point at which the optic canal was 75% enclosed by bone was established as point B (figure 1D). The distance between point A to point B was determined to be the length of the optic canal (figure 1A).

The cross-sectional area of each slice from point A to point B was determined by manually drawing the osseous border with the freehand tool to find the slice with the smallest cross-sectional area (figure 1E). The minimum diameter at the smallest cross-section was calculated by the software (figure 1E). The protocol was repeated for

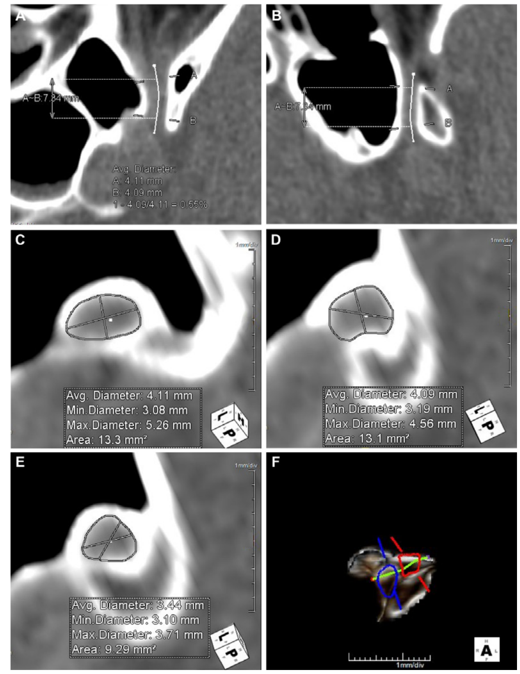

Figure 1 TeraRecon analysis of sinus CT images. (A) The midline is manually traced on the transverse plane using freehand tool. (B) The midline is corrected on the sagittal plane. (C) Point A is established as the beginning of estimated 75% osseous enclosure. (D) Point B is established as the end of estimated 75% osseous enclosure, subsequently producing optic canal length as distance between point A and point B on the transverse and sagittal views. (E) minimum cross-sectional area is established by tracing the cross-sectional area on each slice from point A to point B. The minimal diameter at the smallest cross-sectional area is also established. (F) Reconstructed three-dimensional optic canal is shown; blue tracing represents point A, red tracing represents point B and centre line is shown in green. Of note, figure 1F shows reconstruction for a different optic canal as shown in figure 1A through figure 1E. Small boxes in the lower right-hand corner show orientation. A, anterior; avg, average; F, feet; H, head; L, left; P, posterior; R, right.

the other optic canal. A three-dimensional reconstruction of a right optic canal is shown in figure 1F.

Data analysis

The overall average for lengths, minimum area and minimum diameter at minimum area were calculated for the right eyes, the left eyes and both combined. These averages were calculated for all subjects and racial subgroups including white, black, non-white and non-black patients. As there were relatively few patients of non-white, non-black race, these patients were grouped together into the 'other' category. The average measurements for length, minimum area and minimum diameter was compared among all groups using the one-way analysis of variance (ANOVA). If a statistically significant difference was found, a two-tailed t-test was used to compare parameters between white and black subjects, white and other subjects and black and other subjects.

Table 1 Demographic data of the study population

	Total (n=335)		White (n=213)		Black (n=89)		Other/unknown (n=33)		P value	
Age, years (mean, SD)	67.7	12.7	70.3	11.4	64.1	12.1	60.9	16.6	W/B	**<0.001**
									W/O	**0.002**
									B/O	0.16
Male (%)	128	38.2%	83	39.0%	31	34.8%	14	42.4%	W/B	0.49
									W/O	0.71
									B/O	0.44

Average age and percentage of males in the study population divided into white, black and other/unknown (patients who either did not have recorded race or declined to identify their race). P values calculated using two-tailed Student's t-tests for average age and the z-test for percentage of males.
B, black; O, others/unknown; W, white.

The length, minimum area and minimum diameter for the right and left optic canal of each subject were compared for symmetry. Bilateral measurements were considered to be symmetrical if the right optic canal parameter was within 80%–120% of the left optic canal parameter, non-inclusive. The percentage of subjects overall and in each racial category that had symmetrical parameters were calculated. The percentage of subjects with bilateral symmetry for each parameter in each racial category was calculated and compared using the z-test.

The one-way ANOVA was used to compare the average ages of the white, black and other groups and the two-sample t-test assuming unequal variance was used for comparisons between pairs of groups for any differences found. The z-test was used to compare the proportion of male subjects across the groups. Statistical analyses were performed using Microsoft Excel 2016.

RESULTS

CT sinus scans from 335 subjects (128 males, 38.2%) were measured for a total of 670 optic canals (table 1).

Of these, 213 were white, 89 were black. Another 33 subjects were neither white nor black, including 18 patients who were ethnically Hispanic or Latino and selected their racial group as 'other', 2 Asians and 13 subjects who either did not have a recorded race or declined to identify their race. These non-white and non-black patients were grouped into the 'other' category. The average age was 67.7±12.7 years. The average age of the white group was significantly older than the average age of the black (p<0.001) and the other group (p=0.002), and there was no significant difference in age between the black and other group (p=0.16).

Length, minimum area and minimum diameter at minimum area of optic canal divided by race and laterality are shown in table 2.

A significant difference was found between the three groups for length of optic canal (p=0.02). Specifically, white subjects had shorter optic canals than subjects of the 'other' category (p=0.02). The difference existed for the right optic canal (p=0.04) but not the left (p=0.19).

The bilateral symmetry for length, minimum area and minimum diameter are shown in table 3.

Comparing the left and right optic canals, a higher percentage of the population had asymmetry of length than asymmetry of minimum area. There were no differences in percentage of individuals with asymmetry in length or area between the racial groups.

Comparisons of right and left optic canals were performed for all patients. The canal lateral wall length measurements (right, left, difference, p value) were 5.55 mm, 5.67 mm, −0.12, p=0.120. The minimum area of the optic canal for right, left, difference and p value was 12.12 mm, 11.55 mm, 0.58 mm, p<0.0001. For the minimum diameter at the point of minimum area the measurements were (right, left, difference, p value): 3.33 mm, 3.24 mm, 0.09 mm, p<0.0001.

There were 38 patients identified with glaucoma, not differentiated by subtype, in this study. Cup-to-disc ratios were determined from the last clinic note signed by an attending ophthalmologist or optometrist at our institution. Cup-to-disc asymmetry was determined as greater than 0.05. Size of the optic nerve was not taken into account. Of 38 patients with glaucoma, 23 had greater than 0.05 cup-to-disc asymmetry. Of those 23 with cup-to-disc asymmetry, 18 (78.2%) had evidence of optic canal asymmetry in at least one parameter. In the 15 glaucoma patients without cup-to-disc asymmetry, 6 had evidence of optic canal asymmetry (40%). The relationship of the larger optic canal parameter and larger cup-to-disc ratio was determined. Fifteen of 23 patients (65.2%) had smaller cup-to-disc ratios in the orbits with the larger optic canal.

Only one patient had a history of possible idiopathic intracranial hypertension, and the nerves were symmetric in this case. The lateral walls of the canal were asymmetric in this patient's case, but all other parameters of optic canal dimensions were symmetric.

DISCUSSION

Length of optic canal

Previous studies have found the length of the optic canal to vary significantly from approximately 5–15 mm.[9 10] In this study, we found the average length of the optic canal to be 5.61±2.22 mm. In a study of 25 adult skulls, Akdemir *et al*[10] defined canal length to be the difference

Table 2 Comparisons of optic canal structural parameters

	Total (n=335)		White (n=213)		Black (n=89)		Other (n=33)		P values	
Combined										
Length, mm (mean, SD)	5.61	(2.22)	5.44	(2.07)	5.83	(2.60)	6.10	(1.88)	W/B	0.05
									W/O	**0.02**
									B/O	0.45
Minimum area, mm^2 (mean, SD)	11.84	(3.11)	11.96	(3.17)	11.69	(3.14)	11.45	(2.56)	W/B	0.34
									W/O	0.21
									B/O	0.58
Minimum diameter, mm (mean, SD)	3.28	(0.55)	3.30	(0.55)	3.25	(0.57)	3.25	(0.48)	W/B	0.25
									W/O	0.50
									B/O	0.91
OD										
Length, mm (mean, SD)	5.55	(2.26)	5.33	(2.14)	5.84	(2.56)	6.16	(2.05)	W/B	0.08
									W/O	**0.04**
									B/O	0.52
Minimum area, mm^2 (mean, SD)	12.12	(3.20)	12.27	(3.24)	11.90	(3.28)	11.79	(2.62)	W/B	0.38
									W/O	0.42
									B/O	0.86
Minimum diameter, mm (mean, SD)	3.33	(0.54)	3.34	(0.54)	3.29	(0.59)	3.34	(0.44)	W/B	0.44
									W/O	0.98
									B/O	0.65
OS										
Length, mm (mean, SD)	5.67	(2.17)	5.55	(1.99)	5.82	(2.66)	6.03	(1.72)	W/B	0.32
									W/O	0.19
									B/O	0.67
Minimum area, mm^2 (mean, SD)	11.55	(3.00)	11.65	(3.07)	11.47	(3.00)	11.10	(2.49)	W/B	0.64
									W/O	0.33
									B/O	0.53
Minimum diameter, mm (mean, SD)	3.24	(0.54)	3.26	(0.55)	3.20	(0.54)	3.17	(0.50)	W/B	0.39
									W/O	0.36
									B/O	0.76

Length, cross-sectional minimum area and minimum diameter at minimum area of optic canal divided by race for combined left and right eye, right eyes alone and left eyes alone. P values are calculated using two-tailed Student's t-tests.
B, black; O, others/unknown; OD, right eye; OS, left eye; W, white.

between the distances from the maxilla-lacrimal suture to the intracranial and orbital opening of the optic canal and found an average length of 11.19±2.68 mm for the right eye and 12.42±3.38 mm for the left. Slavin *et al* studied 20 cadaveric specimens and found the length of the canal, defined as equivalent to the intracanalicular portion of the optic nerve, to be 10.74±1.16 mm.[11] Other studies defined the length of the optic canal similarly to this study. Abhinav *et al*[12] performed endoscopic endonasal dissections on 10 fresh human heads, using the optic strut as the beginning of the enclosed osseous canal and found the length of canal to be 5.90±0.70 mm in the right eye and 6.20±0.75 mm in the left, similar to the findings in our investigation.[12]

While Poiseuille's law applies to a completely enclosed canal, in anatomical terms, the flow of CSF is constricted by the bony canal and the dura and subarachnoid maters. It is assumed that an enclosed canal would prevent any meaningful outpouching or laxity in the dura mater and maintain a flow that mimics that of an enclosed tube. Thus, the threshold for enclosure in this study was arbitrarily set at 75%.

In this study, we found that the average optic canal length of the white group was significantly shorter than that of the other group, and on further subanalysis, the difference was only significant for the right eye. Given the small number of subjects in the other category and the racial heterogeneity of this group, further study is recommended before extrapolating this finding. It is possible that with more subjects in the black and other group, a consistent and statistically significant difference would have been found between these and the white group.

Table 3 Comparison of bilateral asymmetry

	Total (n=335)		White (n=213)		Black (n=89)		Other/unknown (n=33)		P values	
Length symmetry (%)	132	39.4%	92	43.2%	28	31.5%	12	36.4%	W/B	0.06
									W/O	0.46
									B/O	0.61
Minimum area symmetry (%)	63	18.8%	41	19.2%	16	18.0%	6	18.2%	W/B	0.81
									W/O	0.89
									B/O	0.98
Minimum diameter symmetry (%)	42	12.5%	29	13.6%	12	13.5%	1	3.0%	W/B	0.98
									W/O	0.09
									B/O	0.10

Percentage of study population with asymmetry of length, minimum area and minimum diameter between right and left eyes, defined as the right eye parameter being less than 80% or greater than 120% of the left eye parameter, non-inclusive. P values calculated using the z-test. B, black; O, others/unknown; OD, right eye; OS, left eye; W, white.

Given that these groups tend to have a higher risk of glaucoma,[13] there may be an underlying link between canal length and glaucoma risk that warrants further research.

Limited prior reports have compared the overall length of the right versus the left optic canal length within study cohorts and have found no significant difference.[14] However, while variations may level out on a population level, few studies have looked at the amount of symmetry present on an individual level. We found that 132 of 335 patients (39.4%) had greater than 20% difference in the length of bilateral canals. In terms of Poiseuille's equation, length is a much smaller determinant of pressure than radius, though it remains a consideration.

Minimum cross-sectional area

In this study, we found the average minimum area of the optic canal to be 11.84±3.11 mm^2. Prior studies have mostly focused on the size of the optic foramen or the cranial foramen, though a few have looked at minimum cross-sectional area through the entire length of the canal. Jiang *et al*'s study reviewed optic canal CT images of 100 healthy volunteers using 2.5 mm slice thickness, reconstructed 0.625 mm thickness and showed that the narrowest part of the optic canal tends to be in the middle of the canal.[8] Another study using CT images from 300 healthy volunteers found a minimum cross-sectional area of 13.85±2.89 mm^2 with a range of 11 to 16.75 mm^2, which are similar to our findings.[15] Lee *et al* investigated comparisons of the narrowest cross-sectional area of the optic canal between 38 patients with fibrous dysplasia and 38 healthy controls and found an average area of 11.9±2.8 mm^2 in the control group, also comparable with our findings.

The optic canal places constraints on the subarachnoid space around the optic nerve and may subsequently influence CSF dynamics. Killer *et al* performed CT cisternography on 18 patients with bilateral normal tension glaucoma (NTG) and found a higher concentration of contrast-loaded CSF in the intracranial space compared with the subarachnoid space around the optic nerve, which was not found in the control group.[16] A smaller optic canal may act as bottleneck and contribute to compartmentalisation in addition to other factors such as increased meningothelial cell proliferation secondary to increased ICP as well as large numbers of trabeculae and septae in the optic nerve subarachnoid space.[17 18] Pircher *et al*[19] showed that the average orbital opening of the optic canal in patients with NTG is smaller than that of healthy patients and posit that the narrower optic canal opening may be disrupting the CSF flow. Establishing a baseline for the narrowest part of the optic canal provides ease of comparison in future studies and provides anatomical information for clinical decision making. For example, Bekerman *et al*[15] suggests measuring optic canal size concurrently with optic nerve sheath diameter (ONSD) when monitoring ICP and to interpret ONSD cautiously when the optic canal is narrower than 6.6 mm^2. At this cut-off, 4.8% (16/335) of optic canals would be excluded from ONSD monitoring based on these criteria. We do suggest, however, that interpretation of ONSD monitoring would not take into account only optic canal dimensions but the actual intracanalicular patent subarachnoid space, as this determines the true capability of CSF pressure transmission between the cranial and orbital compartments.

Of 335 subjects in our study, 272 (81.2%) had symmetric optic canals, leaving 18.8% of the population with optic canals that differed more than 20% bilaterally. Sohan Hayreh in 1964 suggested that the optic canal was important in the transmission of CSF pressure from the cranial compartment to the orbital compartment.[9] He suspected that this was the underlying reason for cases of unilateral or asymmetric papilloedema with increased ICP. In a study by Bidot *et al*[2] of 559 adult patients with idiopathic intracranial hypertension, 20 patients had very asymmetric papilloedema. Of those 20 patients, eight patients had neuroimaging, which showed smaller optic canal on the side with lower grade oedema for all eight patients.[2] Since asymmetry of canal size is associated with asymmetric pathology, establishing the prevalence of asymmetry informs clinical understanding of the potential latent predisposition towards asymmetrical pathology in a population. Wall and White studied 478 patients with idiopathic intracranial hypertension and found the prevalence of highly asymmetric papilledema to be 10%.[18] If asymmetry of minimum cross-sectional area is the underlying aetiology of asymmetric papilloedema, in this study, we found twice the amount of asymmetry compared with Wall and White prior. However, there is likely a gap of unknown magnitude between measurable optic canal minimum area asymmetry and the degree of minimum area asymmetry that results in appreciable asymmetric papilloedema.

Minimal cross-sectional diameter

Bekerman *et al* measured CT scans from 300 volunteers and found that the average minimum diameter at the minimal area of the optic canal is 4.2±1.7 mm for circular lumens and 4.0±1.6 mm for oval lumens,[15] which are somewhat larger but still comparable to our average of 3.28±0.55 mm. Jiang *et al*[8] measured multiple layers through the optic canal and found a minimum diameter of 4.86±0.26 mm on the left and 4.91±0.30 mm on the right which is slightly larger than our measurements, likely as a result of averaging measurements at each set slice rather averaging results at the narrowest portion of each canal. Of the 335 subjects in this study, 293 (87.5%) had bilateral minimum diameters that did not differ more than 20%, without differences in proportions between racial groups. Our finding of 13% prevalence of asymmetry in minimal cross-sectional diameter corresponds more closely with the 10% prevalence of highly asymmetric papilledema found by Wall and White compared with our finding of 18.8% prevalence of asymmetry in minimum area.[20] It is possible that minimum cross-sectional diameter is the more significant underlying factor in producing clinically appreciable asymmetry in conditions such as papilloedema rather than cross-sectional area as discussed above. To our knowledge, this is the first comparison of optic canal minimum cross-sectional diameters among racial groups.

Implications

The concept of the TLPD was introduced at the turn of the 20th century by Kasmir Noishevsky. He performed an experiment on a dog to prove his hypothesis that NTG was due to an imbalance between IOP and CSF pressure. The dog, which was drained of its CSF for 1 month, developed ‘glaucomatous excavation’ of its optic nerves.[21] This theory was investigated in retrospective fashion nearly 100 years later by Berdahl and colleagues.[7] Patients with primary open angle glaucoma and NTG had lower CSF pressures compared with non-glaucomatous controls, while patients with ocular hypertension had higher CSF pressure compared with their own control group. This suggested that an increased CSF pressure could actually be protective against the formation of glaucoma.[7]

The reverse may hold true as well, based on case reports and a case series.[22–24] The authors treated bilateral ocular hypertension with unilateral trabeculectomies, only for these eyes to form oedematous nerves despite low but non-hypotonous IOPs. After appropriate workup, the patients were found to have elevated or borderline-elevated CSF pressures, suggesting that increased IOPs may have masked papilloedema by serving as a counterbalance to increased ICP. Extrapolating this concept, we suggested the possibility of treating papilloedema from idiopathic intracranial hypertension or from SANS by inducing permissive ocular hypertension.[25] To follow-up this concept, we performed a large, retrospective study on the relationship of the translaminar pressure differential and papilloedema severity.[26] The study concluded that there was no relationship between any of the significant TLPD parameters and suggested other factors must be more important in this relationship. We failed to include optic canal size and asymmetry as relevant parameters, and this was the likely reason for the negative results. Direct investigations of orbital and intracranial CSF pressure by Morgan *et al*, Hou *et al* and Liu and Kahn all suggest that the optic canal restricts fluid connectivity, thereby reinforcing this conclusion.[27–30]

In the present study, we identified patients with glaucoma and correlated the frequency of optic canal asymmetry to asymmetric nerve cupping. While this is an otherwise inadequate estimate of glaucoma severity, as the study was not designed to correlate type and severity of glaucoma, this retrospective analysis could only serve as an estimate of this relationship. It was interesting to note the frequency of larger optic canals in the eyes with smaller cup-to-disc ratios. If this were to be extrapolated to true glaucoma severity, then it would be theorised that the increased dimensions of the optic canal permit increased CSF flow and therefore form a ‘protective’ affect behind the lamina cribrosa. This is an area of future investigation.

Strengths/weaknesses

The study serves to establish a baseline of optic canal dimensions using CT. Although there have been many studies of optic canal dimensions, the strength of our approach includes defining the optic canal in a way that is relevant to the fluid mechanics within the canal, which has implications for conditions such as glaucoma and papilloedema, and by performing three-dimensional reconstructions to ensure localisation accuracy. These measurements are easily replicated in living patients, as a CT maxillofacial and sinus is a non-invasive test that is widely available. Furthermore, rather than calculating the area of the optic canal from height and width, we used a manual freehand tracing of the area, allowing more precise calculations of area especially in cases of more irregular lumen.

Weaknesses of this study include a smaller non-white, non-black cohort, as the ‘other’ category only had 33 patients and included patients of various racial backgrounds. Furthermore, while we attempted to exclude all patients who have conditions that may affect the optic canal dimensions including facial and cranial trauma, intracranial surgery, Paget's disease and fibrous dysplasia, there may have been patients with undiagnosed conditions that may affect optic canal size. We suspect this would only affect a small minority of our study group. Lastly, visualisation of the optic nerve itself and the fluid space around the nerve is suboptimal on CT, with MRI being more sensitive for soft tissue. A combination of both of these modalities may provide better resolution of actual patent intracanalicular subarachnoid space, but even this would be a difficult task given the small space afforded for CSF flow in this space. Furthermore, The optic canal consists of bone and the arachnoid layer formed by pressure-sensitive meningothelial cells.[31] Lastly, the intracanalicular dural–pial adhesions limit regional flow within the canalicular nerve. [32 33]

Despite these limitations, our study provides valuable optic canal measurement data using an easily reproducible protocol in a population larger than was available in previously published works. Future studies would benefit from a larger sample size and a more sensitive MRI protocol tailored for optimal visualisation of the optic canal, optic nerve and subarachnoid space.

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