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Measurement of 0 to 2 age normal eyeball volume by the use of multidetector computed tomography

Mustafa Kaya[1], Enes Gürün[2], İsmail Akdulum[3]

[1]Gazi University, Faculty of Medicine, Department of Radiology, Ankara, Turkey
[2]Samsun University, Faculty of Medicine, Department of Radiology, Samsun, Turkey
[3]İsmail Akdulum Office, Kızılırmak, Galen Center, Ankara, Turkey

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ABSTRACT

Aim: To diagnose microphthalmia or macrophthalmia, it is necessary to know the normal reference values of the eyeball volumes. However, we do not have a table of normal reference values to evaluate normal eyeball volume at 0-2 years of age. To compensate for this deficiency, we aimed to detect normal eyeball volumes in the age group of 0-2 years with multidetector computed tomography (MDCT).

Material and Method: A total of 90 patients who underwent MDCT with a prior diagnosis of head trauma but without traumatic pathology were included in the study. Patients were divided into age groups of 0-1 months, 2-6 months, 7-12 months, 13-24 months. The mean values of patients in each age group were examined with a 95% confidence interval. The correlation between bilateral eyeball volumes and age was calculated using the Pearson correlation test. The relationship between the age groups and the volume of the eyeball was studied using one-way ANOVA test. The relationship between eyeball volumes and sex was evaluated using the Mann Whitney U test.

Results: Mean eyeball volume was measured as 3.91±0.54 cm^3 for 0-1 months, 4.44 ±0.66 cm^3 for 2-6 months, 5.81 ±0.68 cm^3 for 7-12 months, and 5.83±1.09 cm^3 for 13-24 months. A strong positive correlation was observed between eyeball volume and age ($p < 0.001$). There was no statistically significant relationship between eyeball volume and sex ($p > 0.05$). No statistically significant difference was observed between right eyeball volume and left eyeball volume ($p> 0.05$).

Conclusions: The increase in eyeball volume is most rapid in the first year of life. In this study, the reference eyeball volumes were determined in order to properly assess this rapid increase.

Keywords: Eye, eye length, buphtalmos, microphtalmos

INTRODUCTION

The eye is a visual receptor organ that contains dense nerve endings in the posterior part and is filled with humor in the central part (1). Eyeball volume can change in many diseases. Trauma, benign or malignant neoplasms, glaucoma, myopia etc. Normal values are required to diagnose microphthalmos, buphthalmos or macrophthalmos and to consider appropriate treatment options. In addition, it is important to know the eyeball volume for craniofacial surgery (2-5).

In the literature, there are publications using ultrasonography, computed tomography or magnetic resonance for measurement of eyeball volume or other structures (6-12). There are volumetric eyeball measurements for various races, but the majority of them are for adults. There have been studies on the diameters of orbital structures in pediatric age groups (13-15). With the help of computer programs, it is possible to obtain volume measurements that are as close to the truth as possible in tomography images, reducing the margin of error. In comparison to a single diameter comparison, two-dimensional images produce more accurate results.

The aim of this study was to determine the normal value range of eyeball volume in the pediatric patient population aged 0-2 years, and to evaluate its relationship with gender and age in multi-detector computed tomography (MDCT) images.

Corresponding Author: Mustafa Kaya, radmustafakaya@hotmail.com
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MATERIAL METHOD

The study was approved by the Gazi University Non-Interventional Studies Ethics Committee (Date: 29.1.2021, Decision Number:140). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. The informed consent was waived due to the retrospective nature of the study and the assessment utilized anonymous research findings. The study included 107 cranial MDCT scans. All cases consisted of patients who were referred to the emergency radiology department due to traumatic reasons such as falling from a height and an in-vehicle traffic accident. Cases with fractures involving the orbital walls and images that were not clear, due to motion artifacts were excluded from the study. The final group consisted of 90 patients (47 males, 43 females). This study was conducted over a nine-month period from March 2021 to December 2021.

All of the MDCT studies were performed using a multidetector 192 row helical CT scanner (Somatom Force, Siemens Healthineers). The following parameters for scanning were applied: tube voltage 120 Kv, tube current 300 mA, beam collimation 1 mm×16, field of view 240 mm, gantry rotation time was 0.75 s. Thin-section CT data were reconstructed at a slice thickness of 1 mm with 0.8-mm intervals. Image matrix of 512 x 512. Intravenous contrast medium was not administered.

Volume of the eyeball were analyzed using a workstation Syngo.via (Siemens Healthineers) by only one radiologist (M.K.) with 15 years experienced in Head - Neck Imaging. The eyeball contour was manually evaluate by the examiner.

Via a closed polygon tool, the contours of the eyeball were defined by two dimensional segmentation. The volumes were measured by manually segmenting the region of interest in each CT slice using Syngo. via (Siemens Healthineers) postprocessing imaging software after drawing the outlines of the eyeball in all slices. Eventually, the volume was measured by the software and three-dimensional reconstruction of the organ was produced (**Figure 1A,1B,1C**). The eyeball volume was measured as cm^3.

Figure 1A,B,C. Orbital diameter and volume measurements

The bilateral eyeball was re-evaluated 1 week after the initial evaluation to assess the reproducibility of the same observer for 20 patients.

Statistical Analysis

Statistical analyzes were performed via the SPSS v.22 package program (IBM SPSS Statistics, Chicago, IL, USA). Participant age and gender were recorded. Descriptive statistics are given with mean, standard deviation, median, minimum, maximum values for categorical variables. Kolmogorov–Smirnov test was used as a test of normality. Patients were divided into age groups of 0-1 months, 2-6 months, 7-12 months, 13-24 months. Minimum, maximum, mean and standard deviations have been calculated for all age groups and all case groups. The relationship between eyeball volume and gender, and the relationship between right eyeball volume and left eyeball volume were evaluated using the Mann Whitney U test. In addition, one way ANOVA tests were used to assess the relationship between age groups and eyeball volumes. The correlation between the bilateral eyeball volumes and age was calculated with the Pearson test. P-value of less than 0.05 was considered statistically significant. The intraclass correlation coefficient (ICC) test was used to analyze intraobserver reliability for repeated measurements with a 95% confidence interval. ICC was interpreted as follows: below 0.50: poor, between 0.50 and 0.75: moderate between 0.75 and 0.90: good, above 0.90: excellent.

RESULTS

A total of 107 participants were included in the study. The clinical characteristic of the participants are presented in **Table 1**. In 17 patients, the measurement could not be obtained due to the technical reasons, such as the motion artifact.

Table 1. The clinical characteristic of the participants

Clinical characteristic	Total (n=90)
Age (month)	7.27±6.28 (1-24)
Gender (M/F)	47/43

-Data are expressed as n (number) or the mean± standard deviation (range). F: Female M: Male

The ICC values for all diameter measurements and volumes were>0.80-0.90, indicating good and excellent agreement.

There was no statistically significant relationship between eyeball diameters,volumes and sex (p>0.05). No significant difference was observed between the right and left eyeballs in terms of diameters and volumes (P>0.05).

Pearson correlation analysis was performed for comparison of eyeball diameters,volumes and age. It was observed that age had a strong positive correlation with eyeball diameters and eyeball volumes (p<0.001) (**Table 2**).

Because the Levene test did not show a significant difference between all age groups, the datashowed a homogeneous distribution (P>0.05). Mean eyeball measurements with upper and lower 95% confidence intervals for right and left eyeball according to age groups are listed in **Table 3**. In REAPD, although a significant relationship was found between the 1st and 2nd age groups, no statistically significant relationship was found in other measurements. In addition, no significant difference was found in measurements of eyeball diameter and volume in the 3rd and 4th groups in all age groups (p> 0.05).

Table 2. Correlation Test Between month and eyeball diameters and volumes

Parameters	REAPD	RETRD	RECCD	REV	LEAPD	LETRD	LECCD	LEV
r	.729**	.740**	.750**	.783**	.759**	.731**	.757**	.792**
Pa	.000	.000	.000	.000	.000	.000	.000	.000

[a]Pearson correlation test. Statistically significant at P<.05. REAPD: Right eyeball anterior posterior diameter. LEAPD: Left eyeball anterior posterior diameter. RETRD: Right eyeball transverse diameter. LETRD: Left eyeball transverse diameter. RECCD: Right eyeball craniocaudal diameter. LECCD: Left eyeball craniocaudal diameter. REV: Right eyeball volume. LEV: Left eyeball volume

Table 3. Eyeball diameters and volumes according to age groups (Months)

		N	Mean	Std. Deviation	95% Confidence Interval for Mean		F	Pa	Difference
					Lower Bound	Upper Bound			
REAPD	1 (0 to 1)	13	18.92	.862	18.40	19.44	20.048	0.029	1 to 2
	2 (2 to 6)	35	20.06	1.103	19.68	20.44		.000	1 to 3
	3 (7 to 12)	18	21.58	.845	21.16	22.00		.000	1 to 4
	4 (13 to 24)	24	21.61	1.672	20.89	22.33		.000	2 to 3
	Total	90	20.60	1.551	20.27	20.93		.000 1.000	2 to 4 3 to 4
LEAPD	1 (0 to 1)	13	18.77	.832	18.27	19.27	30.460	0.076	1 to 2
	2 (2 to 6)	35	19.74	1.067	19.38	20.11		.000	1 to 3
	3 (7 to 12)	18	21.89	.832	21.47	22.30		.000	1 to 4
	4 (13 to 24)	24	21.70	1.636	20.99	22.40		.000	2 to 3
	Total	90	20.54	1.666	20.19	20.89		.000 1.000	2 to 4 3 to 4
RETRD	1 (0 to 1)	13	19.85	.899	19.30	20.39	23.400	.913	1 to 2
	2 (2 to 6)	35	20.43	1.139	20.04	20.82		.000	1 to 3
	3 (7 to 12)	18	22.61	.916	22.16	23.07		.000	1 to 4
	4 (13 to 24)	24	22.30	1.690	21.57	23.04		.000	2 to 3
	Total	90	21.27	1.648	20.92	21.62		.000 1.000	2 to 4 3 to 4
LETRD	1 (0 to 1)	13	19.69	.947	19.12	20.26	21.710	.181	1 to 2
	2 (2 to 6)	35	20.56	1.143	20.16	20.95		.000	1 to 3
	3 (7 to 12)	18	22.33	1.085	21.79	22.87		.000	1 to 4
	4 (13 to 24)	24	22.30	1.490	21.66	22.95		.000	2 to 3
	Total	90	21.24	1.578	20.91	21.57		.000 1.000	2 to 4 3 to 4
RECCD	1 (0 to 1)	13	19.85	1.345	19.03	20.66	23.928	.195	1 to 2
	2 (2 to 6)	35	20.76	1.114	20.37	21.14		.000	1 to 3
	3 (7 to 12)	18	22.72	1.074	22.19	23.26		.000	1 to 4
	4 (13 to 24)	24	22.78	1.622	22.08	23.48		.000	2 to 3
	Total	90	21.54	1.722	21.18	21.91		.000 1.000	2 to 4 3 to 4
LECCD	1 (0 to 1)	13	20.08	1.115	19.40	20.75	23.891	1.000	1 to 2
	2 (2 to 6)	35	20.59	1.154	20.19	20.98		.000	1 to 3
	3 (7 to 12)	18	22.56	1.042	22.04	23.07		.000	1 to 4
	4 (13 to 24)	24	22.78	1.594	22.09	23.47		.000	2 to 3
	Total	90	21.48	1.679	21.12	21.83		.000 1.000	2 to 4 3 to 4
REV	1 (0 to 1)	13	3.9231	.55701	3.5865	4.2597	27.216	.193	1 to 2
	2 (2 to 6)	35	4.4886	.67247	4.2576	4.7196		.000	1 to 3
	3 (7 to 12)	18	5.8278	.66049	5.4993	6.1562		.000	1 to 4
	4 (13 to 24)	24	5.8261	1.12501	5.3396	6.3126		.000	2 to 3
	Total	90	5.0225	1.10049	4.7907	5.2543		.000 1.000	2 to 4 3 to 4
LEV	1 (0 to 1)	13	3.9000	.53229	3.5783	4.2217	30.911	.285	1 to 2
	2 (2 to 6)	35	4.4057	.64941	4.1826	4.6288		.000	1 to 3
	3 (7 to 12)	18	5.7944	.70333	5.4447	6.1442		.000	1 to 4
	4 (13 to 24)	24	5.8391	1.06248	5.3797	6.2986		.000	2 to 3
	Total	90	4.9831	1.10064	4.7513	5.2150		.000 1.000	2 to 4 3 to 4

ANOVA=analysis of variance. a One-way ANOVA. Statistically significant at P < .05. REAPD: Right eyeball anterior posterior diameter, LEAPD: Left eyeball anterior posterior diameter, RETRD: Right eyeball transverse diameter, LETRD: Left eyeball transverse diameter, RECCD: Right eyeball craniocaudal diameter, LECCD: Left eyeball craniocaudal diameter, REV: Right eyeball volume, LEV: Left eyeball volume, *Unit of length: mm, *Unit of volume: cm^3

DISCUSSION

Understanding the normal value ranges for the eyeball volume is critical for diagnosis, treatment and, evaluation prior to surgical procedures (16-19). Although MDCT is more successful than other in vivo imaging modalities for assessing eyeball volume, it is not preferred for routine examination because it contains ionizing radiation (7). However, as demonstrated in our study, volume calculations can be performed retrospectively on MDCTs obtained for any reason (e.g., trauma).

In our study, mean eyeball volume was measured as 3.91±0.54 cm^3 for 0-1 months, 4.44 ±0.66 cm^3 for 2-6 months, 5.81 ±0.68 cm^3 for 7-12 months, and 5.83±1.09 cm^3 for 13-24 months. The volume of the eyeball increased with age.

In their study of 198 participants (83 females, 115 males) aged 5 to 74 years, Ozer et al. (16) found that right eyeball volume was 6.50±0.80 ml and left eyeball volume was 6.46±0.76 ml in the entire study group. In the same study, no statistically significant relationship was found between eyeball volumes and gender. Furthermore, in the same study, no significant relationship was found between age and eyeball volumes in the entire study group. Our study differs from the study of Özer et al. in terms of age group. In our study, pediatric age groups were defined as follows: 0-1 month, 2-6 months, 7-12 months, 13-24 months. Eyeball volume increased with age in both boys and girls. In addition, a positive correlation between age and eyeball volume was found in the entire study group.

In their study of 200 participants (122 males, 78 females) aged 3 to 84 years, Igbinedion et al. (7) reported both eyeball volumes as 5282.23 mm^3±1755.13 mm^3 (mean±2SD) The right eyeball volume was 5264.26 mm^3 ±1781.12 mm^3, and the left eyeball volume was 5300.20 mm^3 ±1771.57 mm^3. In the same study, they found a positive correlation between the ages of the patients and their eyeball volumes. Chau et al. (20) found no significant relationship between gender and the volume of both eyeballs in a magnetic resonance study of 33 adult patients with varying degrees of ametropia. In this study, the mean eyeball volume was reported as 6.70 cm^3 (5.11-8.83). Hahn et al. (6) found a rapid rise in eyeball volume from birth to two years of age, followed by a relative increase until the age of thirty in their CT-based investigation with 100 participants. In our study, we found that the increase in eye volume increased rapidly from birth to the first year of life, but there was no significant increase in eye volume between the ages of 1 and 2 years.

Our study had two major limitations. First of all,our study includes only a limited number of patients and is single centered. Future multi-center studies with higher patient numbers will provide more accurate information. Secondly, ethnicity may alter the normal values obtained, our study reflects only the normal values in the Turkish population. We think that our study will serve as a modal for larger series and multicenter studies conducted in other ethnic groups in the pediatric age group.

CONCLUSION

It is vital to understand the variations in eyeball volumes with age in order to diagnose macrophthalmos or microphthalmos. To the best of our knowledge, our study is the most comprehensive MDCT study showing normal eyeball volumes in the age group 0-2 years.

ETHICAL DECLARATIONS

Ethical Committee Approval: The study was approved by the Gazi University Non-Interventional Studies Ethics Committee (Date: 29.1.2021, Decision Number:140).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of interest: The authors declare that they have no conflict of interest.

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