Normative Measurements of the Ocular Globe Position in Relation to Interzygomatic Line, using Magnetic Resonance Imaging among Adults in Zaria, Nigeria

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ABSTRACT

Introduction: Proptosis and enophthalmos are cardinal signs of many orbito-ocular and systemic diseases which are common in our environment. The need for an imaging parameter that will aid its early diagnosis is necessary as visual compromise is a major consequence if they are not diagnosed and managed early. **Aim and Objectives:** This prospective study was aimed at using magnetic resonance imaging (MRI), to determine interzygomatic distance, distance between the anterior and posterior borders of the globes and the interzygomatic line (IZL), and then using these parameters to determine the normal position of the ocular globes within the orbits. **Methodology:** The study was conducted within 6 months spanning November 29, 2011–May 28, 2012, at the Department of Radiology, Ahmadu Bello University Teaching Hospital, Zaria. The distance between anterior border of the globe (corneal apex) and IZL which is referred to as Hertel-index, distance between posterior border of the globe and IZL, and length of the IZL were measured at the level of the lens for 340 normal ocular globes of 170 patients on T1-weighted MRIs. **Results:** The normal ranges for the orbital measurements are as follows (mean ± standard deviation): The normal position of the posterior pole of the right globe was 6.34 ± 0.99 mm from IZL (ranged 5.40–7.33) while that of the left globe was 6.56 ± 0.93 mm (ranged 5.63–7.50). All measurements in male patients were significantly higher than those in female patients ($P < 0.001$) and the position of the right globe within the orbit was significantly different from that of the left for both sexes ($P < 0.001$). **Conclusion:** The results obtained from this study may help ophthalmologists, radiologists, and other clinicians to quantitatively evaluate patients with enophthalmos, exophthalmos, or other changes in the orbital morphology.

Key words: Hertel-index; interzygomatic line; magnetic resonance imaging; ocular globe

Introduction

The position of the ocular globe within the orbit is objectively assessed in relation to the interzygomatic line (IZL), which is a line joining the anterior margins of the zygomas.[1,2] The perpendicular distance of the anterior and posterior margins of the globe to the IZL at the level of the lens on axial magnetic resonance imaging (MRI) images could accurately determine the position of the globe within the orbit.[2] Establishing a much-needed nomogram will help in making early diagnosis of proptosis and enophthalmos.

The term proptosis is defined as abnormal protrusion of the eyeball(s) or anterior displacement of one or both globes

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within the bony orbit.[1,2] Owing to the rigid bony structure of the orbit with only anterior opening for expansion, any increase in orbital contents taking place from the side or from behind will displace the eyeball forward.[1] It is a cardinal sign that suggests orbital space occupying lesion and can be the result of a myriad of disease processes including infections, inflammation, tumor, trauma, metastases, endocrine lesions, vascular diseases, and extraorbital lesions.[1]

Irrespective of the cause, proptosis can compromise visual function and the integrity of the eye. A proptotic eye not adequately protected by the lids can develop exposure punctate keratopathy.[3] Such disruption of the finely orchestrated homeostatic mechanism to protect the eye will result in corneal compromise, epithelial death, ulceration, and possible corneal perforation in severe cases.[3] Early diagnosis of proptosis is, therefore, imperative so as to avert its negative consequences.

No evidence exists to prove that proptosis is more common in Nigeria than other parts of the world. However, certain causes of proptosis make it more likely to be seen here due to late presentation. Poverty, ignorance, paucity of skilled health professionals in the rural areas where most Nigerians live, and low index of suspicion coupled with inadequate diagnostic facilities are the reasons adduced for the late presentation of patients.[4-9]

Enophthalmos, on the other hand, is defined as a posterior displacement of the globe within the orbit.[1,2] It could arise as a result of trauma, chronic maxillary atelectasis (silent sinus syndrome), neoplasm, vascular disorders, scleroderma, and fat atrophy, particularly in the elderly.[10-12] Visual impairment could also result if not diagnosed and managed early.

Proptosis and enophthalmos being signs of many orbito-ocular and systemic diseases, the causes of which may require evaluation using computerized tomography (CT) scan and MRI, this study will provide useful data that can be used to objectively assess their occurrence in any patient.

There is a need for research to establish a nomogram which will stand as a baseline; bearing this in mind, the documented values in literature are findings among the Caucasians as there may be racial variations.[13]

Materials and Methods

This study was carried out over a 6-month period spanning November 29, 2011–May 28, 2012, at the Department of Radiology, Ahmadu Bello University Teaching Hospital, Zaria. The study was conducted with 0.2 Tesla permanent magnet MRI (Siemens) systems with a general purpose head coil for the acquisition of the images.

The study population involved adult individuals 18–80 years who did not have clinical or radiological evidence of proptosis or enophthalmos, referred for MRI of the brain and/or paranasal sinuses. The referring clinician and the supervising ophthalmologist examined the participants clinically and ensured that none of them had proptosis and/or enophthalmos.

Individuals with endocrine diseases which affect the orbit, particularly thyroid ophthalmopathy, those with orbital disorders, and individuals with asymmetric scans, or scans with artifacts for any reason (e.g., eye implants, eye motion etc.,) that may cause errors in orbital measurements and those with ferromagnetic prosthesis were all excluded from the study.

Having ascertained eligibility of the subjects, the procedure was explained to them and informed consent was obtained. The participants were instructed to remove all metallic objects and phones, aimed at averting missile injury and/or radiofrequency interference. They were registered, weighed, and positioned on the examination couch of the MRI system.

The examination was carried out in supine position with head first and arms beside the trunk. Radiofrequency coil (head coil) was then applied and the field of view centered on the nasion in the midline.

T1- and T2-weighted spin echo sequences in the axial, coronal, and sagittal 3 mm thick sections with 0.3 mm intersection gap were obtained with the MR system by the use of 21 cm diameter head coil. The scan range in the axial plane spanned from the foramen magnum to the vertex, and the matrix size was 256 × 256.

The participants were asked to maintain a primary gaze and gentle eye closure during the scans to prevent asymmetrical extraocular muscle contraction. Imaging of the orbit was performed sequentially with that of the brain. The axial plane corresponded to the line joining the genu and splenium of the corpus callosum while coronal plane was perpendicular to the same line, and sagittal plane was parallel to the corpus callosum.[14]

For the determination of the normal globe position, T1-weighted axial images at the level of the lens (mid-globe section) were used. The IZL was drawn with electronic caliper and used as a reference line. The length of the IZL, axial length of the globes, and the perpendicular distance of the IZL to the posterior and anterior margins of the globes were obtained with the aid of electronic calipers at this level [Figure 1].

Data analysis

The data were analyzed using Statistical Package for Social Science version 16. Analysis tests used in this study were independent samples *t*-test, paired samples *t*-test, ANOVA, and Pearson correlation. All tests of significance were two-tailed and $P \leq 0.05$ was considered statistically significant.

Results

A total of 340 orbits of 170 patients were evaluated. The age range of these participants was 18–80 years, with a mean value of 40.4 ± 14.84 years. One-hundred thirteen (66.5%) of the participants were males whereas 57 (33.5%) were females, giving a male: female ratio of 2:1. Paired samples correlation and paired samples test showed statistically significant differences between data obtained for the right and left globes. The posterior margin of the globes to the IZL and corneal apex to the IZL show statistically significant different measurements for the right and left orbits ($P < 0.001$). In view of this, the mean values and normal ranges of globe position were individualized for each globe.

The mean values of the right and left orbital measurements by age group are shown in Table 1. The values obtained among various age groups show marginal differences in the entire parameters, but the differences observed were not statistically significant. Furthermore, the difference observed in the length of the IZL (facial size) among the various age groups was statistically insignificant ($P = 0.199$).

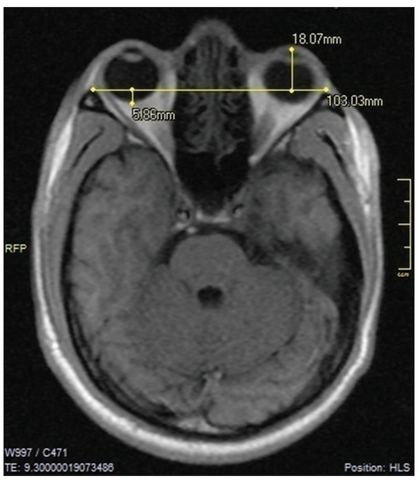

Figure 1: Axial T1-weighted magnetic resonance imaging at the level of the lens, demonstrating the normal position of the ocular globe in relation to the interzygomatic line. Anterior margin of the left globe to the interzygomatic line = 18.07 mm posterior margin of the right globe to the interzygomatic line = 5.86 mm length of interzygomatic line = 103.03 mm

The distance between the posterior margins of the right globe and IZL was 6.34 ± 0.99 mm (ranged 5.35–7.33 mm) and the right globe AP dimension was 23.32 ± 1.34 mm, implying that 27.2% of the right ocular globe was situated behind the IZL. In addition, the mean value of the distance between the posterior margin of the left globe and IZL (LPM) was 6.56 ± 0.98 mm (ranged 5.58–7.54 mm). This was significantly higher than the mean value obtained for the right ocular globe ($P < 0.001$). The left globe AP dimension was 23.29 ± 1.22 mm, signifying that 28.2% of the left globe lies behind the IZL.

There were significant sex differences in the values of the orbital measurements. Higher values were noted among male participants [Table 2]. The posterior margin of the right globe was 6.44 ± 1.05 mm away from the IZL in males as against females' that was 6.14 ± 0.86 mm ($P = 0.045$). Furthermore, the distance between the posterior margin of the left globe and IZL was 6.67 ± 1.01 mm in males whereas the mean value for the females was 6.32 ± 0.86 mm ($P = 0.028$).

The distance between the right corneal apex and IZL was 17.11 ± 1.66 mm and 16.81 ± 1.35 mm for male and female cases, respectively, while that of the left was 16.84 ± 1.54 mm and 16.46 ± 1.15 mm for male and female participants, respectively.

The correlations of age with orbital measurements are shown in Table 3. There was no correlation between participants' age and IZL length (facial size), and position of the ocular globes within the orbit on the right and left side, respectively. Furthermore, the IZL length (facial size) did not show significant correlation with the position of the ocular globes.

Discussion

The ocular globe position is expressed by the perpendicular distance between the IZL and the posterior margin of the

Table 1: The means and standard deviations of the ocular globes' parameters by age groups

Age group (years)	*n*	Mean±SD				
		IZL (mm)	RAM (mm)	RPM (mm)	LAM (mm)	LPM (mm)
18-19	9	102.12±3.90	16.60±1.48	6.81±1.44	16.51±1.39	6.70±1.20
20-29	42	102.60±5.13	16.87±1.38	6.54±1.11	16.52±1.23	6.69±1.00
30-39	35	104.63±4.40	17.12±1.47	6.20±0.82	16.93±1.10	6.49±0.82
40-49	47	102.09±4.53	16.99±1.86	6.13±0.96	16.81±1.74	6.35±0.97
50-59	17	104.62±4.64	16.68±1.69	6.47±0.92	16.50±1.64	6.65±1.09
60-69	11	103.37±6.70	17.37±1.23	6.18±0.95	16.56±1.39	6.66±0.86
≥70	9	103.99±3.06	17.91±1.17	6.57±0.80	17.12±1.49	6.60±1.22
Mean of Total	170	103.18±4.78	17.01±1.56	6.34±1.00	16.72±1.43	6.56±0.98

SD – Standard deviation; IZL – Length of the interzygomatic line; RAM – Distance between the right corneal apex and the interzygomatic line (right Hertel-index); RPM – Distance between the posterior margin of the right globe and the IZL; LAM – Distance between the left corneal apex and the interzygomatic line (left Hertel-index); LPM – Distance between the posterior margin of the left globe and the IZL

Table 2: The means and standard deviations of the ocular globes' parameters by gender

Parameters	Mean±SD		Mean difference	*P*
	Male (*n*=113)	Female (*n*=57)		
Age (years)	42.37±14.77	36.49±14.32	5.88	0.014
IZL (mm)	104.19±4.82	101.17±4.05	3.02	<0.001
RAM (mm)	17.11±1.66	16.81±1.35	0.30	0.242
RPM (mm)	6.44±1.05	6.14±0.86	0.30	0.045
LAM (mm)	16.84±1.54	16.46±1.15	0.38	0.072
LPM (mm)	6.67±1.01	6.32±0.86	0.35	0.028

SD – Standard deviation; IZL – Length of the interzygomatic line; RAM – Distance between the right corneal apex and the IZL (right Hertel-index); RPM – Distance between the posterior margin of the right globe and the IZL; LAM – Distance between the left corneal apex and the IZL (left Hertel-index); LPM – Distance between the posterior margin of the left globe and the IZL

Table 3: Correlation of age with right and left orbital parameters

Parameters	Coefficient of correlations (*r*)	*P*
RAM	0.102	0.187
RPM	−0.072	0.352
LAM	0.041	0.593
LPM	−0.035	0.647

**Correlation is significant at 0.01 levels (two-tailed), *Correlation is significant at 0.05 levels (one-tailed). RAM – Distance between the right corneal apex and the IZL (right Hertel-index); RPM – Distance between the posterior margin of the right globe and the IZL; LAM – Distance between the left corneal apex and the IZL (left Hertel-index); LPM – Distance between the posterior margin of the left globe and the IZL; IZL – Length of the interzygomatic line

ocular globes at the mid globe section (level of the lens). The IZL is a line joining the anterior margins of the zygomas, drawn on axial MRI at the level of the lens.

The mean length of the IZL, which is a reflection of the size of the face, was 103.18 ± 4.78 mm for the entire research participants. It was, however, found to be significantly higher in males than females ($P < 0.001$). The mean value in males was 104.19 ± 4.82 mm while that of the female participants was 101.17 ± 4.05 mm. This observation is in tandem with the larger head size usually found in males and it concurs with the findings of other authors.[15] Ozgen and Aydingöz[16] used 0.5 Tesla MRI systems to determine the normal measurements of orbital structures in Turkey. They also found that the IZL length was significantly higher among male participants. Again, Ozgen and Ariyurek[17] and Lee *et al*.[13] used CT for normative measurements of orbital structures in Turkey and Korea, respectively. The length of IZL was also found to be higher among male participants in both studies.

The index study revealed a significant difference in the position of the right and left ocular globes within the orbits ($P < 0.001$). This finding is not in consonance with the outcome of similar studies done by other authors in other parts of the world.[13,16,17] Ozgen and Aydingöz[16] did not find any significant statistical difference between data for the right and left orbits in any orbital structure. There was also no significant difference in parameters for right and left orbits in the studies of Lee *et al*.[13] and that of Detorakis *et a1*.[18] The discordance observed in the outcome of this study and earlier research works enumerated above may be due to differences in technique and possibility of asymmetrical extraocular muscles contraction that could occur during the scan as the 0.2 Tesla MRI system used in the index study normally results in prolonged scan time as against 0.5 and 1.5 Tesla MRI systems used by earlier authors.[16,18] Furthermore, some of the authors[13,17] used CT for their studies. Image acquisition is faster with CT and asymmetrical extraocular muscles contraction may not occur with this modality.

In the index study, the posterior margin of the right ocular globe was 6.34 ± 0.99 mm (ranged 5.4–7.3 mm) behind the IZL while the left was 6.56 ± 0.93 mm (ranged 5.6–7.5 mm) from the IZL.

Ozgen and Aydingöz[16] determined the normal position of the ocular globes with the aid of MRI and discovered that the normal position of the posterior pole of the globe was 8.9 mm behind the IZL (ranged 5–12.7 mm). Ozgen and Ariyurek[17] used CT for similar study in Turkey and found a mean value of 9.4 mm (ranged 5.9–12.8 mm) as the distance between the IZL and posterior margin of the globes.

Lee *et al*.[13] also carried out similar study among Koreans and found normal position of the ocular globe to be 11.2 mm behind the IZL. A similar study in Canada by Nugent *et al*.[19] revealed that 95% of the cases had the posterior margins of their globes lying 6.5 mm or more behind the IZL. They also noted that 5 mm behind the IZL is an appropriate cutoff value for the posterior globe margin. This is similar to the outcome of the present study. The differences that existed between the findings regarding the position of the ocular globes in the present study among Nigerians and findings among Turkish and Koreans as stated above might be due to racial variation and environmental influence.[17] Benjamin and Borish[20] published an epidemiological study concerning ethnic differences, which suggested a general pattern of the highest prevalence of myopia in Asian, intermediate in Caucasian, and lowest in African-American. There is a paucity of data regarding this in Africa, making comparison difficult.

A perpendicular line from the IZL to the apex of the globe (corneal apex) has been used by other authors to depict the measurement of proptosis. Normally, 1/3 of the globe is located behind the IZL while 2/3 is located anterior to the line.[21] A study conducted by Kirsch *et al*.[21] in Switzerland showed that a Hertel-index (the distance between the corneal apex and the IZL) greater or equal to 22 mm (≥22 mm) is pathological and connotes proptosis. In the index study, however, the mean Hertel-indices were 17.01 ± 1.56 mm and 16.72 ± 1.43 mm on the right and left side, respectively. These are much lower than the upper limit of normal established by other authors.[21,22] As noted earlier, the posterior margin of the right ocular globe was 6.34 ± 0.99 mm (ranged 5.4–7.3 mm) behind the IZL while the left was 6.56 ± 0.93 mm (ranged 5.6–7.5 mm) from the IZL. These indicated that 27.2% of the right ocular globe is located behind the IZL while 28.2% of the left globe lies behind the IZL. This is slightly different from the findings of Kirsch *et al*.[21] where 33% of the ocular globe was found to be located behind the IZL.

As the research participants were all adults, the mean length of the IZL, distance between the posterior margin of the globe and the IZL, and distance between corneal apex and the IZL did not show significant correlation with age. These findings concur with that of Lee *et al*.[13] where no statistically significant differences in orbital measurements were found among the studied age groups.

The facial size, which is represented by the length of the IZL, showed statistically significant correlation with the Hertel-index. It, however, did not correlate with the position of the globe, i.e., the distance between the posterior globe margin and IZL. These findings are similar to that of Ozgen and Ariyurek.[17] They correlated the length of the IZL with some of the measurements of orbital structures and found that majority of the variables showed statistically significant relationship with IZL. It was, however, not correlated with globe position in that study.

The position of the globes showed statistically significant differences among gender groups in the index study. This contrasts earlier studies where dimensions of orbital structures were actually marginally higher in males; however, the gender differences were not statistically significant.[13,16-19,21,23,24] The statistically significant difference in the ocular globe measurements among gender groups in the index study may be due to marked disparity in male: female ratio. Equal representation in view of number of male and female participants may minimize or even eliminate the differences observed among them.

Limitations of the study

The use of 0.2 Tesla permanent magnet MRI systems was a major limitation of this study. Image acquisition was slow and possibility of asymmetrical extraocular muscles contraction cannot be ruled out absolutely. A higher strength magnetic field MRI system with faster image acquisition time is advised for further studies.

Conclusion

The position of the globes within the orbits has sexual dimorphism with males having higher values. Furthermore, a statistically significant difference in globe position was observed between right and left orbits. The distance between the posterior margin of the globe and the IZL which is a determinant of the globe position was found to be smaller among the research participants compared with Caucasians, Koreans, and Asians. This further affirms that race and environmental influence have significant effects on the position of the ocular globes.

The results obtained from this study may help ophthalmologists, radiologists, and other clinicians to objectively evaluate patients with enophthalmos, exophthalmos, or other changes in orbital morphology.

Ethical consideration

The approval for this study was obtained from the ethics and research committee of Ahmadu Bello University Teaching Hospital, Zaria.

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Conflicts of interest

There are no conflicts of interest.

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