Original Article

Computed tomography imaging-based normative orbital measurement in Indian population

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Purpose: This study aims to evaluate normal orbital structures with nonenhanced computed tomography (NCCT) and determine normative data for the Indian population. **Methods:** CT images of the orbits of 100 patients were retrospectively reviewed on a work station to record the normative data of the orbits. Clinical details of all patients were reviewed to ensure that they did not have ocular/orbital diseases. Both axial and coronal images were utilized to record the data. **Results:** The mean age of the population evaluated was 34.07 years, with male to female ratio of 1.77. The average orbital index for the left orbit was 97 and for the right side was 103. The mean thickness of left inferior rectus, lateral rectus, medial rectus, and the superior rectus was 3.36 mm, 3.14 mm, 3.80 mm, and 3.75 mm, respectively. The right inferior rectus, lateral rectus, medial rectus, and the superior rectus measured 3.46 mm, 3.14 mm, 3.83 mm, and 3.78 mm, respectively. The optic nerve sheath complex diameter varied between 3.05 mm and 7.17 mm for the left eye and 3.05 mm and 7.0 mm for the right eye. **Conclusion:** The study provides normative data on various orbital structures in an Indian population. This data is likely to be useful for diagnosing various orbital pathologies and in planning surgical orbital procedures.

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The orbit is a complex anatomic region. Various pathologies can involve the orbit or its contents. A sound knowledge of the normal orbital dimensions is essential for the diagnosis and management of the various diseases that may affect the orbit. The extraocular muscle may be enlarged in conditions such as thyroid ophthalmopathy, neoplasms, metastasis, infections, and vascular malformations.[1] Similarly, the optic nerve sheath complex may be enlarged in a variety of pathological states such as optic neuritis, optic nerve glioma, and meningioma.[2] Moreover, the position of the globe relative to the surrounding bony landmarks is important for the diagnosis of proptosis and exophthalmos. The existing normative data of the orbit is predominantly based on the western population. There are reports enumerating normative data for these structures among select populations with some variation in the measurements depending upon ethnicity of the population. However, there is no data available from the Indian subcontinent. This study aims to evaluate normal orbital structures with nonenhanced computed tomography (NCCT) and determine normative data for the said population.

Methods

NCCT images of 100 patients, who were referred for NCCT of head and neck for diseases other than those of the orbits, were retrospectively reviewed. Clinical details of all patients were reviewed to ensure that they did not have ocular/orbital diseases. Patients having any ocular, orbital, or facial disorder or history of ocular, orbital, or facial surgery were excluded from the study. The patients were of all age groups and either sex and of mixed socioeconomic background. Departmental ethics board approval was obtained for conducting this study. Informed consent was obtained from all patients.

Image acquisition

All CT scans were done on a four-slice spiral CT scanner. The patients were asked to look in primary gaze during the CT scan procedure. Noncontrast enhanced axial and direct coronal 5-mm thick slices were acquired without any interslice gap. The axial sections were acquired at an angle of 10–15 degree to the orbito-meatal line and coronal sections were acquired perpendicular to it. This data were then reconstructed at 2.5-mm thickness and transferred to a workstation. The significance of gender on these measurements was also evaluated.

Image evaluation

All images were reviewed and evaluated on a dedicated workstation. Two neuroradiologists with 5–8 years of experience of head and neck imaging independently reviewed the images and selected those on which measurements were to be taken.

Bony margins were measured at a window width of 1800 HU and center of 400 HU. For soft tissue structures, window width ranging 40–60 HU and center ranging 250–300 HU were used. We did not use a fixed window setting for measuring soft

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tissue structures as their outline was not uniformly clear on fixed window settings.

The horizontal orbital diameter was evaluated by measuring the maximum distance between medial and lateral orbital wall on axial scan and the widest diameter was taken. The maximum distance between superior and inferior orbital wall on coronal scan was considered as the vertical diameter [Fig. 1a]. Orbital index (OI) was calculated using the following formula:

OI = Maximum vertical distance of the orbital cavity/maximum horizontal distance × 100

Interorbital distance was assessed by calculating the minimum distance between medial orbital walls on coronal scan. Interzygomatic distance was calculated as the maximum distance between the points on the anterior part of the zygomatic arch [Fig. 1b].

Extraocular muscle thickness (i.e., the maximum diameter) of medial, lateral recti was measured on axial scans. The maximum thickness of superior rectus–levator palpebrae superioris complex and inferior rectus was measured on the coronal scans. The axial and coronal images were scanned and the point where the muscle was the thickest, the maximum diameter measurement was taken [Fig. 2a, c]. The maximum diameter of optic nerve along with its sheath was measured on the coronal scans (optic nerve sheath complex diameter, [Fig. 2b] and the nasolacrimal duct diameter were also computed).

Globe position was determined by measuring the distance between the interzygomatic line and the posterior ocular surface on axial scans in the midglobe slice [Fig. 2d]. Data for right and left orbit were recorded separately.

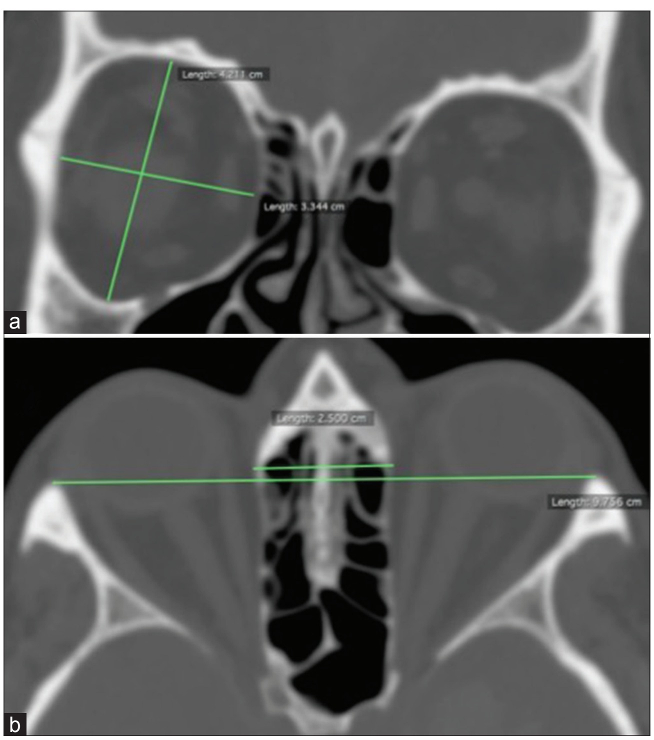

Figure 1: Coronal (a) and axial (b) images in bone window showing measurement of orbital dimensions (a) and interorbital and interzygomatic distances (b)

Statistical evaluation

All statistical analysis was performed using SPSS for windows software (SPSS Inc. Illinois, Chicago, USA; http://www.spss.com/spss).

Results

CT images of 100 patients, i.e. total 200 orbits (n = 200) were evaluated in this study. Out of the total 100 patients, 64 were males and 36 females. The age ranged between 7 and 71 years, with a mean age of 34.07 years.

The mean horizontal orbital diameter was 36.39 and 37.10 mm for left and right orbits, respectively. The mean vertical orbital diameter was 37.68 mm and 37.90 mm for left and right orbits, respectively [Fig. 3a]. The average orbital index for the left orbit was 97 and for the right side was 103. The horizontal orbital diameter, vertical orbital diameter, and orbital index in males for the right orbit were 37.4 mm, 38.5 mm, and 103, respectively. For females these were 36.5 mm, 37.5 mm, and 102.7, respectively. The left orbit measurements were 97.9 (orbital index; male), 37.1 mm (horizontal orbital diameter; male), 38.4 mm (vertical orbital diameter; male), 96.4 (orbital index; female), 36 mm (horizontal orbital diameter; female), and 37.3 mm (vertical orbital diameter; female).

The mean thickness of left inferior rectus, lateral rectus, medial rectus, and the superior rectus was 3.36 mm, 3.14 mm, 3.80 mm, and 3.75 mm, respectively. The right inferior rectus, lateral rectus, medial rectus, and superior rectus measured 3.46 mm, 3.14 mm, 3.83 mm, and 3.78 mm, respectively [Fig. 3a]. There was no statistically significant difference between the muscle thicknesses in the bilateral orbits.

The optic nerve sheath complex diameter varied between 3.05 mm and 7.17 mm for the left eye and 3.05 mm and 7.0 mm for the right eye. The mean optic nerve sheath diameter was 4.78 mm. The average interorbital distance was 26.89 mm and the interzygomatic distance was 96.5 mm [Fig. 3b]. The average interorbital distance in females and males was 25.93 mm and 27.46 mm, respectively. The average interzygomatic distance was 94.08 in females and 97.98 mm in males. The globe position was 7.9 mm and 7.8 mm for left and right sides, respectively [Table 1].

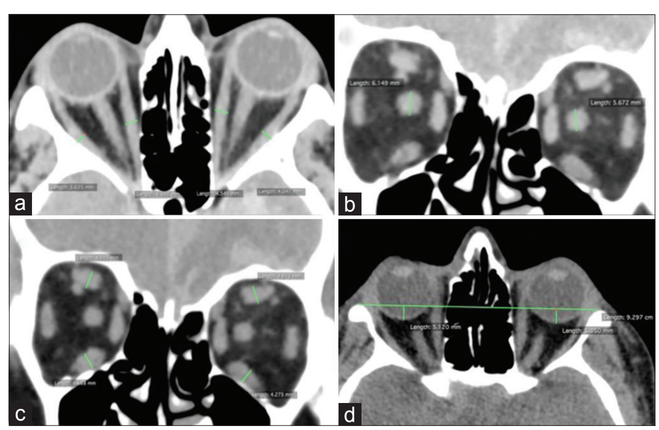

Figure 2: Axial plain CT images in soft tissue window showing measurement of extraocular muscles (a and c), optic nerve sheath diameter (b) and globe position (d)

Figure 3: Coronal image (a), white arrows depict the horizontal and vertical diameters of left orbit. The black arrows show the measurements of medial rectus, lateral rectus, inferior rectus, and superior rectus muscle thickness. The measurement of optic nerve sheath complex is marked by a star. In the image (b), the white long arrow marks the interzygomatic distance. The two shorter white arrows show how much behind the posterior surface of globe is in relation to the interzygomatic line which is a measurement for the globe position. The thick white arrow marks the interorbital distance

Table 1: Normative measurements of the orbits

Measurements	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D
Horizontal orbital diameter				
Left	32.52	40.7	36.69	1.72
Right	29.09	40.7	37.10	1.87
Vertical orbital diameter				
Left	32.12	44.3	37.68	1.88
Right	32.69	49.15	37.90	2.3
Orbital index				
Left	86	137	103	0.05
Right	85	111	97	0.08
Inferior rectus				
Left	2.14	43.8	3.36	0.62
Right	2.14	5.4	3.46	0.64
Lateral rectus				
Left	1.8	4.9	3.14	0.63
Right	1.52	5.51	3.14	0.73
Medial rectus				
Left	2.9	5.3	3.8	0.56
Right	2.49	6.23	3.83	0.56
Superior rectus				
Left	2	7.01	3.75	0.86
Right	1.65	6.33	3.78	0.84
Optic nerve complex				
Left	3.05	7.17	4.83	0.82
Right	3.05	7.0	4.72	0.74
Globe position				
Left	2.2	12.5	7.88	2.15
Right	2.5	13.88	7.77	2.23
Nasolacrimal duct diameter				
Left	2.8	7.6	5.13	1.01
Right	3.3	7.5	5.2	0.96
Interorbital diameter	8.77	37.2	26.89	3.74
Interzygomatic line	82	105.1	96.54	4.40

Discussion

The normative measurements are important as they act as a benchmark against which diseased states can be evaluated. Literature review revealed studies from various countries. The various reports of normative measurements of orbit show some variation in the measurements based on race, region, and ethnicity. The Indian subcontinent has a large burden of orbital diseases and no such imaging normative data exists to our knowledge. Thus, this study was undertaken to provide normative data for the Indian population.

Measurements of orbital dimensions are essential in preoperative planning and post trauma reconstruction.[3] Dhanwate *et al*. studied dry skulls in a segment of Indian population in Aurangabad.[4] In males, they calculated a mean horizontal diameter of 37.52 mm (1.95 SD) for the right orbit and 37.08 mm (1.96 SD) for the left orbit. The vertical orbital dimension was 32.64 mm (2.07 SD) and 32.39 mm (2.18 SD) for right and left orbits, respectively. The orbital index was 87.28 and 87.66 for right and left orbits, respectively. In females, the mean orbital height for right and left sides were 32.55 ± 1.91 and 32.31 ± 1.55 mm, respectively. Orbital width was 37.25 ± 1.64 and 36.67 ± 1.56 mm. Orbital Index was 87.52 ± 6.15 and 88.24 ± 5.22, respectively. In our study using cross-sectional imaging, the values for horizontal, vertical dimensions, and orbital index were higher. This may be because of the effects of race and genetics, as well as the different methodologies (i.e. cross-sectional imaging vs dry skull measurement) used. The orbital diameters are also larger compared to the cohort evaluated in the Korean population.[5] In comparison with the Iranian population, average vertical orbital dimension was found to be higher in our patients whereas the horizontal dimension was similar.[3]

Extraocular muscle thickness is increased in many conditions such as inflammatory pseudotumor, infections, grave's ophthalmopathy, vascular malformations, and neoplasms.[6] The character of muscle enlargement, density, enhancement, and clinical profile help to differentiate between these conditions. Extraocular muscle enlargement may be seen in up to 85% of the Grave's disease cases. The inferior rectus muscle is the first and most commonly involved muscle.[7] To decide whether a muscle is enlarged or not, the absolute measurements of these muscles are essential. In our study, of all the extraocular muscles, we found medial rectus to have the maximum diameter (3.8 mm) and lateral rectus to have the minimum diameter (3.1 mm). In a study by Lee *et al*., the mean diameter of inferior rectus muscle, superior complex muscles, and medial and lateral recti was 4.1 mm, 4.0 mm, 3.7 mm, and 3.4 mm, respectively. They found inferior rectus to be the thickest muscle.[8] Various authors have reported that the diameter of the medial rectus on CT lies between 3.7 mm and 4.2 mm. The lateral rectus dimension varied 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.[8] Lerdelum *et al*. also found the inferior rectus to be the thickest extraocular muscle.[9] Similarly, in a study by Zang *et al*. involving 50 normal volunteers, the lateral rectus was found to be the thinnest and inferior rectus the thickest muscle.[10] However, there is variability in these results in the literature. Another study by Sacca *et al*. found that the average thickness of the medial rectus was the maximum in adults.[11] In our evaluation, we found the medial rectus to be the thickest extraocular muscle. This variation in size of the muscles might be due to genetic causes, and that is the reason for which normative data for patient populations of different races and ethnicity needs to be defined.

The increase in the optic nerve complex diameter is an indirect indicator for the increased intracranial pressure. This measurement is utilized in the evaluation of graves orbitopathy, traumatic brain injury, glaucoma, patency of ventriculo-peritoneal shunt, or other causes of raised intracranial pressure.[12-16] Various authors have provided normative data for Canadian, Turkish, Thai, Korean, Greek, and French populations and all have some variations. We were unable to find any previously published normative data for normal Indian population. Nugent *et al*. have reported a mean optic nerve sheath diameter of 4.2 mm.[16] Similarly Lee *et al*. have given a mean diameter of 4.1 mm.[8] Karakitsos *et al*. have evaluated the role of optic nerve sheath diameter measurement in severe brain injury. They obtained a diameter of 3.49 mm ± 1.1 mm in their control population.[12] 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*.[17] In our study, the mean optic diameter was found to be 4.7 mm, which is slightly higher than the rest of the populations. This is significant as the cut-off values for various disorders in the Indian population will also be different.

Orbital hypertelorism is a manifestation of different craniofacial deformities such as craniofacial dysplasia's, clefts, Apert, and Crouzon syndromes.[18] It is characterized by increased interorbital distance. Similarly, hypotelorism may be associated with various pathologies such as holoprosencephaly and craniosynostosis.[19] Mafee *et al*. have calculated the bony interorbital distance on CT in 400 patients. They gave a mean dimension of 2.67 cm in males and 2.56 cm in females.[20] These measurements in our population was similar. In an anthropometric analysis among ethnic south Indian adults, the mean intercanthal distance was found to be 34.27 ± 3.57 mm and 33.41 ± 3.09 mm in males and females, respectively.[21] Our values were lesser when compared to this study. This may be due to difference in the techniques in addition to the genetic influence. The normal interzygomatic distance lies between 90 mm and 109 mm.[8,22,23] These values are similar to those noted in our population.

Exophthalmos is described as forward protrusion of the eye ball in the bony orbit.[24] It can have various etiologies including vascular, neoplastic, infective, inflammatory, traumatic, endocrine, and extraorbital causes.[24] In our study, we have measured the globe position by evaluating the distance between the posterior margin of the globe and the interzygomatic line. The mean normal globe position was 7.9 mm on the left and 7.8 mm on the right. Lee *et al*. have given a mean value of 11.7 mm.[8] 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.[16,22,23] In addition to the inherent genetic and racial differences, this result may be complicated by the variability in prevalence of myopia in these subgroups.

The major limitation of this study is the small number of scans. Further, the normative data is ideally measured on dry skull bone specimens, but in our case CT images were used. This may have led to variation in the measurements.

Conclusion

In conclusion, our study has given normative mean measurements for various orbital structures that are essential to surgeons, ophthalmologists, and radiologists. This might help in accurate assessment of extraocular structures, exophthalmos, and in understanding various orbital pathologies in the Indian population.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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