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Normative Orbital Measurements By Computed Tomography In North Indian Population – A Retrospective Study.

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Abstract
Background
Knowledge of normal orbital dimensions is essential for the diagnosis of orbital pathologies. Precise orbital measurements can be obtained with reasonable accuracy using computed tomography (CT). The present study was carried out to ascertain criteria for the normative values of the various orbital dimensions using computed tomography in patients visiting our institution .We measured parameters like orbital volume, length of the interzygomatic line , ocular diameter, the distance of the posterior extent of the globe from the interzygomatic line, diameters of extraocular muscles (medial, lateral, superior group, and inferior rectus), globe position, and lens density in each eye of 90 patients who came for head CT in our institution . Besides getting normative value for general population, normative value for different sexes was also obtained. Comparison was also made for variables and age wherever applicable.
Results
Mean values (mean±SD) of orbital volume, ocular diameter (anteroposterior and mediolateral), interzygomatic line , globe position and lens density were 18.95±3.16 cm^3 , 2.19±0.10 cm and 2.31+/- 0.10 cm, 96.5±4.3 mm, 6.5 +/- 2.2 mm and 78.50 ± 6.92HU respectively. Mean diameters of extraocular muscles were 0.40 ± 0.06 cm, 0.32± 0.07 cm, 0.74±0.11 cm and 0.82±0.12 cm for medial rectus, lateral rectus, inferior rectus and the superior group respectively. There was no significant age and gender difference in most of the measurements. Lens density and age of subject showed significant positive correlation. Also there was significant correlation of interzygomatic line with lens diameters. There was no significant difference in measurements of left with right eye for same individual.
Conclusion
Measurement of ocular parameters observed in this study was comparable to studies taken on foreign soils. However this study determines a significant difference in some parameters in male and female population in India. This study also helps to create a database for normal ocular parameters in north India.
Keywords : *CT, Orbital diameters, ONSD, orbital measurements, orbit*

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I. BACKGROUND

Vision is one of the special senses. Eyes are the sense organs for vision. Many diseases (like macrophthalmia and microphthalmia, hypermetropia and myopia, astigmatism, presbyopia etc.) that cause alteration in the dimensions of eye and/or its components may result in visual abnormalities[1]. Dimensions of eye are also checked at TIFFA scan in prenatal babies and may confirm the presence of other abnormalities also. The orbits should be evenly spaced and nearly equal in size. Interorbital distance is approximately equal to width of each orbit dividing the face into three parts each constituting approximately one-third of the extraocular distance. Diseases associated with reduced ocular volume include persistent hyperplastic primary vitreous, Phthisis bulbi and Coat's disease. Glaucoma may lead to increased ocular volume. Similarly some other conditions like Grave's disease cause enlargement of extraocular muscles. Besides, various neoplasms and inflammatory conditions can cause enlargement of extraocular muscles[2]. While nomogram of different set of populations is available it is imperative to have a nomogram of local population as orbital dimensions are race and ethnicity dependent[1].Optic nerve is one structure that has its direct origin from brain and is composed of oligodendrocytes rather than

Schwann cells like peripheral nerves. Because of its special origin changes in optic nerve sheath diameter (ONSD) may indicate changes in intracranial pressure[3].Orbital volume can keep on changing throughout life with aging and other short and long term changes[4]. While there is no actual estimate of how to calculate orbital volume, initial studies relied on calculating the volume by filling water in dead skulls[4]. The values obtained such have been found to be in accordance with values obtained by CT scan[4].CT is an important modality to diagnose and evaluate various parameters of eye. CT offers high precision and objective study is possible. There is a relative lack of literature and original data on normal dimensions of orbital structures involving North Indians on CT imaging. Hence this CT based study was carried out to help establish nomogram of various orbital dimensions and create a database that may be referred to evaluate further normal and abnormal values.

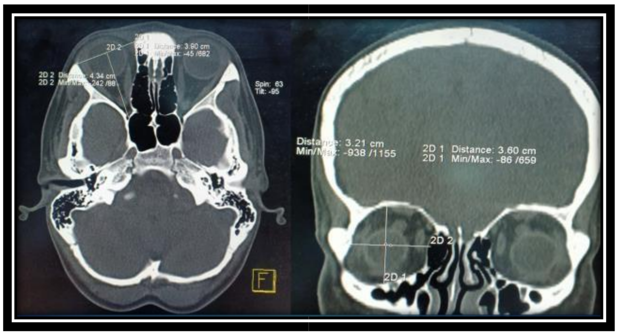
II. METHODS

A retrospective cross-sectional study was carried out in our institution. A total of 90 patients who had undergone head CT for some medical condition in the time period of July to December 2020 were included in the study. Thus data on 180 eyes was obtained. General and medical history of the patients taken was obtained as maintained in the record books of CT. The names and identity of the patients is kept fully confidential. Purposive sampling method was used. All the patients with any skull, orbital bone or maxillary fracture or any other soft tissue injury in or around the eye were excluded. Patients who were operated for cataract with intraocular lens were excluded. Patients with history of thyroid disease or any known disease were excluded from the study. Further CT scans with motion artifacts, eye motion or those showing abnormal values were excluded. Also all the patients not looking straight or with motion artifact in eye were excluded.

All cases below the age of 10 were excluded. In our study youngest case was 11 years in age and eldest 75 years in age.

Orbital volume was obtained by likening eye orbit to that of a cone. Front bony socket was designated as base of cone and height of cone was obtained from the line representing the diameter of cone to the most posterior corner of orbit as the tip of cone. Diameter of cone was obtained by first taking coronal view of the orbit. Then both supero-inferior and mediolateral diameters were obtained for each eye socket. Average of two was considered diameter of base. After obtaining height, formula of volume of cone was applied ($4\pi r^3/3$). All the images were reviewed at constant window level/ width setting of 50/300 and slice thickness of 1 mm.

To determine the normal globe position in CT, the interzygomatic line (IZL) at the midglobe section was used as a reference line. The length of the IZL represents the transverse head size, and was defined by the anterior extent of the lateral bony orbital rims. The globe position (GP) was given as the perpendicular distance between the interzygomatic line and the posterior margin of the globe. The optic nerve sheath diameters (ONSD) of both eyes were also measured at 10 mm distance from the globe, perpendicular to its course in the axial sections. The superior rectus, superior oblique and levator palpebrae superior muscle had to be measured collectively as a single unit referred to superior group (SG) henceforth as these could not be differentiated individually. We measured diameters of the superior group (SG) and inferior rectus (IR) muscles on coronal section and lateral rectus (LR) and medial rectus (MR) muscles were measured on axial CT section. The images were adequately magnified to allow easy placement of the cursors of the measuring calipers. Ocular diameters (OD) were measured in the form of *axial length* (distance through the visual axis from the anterior corneal surface to the posterior wall of the choroid in axial view and it included the anterior chamber depth, lens thickness, and vitreous length) and *width* (maximum transverse distance between the temporal and nasal ends of the globe in axial view) - **Figure 1** . The slices chosen for ocular measurements were mid-ocular slices showing the maximum axial size of the eyeball, the lens and optic nerve as well as the insertions of the medial and lateral rectus muscles. The attenuation of the lens was measured by drawing a region of interest selecting ROI tool available in the software in the center of eye lens. The average attenuation in Hounsfield Unit (HU) displayed was recorded as the lens density (LD). Data was collected on an Excel spreadsheet (Microsoft Corp., Redmond, WA, USA). Data was analyzed with Statistical Package for Social Studies (SPSS 23) (IBM Corp., New York, NY, USA) and tested for normal distribution. The mean, standard deviation and range were calculated. The variations of Orbital Volume, diameters of Medial Rectus, Inferior Rectus, Lateral Rectus, Superior group, Orbital diameters and Lens Density in different age and sex groups were analyzed. Also variation of orbital diameters with interzygomatic line was also assessed. The independent-sample t-test was used to compare data obtained from male and female patients as well as the right and the left orbit to check statistical significance at the $p=0.05$ level. The difference of means and 95% confidence interval (CI) were used to evaluate the variations by gender and different age groups. Correlation analysis was performed using the method of Karl-Pearson. Group comparisons were made using parametric and nonparametric two-tailed t-tests wherever appropriate and indicated. A p value< 0.05 was considered statistically significant.



A B

Figure 1 : Showing method of measurement of *axial length* on axial CT section (A) and *ocular diameter* , which is the average of vertical and horizontal diameters on a coronal image (B).

III. RESULTS

Out of the 90 individuals taken up for study 51(57%) were males and 39 (43%) were females. Age of individuals range from 11-75 with maximum cases (>50 percent) among age group 20-40 years and mean age 36.144 years.

Mean and range of orbital volume, antero-posterior diameter , medio-lateral diameter, global position and diameter of medial rectus, lateral rectus, inferior rectus and superior muscle group, lens density, orbital nerve sheath diameter and interzygomatic distance for each eye were obtained (Table 1 and 2) .

Table.1.

Right Eye	Mean ± SD	Maximum	Minimum	Range (Max-Min)
ORBITALVOLUME(cm^3)	18.99 ± 3.18	28.7	12.83	15.87
AP(cm)	2.19 ± 0.10	2.47	1.96	0.51
MLO(cm)	2.32 ± 0.10	2.64	2.12	0.52
IZL(cm)	9.65 ± 0.43	10.89	8.69	2.20
GLOPOS(cm)	0.65 ± 0.21	1.09	0.12	0.97
MR(cm)	0.41 ± 0.07	0.57	0.26	0.31
LR(cm)	0.32 ± 0.07	0.53	0.13	0.40
IR(cm)	0.75 ± 0.10	0.93	0.45	0.48
SG(cm)	0.83 ± 0.11	1.18	0.59	0.59
LENS DENSITY (HU)	78.50 ± 6.92	93.00	47.20	45.8
ONSD(cm)	0.43 ± 0.06	0.58	0.28	0.30

AP = anteroposterior diameter , MLO = mediolateral diameter, IZL = interzygomatic line, GLOPOS= globe position, MR = medial rectus ,
LR= lateral rectus , IR =inferior rectus , SG = superior group muscles, ONSD = Optic nerve sheath diamter

Table.2.

Left Eye	Mean ± SD	Maximum	Minimum	Range (Max-Min)
ORBITALVOLUME(cm^3)	18.89 ± 3.15	27.96	12.79	15.17
AP(cm)	2.19 ± 0.10	2.51	2.01	0.5
MLO(cm)	2.31 ± 0.10	2.54	2.12	0.42
IZL(cm)	9.65 ± 0.43	10.89	8.69	2.2
GLOPOS(cm)	0.66 ± 0.23	1.17	0.18	0.99
MR(cm)	0.40 ± 0.06	0.6	0.27	0.33
LR(cm)	0.32 ± 0.07	0.5	0.14	0.36
IR(cm)	0.74 ± 0.11	0.97	0.39	0.58
SG(cm)	0.82 ± 0.13	1.16	0.5	0.66
LENSDENSITY (HU)	79.32 ± 6.38	95	63	32
ONSD(cm)	0.41 ± 0.07	0.62	0.31	0.31

AP = anteroposterior diameter , MLO = mediolateral diameter, IZL = interzygomatic line, GLOPOS= globe position, MR = medial rectus , LR= lateral rectus , IR =inferior rectus , SG = superior group muscles, ONSD = Optic nerve sheath diamter

Table.3.

Parameters	Mean ± SD (Right eye)	Mean ± SD (Left eye)	t-value	p-value
ORBITALVOLUME (cm^3)	18.99 ± 3.18	18.89 ± 3.15	0.202	0.840
AP(cm)	2.19 ± 0.10	2.19 ± 0.10	0.015	0.988
MLO(cm)	2.32 ± 0.10	2.31 ± 0.10	0.923	0.357
IZL(cm)	9.65 ± 0.43	9.65 ± 0.43	0.000	1.000
GLOPOS(cm)	0.65 ± 0.21	0.66 ± 0.23	0.407	0.685
MR(cm)	0.41 ± 0.07	0.40 ± 0.06	1.671	0.096
LR(cm)	0.32 ± 0.07	0.32 ± 0.07	0.423	0.673
IR(cm)	0.75 ± 0.10	0.74 ± 0.11	0.596	0.552
SG(cm)	0.83 ± 0.11	0.82 ± 0.13	0.532	0.595
LENSDENSITY (HU)	78.50 ± 6.92	79.32 ± 6.38	0.832	0.407
ONSD(cm)	0.43 ± 0.06	0.41 ± 0.07	1.494	0.137

AP = anteroposterior diameter , MLO = mediolateral diameter, IZL = interzygomatic line, GLOPOS= globe position, MR = medial rectus , LR= lateral rectus , IR =inferior rectus , SG = superior group muscles, ONSD = Optic nerve sheath diamter

There was no statistically significant difference between orbital measurements of right eye and left eye with p-value of all comparisons above 0.05 (Table 3). It was seen that there was statistically significant difference between orbital volume, AP and mediolateral diameter of eye globe, diameter of extraocular muscles and interzygomatic distance between males and females ($p < 0.01$). However no significant difference was observed between globe position, lens density and nerve sheath diameter among the two sexes ($p > 0.01$).(Table 4)

When compared among different age groups it was seen that average orbital volume increases from 0-20 to 20-40 age group and thereafter remains fairly constant. All the other parameters remain fairly constant among different age groups except for lens density which bears a slightly linear co-relation with age having pearson co-relation valued at 0.254 for right eye and 0.240 for left eye (Table 5) P value shows significant correlation (<0.05). Further it was seen that AP and mediolateral diameters of both eyes vary with interzygomatic line in a loosely linear relationship with Pearson correlation values ranging 0.38 to 0.41 and p value <0.01.(Table 6)

Table 4

VARIABLE	Gender	Number	Mean	St. error	St. error mean	t-value	p-value
ORBITAL VOLUME(cm^3)	M	102	20.2310	3.16865	.31374	7.065	0.001
	F	78	17.2569	2.22126	.25151		
AP(cm)	M	102	2.2184	.09420	.00933	3.963	0.001
	F	78	2.1618	.09609	.01088		
MLO(cm)	M	102	2.3378	.09876	.00978	3.429	0.001
	F	78	2.2873	.09694	.01098		
IZL(cm)	M	102	9.8200	.41988	.04157	6.754	0.001
	F	78	9.4333	.32197	.03646		
GLOPOS(cm)	M	102	.6241	.18915	.01873	-2.232	0.027
	F	78	.6969	.24870	.02816		
MR(cm)	M	102	.4006	.06623	.00656	-0.616	0.539
	F	78	.4065	.06147	.00696		
LR(cm)	M	102	.3225	.06691	.00662	0.533	0.595
	F	78	.3171	.06821	.00772		
IR(cm)	M	102	.7610	.09675	.00958	2.327	0.021
	F	78	.7238	.11720	.01327		
SG(cm)	M	102	.8467	.11626	.01151	3.123	0.002
	F	78	.7909	.12185	.01380		
LD (cm)	M	102	77.9059	7.36351	.72910	-2.346	0.02

	F	78	80.2244	5.35596	.60644		
ONSD(cm)	M	102	.4211	.06836	.00677	0.182	0.856
	F	78	.4193	.06165	.00698		

AP = anteroposterior diameter , MLO = mediolateral diameter, IZL = interzygomatic line, GLOPOS= globe position, MR = medial rectus , LR= lateral rectus , IR =inferior rectus , SG = superior group muscles, ONSD = Optic nerve sheath diamter

Table 5

		LD(Right)	LD(Left)
AGE	Pearson Correlation	.254*	.240*
	p-value	0.016	0.023

** Correlation is significant at the 0.05 level (2-tailed).*

Table 6

OCULAR DIAMETER		IZL
AP(Right)	Pearson Correlation	.409**
	p-value	0.001
MLO (Right)	Pearson Correlation	.367**
	p-value	0.001
AP(Left)	Pearson Correlation	0.383**
	p-value	0.001
MLO (Left)	Pearson Correlation	0.373**
	p-value	0.001

*** Correlation is significant at the 0.01 level (2-tailed).*

IV. DISCUSSION

Even though use of computed tomography in measurement of ocular dimensions is non-invasive, it involves exposure to ionizing radiations. Computed Tomography (CT) gives accurate measurement values when compared to other imaging modalities for *in-vivo* assessment[5,6]. Although there are many means of measurement of ocular dimensions, Computed Tomography is considered essential when other methods are unemployable or contraindicated. Not only does CT provide us with dimensions of orbit, it gives anatomic details of the surrounding ocular soft tissues as well as bony structures.

For a given population, the normative measurements act as a benchmark against which diseased states can be evaluated. Literature review revealed studies from various countries. The numerous reports on normative measurements of orbit show definite variation in these measurements based on race, region, and ethnicity.

No such normative data exists for Indian subcontinent though India has a large burden of orbital diseases. Thus, this study was undertaken to provide normative data for the Indian population.

Error can be caused by tracing of computer image. The error is shown to be 1.6% by McGurk et al.[7] The accuracy of measurement was not investigated, because the error is considered to be very small and it was difficult to measure the same orbital area twice as the traced area in this study[7].

In our study a loose co-relation was found between ocular volume and age. The scatter diagram indicated that ocular volume continued to grow upto 20-40 years of age and thereafter it was more or less stable, Similarly in a study on 1232 adult Chinese population in Singapore it was seen that the axial length (a major variable in the calculation of ocular volume) was noted to increase upto 50 years and then reduction was observed, which is in accordance with our findings[8]. Study by Hahn et al[6] supported Priestly Smith's[9] documentation that the cornea of the elderly population is smaller than that of young people which shows that ocular volume reduces with advancing age. Such reduction of ocular volume with increasing age may result in the shallowness of the anterior chamber in old age and may lead to closed angleglaucoma[10].

Although not at significant statistical level, the right ocular volume was slightly larger than the left by 0.53%. This finding in our study is consistent with other studies which reveal that the difference between measurements in two orbits is less than 1%[11]. Thus the volume of one eye can be extrapolated if the volume of other eye is known as it falls within ±1% of the latter. We reported a total average volume of both eyes of 18.94 cm^3. The mean ocular volume was larger in males than females at statistical significant level. This may result from human sexual dimorphism in which the male body habitus is generally bigger than that of the females[12,13] leading to increase in size of the male organs compared to females'. The difference in ocular volume between the sexes was approximately 3 cm^3 which may be considered of significance as it was nearly 15%. In the study by Acer *et al.*[14] percentage difference in the mean between ocular volumes of both sexes was about 3.6%. It was less than that seen by us probably due to poor nutritional status and short stature of women in our population. The mean orbital volume in our study is slightly larger than the one measured in Japanese population and the mean orbital volume in our study was significantly larger in men than the female in accordance to the finding in Japanese population[15].

Previous studies have suggested that the diameters of extraocular muscles vary with different window level and width settings. Hence in our study the window settings have been kept uniform for precise and objective measurement of muscle diameters[3]. Henceforth the normative data generated by this study would be applicable for specific window width and window level which are fixed in our study at 300 and 50 respectively. In the present study, the mean diameter of the rectus muscles were 4.1 mm, 3.2 mm, 8.3 mm and 7.5 mm in medial, lateral, superior complex and inferior rectus muscles respectively. Most of the studies have given a ranking for thickness of extraocular muscles, inferior > superior > medial > lateral. In our study superior group has the highest thickness as we have included superior oblique and superior rectus in this measurement. Lee *et al.* also in their study found inferior rectus to be the thickest muscle[16]. Various studies in the past have revealed that the diameter of the medial rectus on CT lies between 3.7 mm and 4.2 mm. Thickness of lateral rectus muscle ranged from 1.3 mm to 3.3 mm. The superior complex and the

inferior rectus diameters have been seen to range between 3.8 mm and 6.5 mm and 4.8 and 4.9 mm[16] respectively. Lerdelum *et al.* also found the inferior rectus to be the thickest extraocular muscle[17]. Similarly a study by Zang *et al.* which involved 50 normal volunteers, the lateral rectus was found to be the thinnest and inferior rectus the thickest muscle[18]. However, further literature shows variability in these results. Another study by Sacca *et al.* found that the average thickness of the medial rectus was the maximum in adults[19]. We have thus seen there is variation in size of muscles in different genetic and racial groups and it necessitates a normative data for Indian population.

It was seen in this study that the mean diameter of extraocular muscles was higher in males than in females. The same was statistically significant in medial rectus, inferior oblique and superior group of muscles. This may be due to a larger orbit size in accordance to larger body habitus in male.

There was an increase in lens density measurement with increase in age. The mean attenuation value was found to be higher in females than in males but it was not statistically significant ($p>0.05$). This study provided us with the mean as well as the range of attenuation value of the lens. It is predictable that changes in lens thickness and attenuation would also be noted in cases of cataracts on CT[20] but further studies are required to confirm this.

The mean ONSD found in this study (4.2 mm) was comparable to the ONSD measured in Korean populations (4.20 mm, ranging from 3.6 to 4.8 mm)[21] but was higher than measured in a similar study on Nepalese population.[22] Thus these results imply that the optic nerve sheath measurements differ from one population to another, even among neighboring Asian countries, thus highlighting the need to establish normative values which are specific for the Indian population. The increase in the optic nerve complex diameter is an indirect indicator for the increased intracranial pressure. This measurement has its use in the evaluation of various causes of raised intracranial pressure like head trauma, Graves orbitopathy, glaucoma and patency of ventriculo-peritoneal shunt among others.[23,24,25,26,27] Multiple studies have provided normative data for Canadian, Turkish, Thai, Korean, Greek, and French populations and variations can be seen in all of them. There is however, scarcity of normative data for normal Indian population. Nugent *et al.* have reported a mean optic nerve sheath diameter of 4.2 mm.[27] Similarly Lee *et al.* have given mean ocular nerve sheath diameter of 4.1 mm.[15] Karakitsos *et al.* in their study have linked severe brain injury with variation in optic nerve sheath diameter. In this study the Optic nerve sheath diameter of control population was 3.49 mm ± 1.1 mm.[23] The mean nerve sheath diameter in healthy pregnant patients in France has been shown to vary between 4.3 and 4.8 mm by Dubost *et al.*[28] In our study, the mean optic nerve sheath diameter was found to be 4.2 mm, which is comparable to the rest of the populations. Its significance lies in the fact that cut-off values for brain and ocular disorders in the Indian population will also be comparable to the international standards.

Exophthalmos is a condition in which there is forward protrusion of the eye ball in the bony orbit.[29] It can have various etiologies including vascular, neoplastic, infective, inflammatory, traumatic, endocrine, and also extraorbital causes[29]. In the present study the globe position is measured by evaluating the distance between the interzygomatic line and posterior margin of the globe. The mean normal globe position was 6.6 mm on the left and 6.6 mm on the right. Lee *et al.* in their study have found the mean value to be 11.7 mm.[15] Values measured by other authors vary from 6.5 mm in a Nigerian cohort, 9.4 mm in a Turkish population, and 6.5 mm or more behind the inter-zygomatic line in a Canadian population.[27,30,31] Variation of globe position can be seen not only due to genetic and racial variations but also due to the presence or absence of myopia in different groups.

Normative data for ocular biometry is ideally measured on dry skull bone specimens, but in our case CT images were used. This may lead to some variations; however this is the precise way with which same measurements can be obtained in a live person.

Even though routine use of CT for ocular biometry is discouraged because of its ionizing radiations, nevertheless a patient's ocular biometry can be asessed from his/her CT images in case CT was acquired for other reasons.

V. CONCLUSION

Measurement of ocular parameters observed in this study was comparable to studies taken on foreign soils. However this study determines a significant difference in some parameters in male and female population in India. This study also helps to create a database for normal ocular parameters in north India.

ABBREVIATIONS

CT = Computed Tomography
TIFFA = Targeted Imaging for Fetal Anomalies
AP = Anteroposterior diameter
MLO = Mediolateral diameter
IZL = Interzygomatic line
GLOPOS= Globe position
MR = Medial rectus
LR= Lateral rectus
IR = Inferior rectus
SG = Superior group muscles
ONSD = Optic nerve sheath diameter
ROI = Region of interest
HU = Hounsefield units

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