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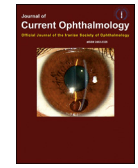

Original research

Orbital radiologic parameters of non-syndromic exorbitism patients in comparison with normal population

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Abstract

Purpose: To measure orbital dimension of patients with exorbitism and defining criteria for its diagnosis.

Methods: Twelve patients with non-syndromic exorbitism (NSE) were compared with 24 control samples by means of computed tomography scan (CT-scan) findings. The proptosis severity, lateral wall length, medial wall length, optic nerve straight length, lateral wall angle, ethmoidal sinus surface area, mid-interorbital distance, anterior interorbital distance, external orbital distance, inter-pupillary distance, and lateral wall curve cord were evaluated in order to define a criterion for NSE.

Results: Among eleven compared radiological parameters between the study and control groups, five parameters including lateral orbital wall angle ($P = 0.02$), mid-interorbital distance ($P = 0.007$), anterior inter-orbital distance ($P < 0.001$), inter-pupillary distance ($P = 0.01$), and proptosis severity ($P < 0.001$) were found to be significantly different between the study groups. Therefore, NSE could be diagnosed with lateral wall angle greater than 41.74°, mid-interorbital distance more than 31.84 mm, and anterior interorbital distance more than 25.90 mm, with a sensitivity of 91% and specificity of 71%.

Conclusions: Using lateral wall angle, mid-interorbital distance, and anterior interorbital distance, we defined the criterion for diagnosis of NSE. Moreover, by focusing on parameters which play a role in developing exorbitism, we can determine the best approach for improvement of aesthetic and functional features of this condition.

Keywords: Non-syndromic exorbitism; Orbitometry; Proptosis

Introduction

Exorbitism is a term used for globe proptosis due to the decrease of orbital cavity volumes with normal orbital content volumes. This term must be distinguished from exophthalmos which is used for proptosis due to the increase of orbital content volumes with normal orbital cavity dimensions.[1,2] Exorbitism can result from craniosynostosis or premature closure of the cranial skull sutures of the neonate.[3] These phenomena are described as syndromic exorbitism in contrast with non-syndromic exorbitism (NSE) wherein no underlying cause can be found in the patient's medical history.[2] Although exorbitism can cause different aesthetic and functional eye debilitations for patients,[2,4] only a small number of studies have focused on precise definition, pathogenesis, and surgical operation success rate in exorbitism.[4]

Orbitometry can play a fundamental role in understanding physiopathogeneis and response to treatment of orbital malformations.[5] Early orbitometry methods were based on

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photography and surface anatomy studies.[6–9] The main drawback in these methods was inability to measure the structures beneath the surface of the eye and periorbital areas.[10] Later endeavors used ex-vivo samples for filling the orbital cavities with different materials such as glass, sand particles, lead, and chalk. Then the volume of the substance was measured, and the orbital volume was calculated. Some experts believe that measuring the volume of the orbit with molded casts is the gold standard method for volumetry of the orbit.[11]

With the introduction and exponential use of computerized imaging in the early 70s, computed tomography scan (CT-scan) and magnetic resonance imaging (MRI) were used increasingly for orbitometry.[12] Providing precision, ability to use on live samples, and repeatability, CT-scan is described as the most precise and trustable method for measuring the orbital diameters.[11] However, studies which have shown reference values for orbitometry possess low reliability due to racial and gender differences, different orbitometry techniques, and error-susceptible measuring methods.[13]

Previously, a criterion for NSE was made based on the differences between the lateral orbital wall angle and mid-interorbital distance in patients with NSE and Graves' disease.[2] Considering the fact that no other similar studies have focused on NSE definition, we performed a study on orbitometry of NSE patients in a 2-year period to examine if the known criterion was valid or not and what other factors played a role in architecting a shallow orbit.

Methods

This study was a prospective cross-sectional study conducted between November 2016 and November 2018 in Farabi Eye Hospital, Tehran, Iran. The protocol of the study was approved by the Institutional Review Board and Ethics Committee of Tehran University of Medical Sciences, and the study was carried out based on the tenets of the Declaration of Helsinki. All patients whose photographs are shown here signed the informed consent for publication of their pictures and information in this study. NSE was defined as a protrusion of the globe because of the decrease in the orbital capacity with normal orbital contents. Patients with Persian origin who had protrusion of the globe in addition to the following features were included in the study: 1. Not having any known systemic disorder with impact on the orbital cavity volume (including Graves' ophthalmopathy, Wegner's granulomatosis, neuroblastoma, orbital cellulitis, dermoid cyst, caverno-carotid fistulae, cavernous hemangioma, leukemia, anophthalmos, sphenoid wing meningioma, mucormycosis, etc.); 2. No major eye trauma and subsequent orbital wall fracture; 3. No known craniofacial and systemic syndromes (including Apert, Pfeiffer, and Cruzon) present in patient's medical history; and 4. Having spherical equivalence between −3 and +3 diopters. These patients were compared to an age- and gender-matched control group. All the control samples had the defined inclusion criteria except for protrusion of the globe so that the chance of having predisposing medical conditions affecting orbital volumes was minimized. Spiral orbital CT-scan with sagittal, axial, and coronal planes was performed for all of the participants in their diagnostic/therapeutic plans. Overall, 12 patients with an age range of 19–36 years met the inclusion criteria for our study. Duplicating the size of the case group for minimal bias, 24 controls with an age range of 20–38 years having the requirements discussed above were selected for further studies (Fig. 1).

Eleven radiological parameters were studied on the patients' orbital multi-slice CT-scan as described below:

1. Proptosis severity: straight distance between the anterior margin of the cornea and the line which connected the anterior part of the lateral orbital rim to the tip of the posterior lacrimal crest (Fig. 2-A).
2. Lateral wall length: straight distance between the anterior part of the lateral orbital rim and beginning of the orbital foramen in the plane that optic nerve could be seen (Fig. 2-B).
3. Medial wall length: straight distance between the tip of the posterior lacrimal crest and beginning of the optic foramen (Fig. 2-C).
4. Optic nerve straight length: straight distance between the anterior and posterior tips of visible parts of the intra-orbital optic nerve (Fig. 2-D).
5. Lateral wall angle: the angle between the lateral orbital wall and sagittal plane (Fig. 2-E)
6. Ethmoidal sinus surface area: maximum surface area of the ethmoidal sinus on each side (Fig. 2-F).
7. Maximum-interorbital distance: maximum distance between the lateral walls of the left and right ethmoidal sinuses (Fig. 2-G).
8. Anterior interorbital distance: straight distance between the tips of the posterior lacrimal crests on both sides (Fig. 2-H).
9. External orbital distance: straight distance between the anterior parts of the lateral orbital walls on both sides (Fig. 2-I).
10. Inter-pupillary distance: straight distance between the centers of corneas on both sides (Fig. 2-J).
11. Lateral wall curve cord: maximum straight distance between a line which connects the anterior and posterior tips of the lateral orbital wall with the depth of the orbital wall (Fig. 2-K).

Each parameter was measured three times using ImageJ © 1.44p with precision of 0.01 mm. Mean value for each parameter was put into analysis as the crude data. All measurements were done by an expert oculoplastic surgeon (M.T.R). Statistical analysis was done by IBM c© SPSS 24 for Windows, and to compare the means, we used "*t*-test for equality of means" with 95% confidence interval.

Results

Mean age (29.50 ± 6.90 years for the study and 30.29 ± 5.49 years for the control group) did not show a

Fig. 1. Photograph samples of control (A, B, C) and case (D, E, F) group patients.

significant difference between the two studied groups ($P = 0.711$). Proptosis severity (Fig. 3-A) was significantly larger among the cases ($P \leq 0.001$) that showed that the case and control groups were chosen correctly (Table 1). The anterior interorbital distance (Fig. 3-H) was found to be larger in the case group with 95% confidence interval of

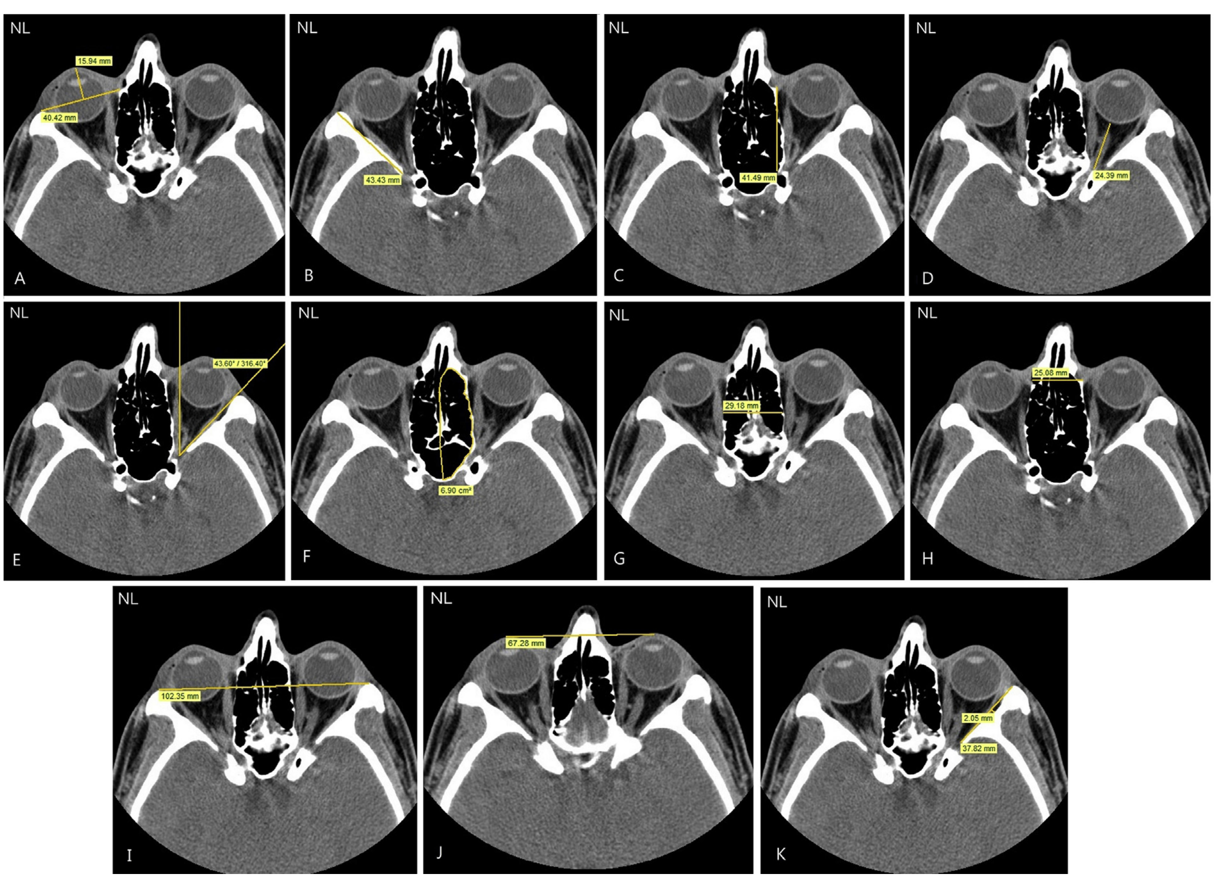

Fig. 2. Normal population. A - Proptosis severity. B - Lateral wall length. C - Medial wall length. D - Optic nerve length. E − Lateral wall angle. F - Ethmoid sinus surface area. G - Mid-interorbital distance. H - Anterior interorbital distance. I - External orbital distance. J - Inter-pupillary distance. K - Lateral wall curve.

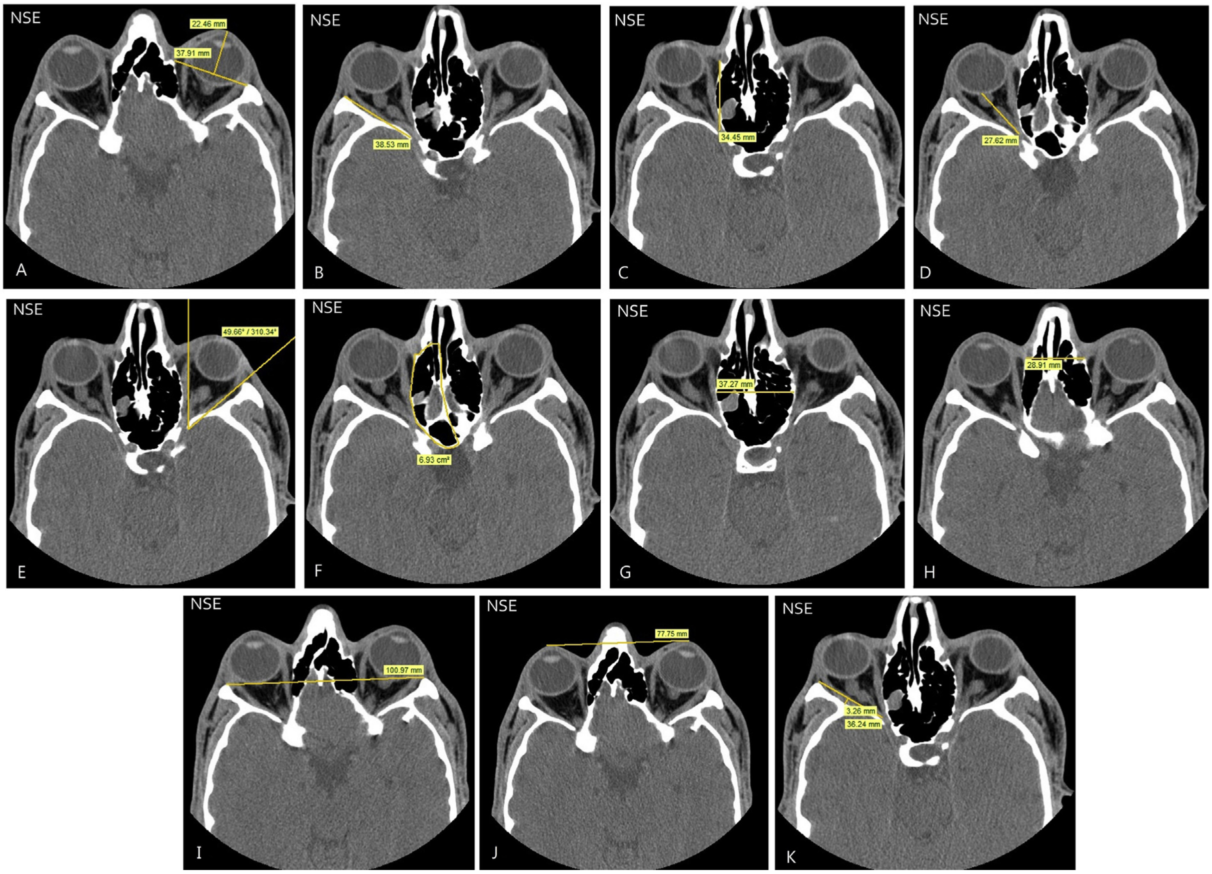

Fig. 3. Non-syndromic exorbitism (NSE). A - Proptosis severity. B - Lateral wall length. C - Medial wall length. D - Optic nerve length. E – Lateral wall angle. F - Ethmoid sinus surface area. G - Mid-interorbital distance. H - Anterior interorbital distance. I - External orbital distance. J - Inter-pupillary distance. K - Lateral wall curve.

25.08–26.82 mm ($P \leq 0.001$). Maximum-interorbital distance (Fig. 3-G) was also significantly larger among the cases ($P = 0.007$). Lateral wall angle (Fig. 3-E) and inter-pupillary distance (Fig. 3-J) showed a significantly different value between the case and control groups, with larger values among the cases ($P = 0.02$ and $P = 0.01$, retrospectively). Other studied parameters were not significantly different between the two groups; these parameters included lateral wall length (Fig. 3-B), medial wall length (Fig. 3- C), optic nerve length (Fig. 3-D), and ethmoid sinus surface area (Fig. 3-F), lateral wall curve cord (Fig. 3-K), and external orbital distance (Fig. 3-I) (Table 1).

Table 1
Significance level of the evaluated parameters in the case and control groups.

Parameter	Case	Control	*P*-value
Proptosis	18.80 (±2.19)	14.48 (±1.34)	<0.001
Anterior interorbital distance	28.05 (±2.05)	24.68 (±1.71)	<0.001
Lateral wall angle	46.23 (±5.85)	41.74 (±3.53)	0.02
Mid-interorbital distance	34.81 (±2.85)	31.48 (±3.51)	0.007
Inter-pupillary distance	70.70 (±8.33)	65.14 (±4.63)	0.01
Lateral wall length	41.73 (±3.91)	43.26 (±3.79)	0.266
Medial wall length	39.40 (±3.92)	39.27 (±3.60)	0.923
Optic nerve length	26.87 (±4.94)	27.73 (±2.87)	0.510
Ethmoid sinus surface area	6.70 (±1.30)	6.48 (±0.74)	0.518
Lateral wall curve	2.57 (±0.84)	2.83 (±0.88)	0.414
External orbital distance	96.88 (±4.75)	96.34 (±3.88)	0.717

All of the significantly different parameters (including: lateral wall angle, proptosis severity, mid-interorbital distance, inter-pupillary distance, and anterior interorbital distance) were compared separately between the males and females in both the case and control groups, and none of them showed significantly different values (Table 2).

Using binary logistic regression (BLR) and receiver operative characteristics (ROC) curve for significantly different parameters, we defined the diagnostic criteria for NSE. With lateral wall angle greater than 41.74°, mid-interorbital distance more than 31.84 mm, and anterior interorbital distance more than 25.90 mm, with a sensitivity of 91% and specificity of 71%, a person can be diagnosed to have NSE (Fig. 4).

Discussion

Despite the fact that exorbitism can have severely debilitating functional and aesthetic consequences and considering the growing use of orbitometry in defining and preoperative evaluation of orbital anomalies, only a small amount of data exists regarding the definition of NSE and orbitometry of the

Table 2
Comparing significantly different parameters between males and females in the case and control groups.

Category	Parameter	Male	Female	*P*-value
Case	Lateral wall angle	48.09 (±9.52)	45.70 (±5.47)	0.506
	Proptosis severity	19.86 (±1.99)	18.58 (±2.27)	0.482
	Mid-interorbital distance	34.93 (±2.81)	34.79 (±3.01)	0.953
	Inter-pupillary distance	69.64 (±11.88)	70.91 (±8.30)	0.854
	Anterior interorbital distance	27.42 (±2.10)	28.72 (±2.09)	0.439
Control	Lateral wall angle	41.11 (±3.52)	42.12 (±3.59)	0.508
	Proptosis severity	14.35 (±1.31)	14.56 (±1.40)	0.708
	Mid-interorbital distance	31.09 (±3.45)	31.71 (±3.64)	0.682
	Inter-pupillary distance	66.03 (±4.61)	64.60 (±4.71)	0.476
	Anterior interorbital distance	24.51 (±1.45)	24.78 (±1.89)	0.711

patients with this condition. Different studies have shown that orbital measurement methods are susceptible to error, and due to different age and racial factors, different reference values are reported in each study. However, we presume that using high-precision measurement software, multi-slice CT-scan, and multiple measurements can minimize these errors and result in more valid data. We also presume using the normal population for the control group, such as what was used in the current study compared to previous studies,[2] can theoretically improve validity of the results and decrease the bias rate.

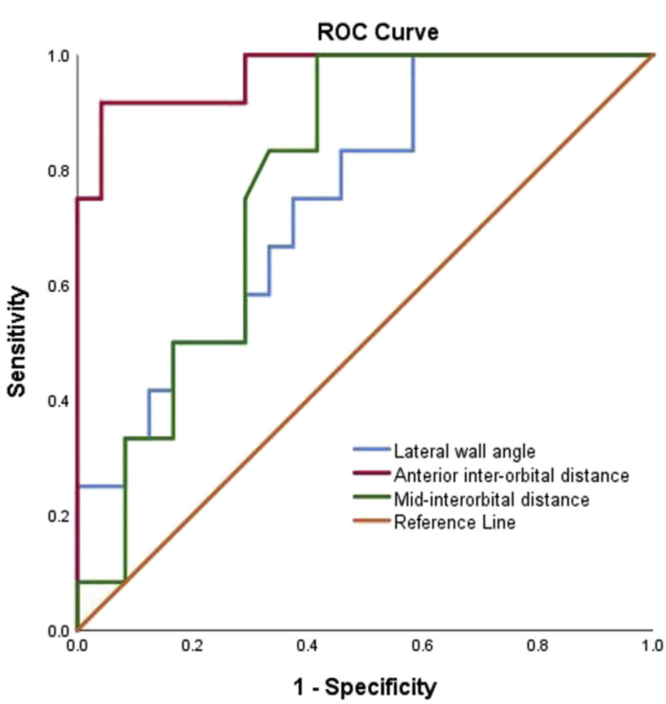

Fig. 4. Receiver operative characteristics (ROC) curve for diagnosis of non-syndromic exorbitism (NSE).

Baujat et al.[2] studied 16 NSE and 57 Graves' patients and defined a criterion for NSE based on significantly different parameters between the NSE and Graves' patients. The lateral orbital wall angle (with sagittal plane) more than 42° and mid-interorbital distance more than 30 mm showed to have diagnostic value for NSE with a sensitivity of 62% and specificity of 78%.

In the current study, a third criterion, known as anterior interorbital distance, was added to previous Baujat criteria and caused 29% more sensitivity at the cost of only 7% decrease in specificity. This finding showed that the lateral orbital wall angle, mid-interorbital distance, and anterior interorbital distance are probably the only valuable point of interest that need to be focused on preoperatively in NSE patients.

In spite of the reported gender impact on the orbital volume as larger orbital diameters in adult males,[14] we found no statistically significant differences between males and females in the case and control groups. This result can be due to a small sample size or may show a different racial anthropology which needs to be tested and evaluated in detail in further studies. Female patients were predominant in the NSE group, which could signify two theories: first, there is a female-dominant trend in the development of NSE, and second, females are more concerned about the aesthetic features of their eyes in the case of not having any pathologies. However, this finding could be due to the small sample size and needs further studies.

On CT-scans, NSE patients were associated with wider lateral orbital wall angle; the wider the lateral orbital wall angle, the less the depth of the orbit, thus resulting in exorbitism and extrusion of the globe. There are a few limitations in this study. A relatively small number of patients and using two-dimensional slices are the main ones. Another drawback is the evaluation of images by only one grader, as having multiple graders could enhance the quality of measurements.

Finally, evaluating the orbital anatomical aspects of patients with NSE could help us determine the best surgical approach for relieving its aesthetic and functional effects. Further research is needed to assess the surgical outcome based on the most important factors which affect this condition.

References

1. Wolfe SA, Kearney R. Blepharoplasty in the patient with exophthalmos. *Clin Plast Surg*. 1993;20(2):275—283. Discussion 283-274.
2. Baujat B, Krastinova D, Bach CA, Coquille F, Chabolle F. Orbital morphology in exophthalmos and exorbitism. *Plast Reconstr Surg*. 2006;117(2):542—550. Discussion 551-542.
3. Cruz AA, Akaishi PM, Arnaud E, Marchac D, Renier D. Exorbitism correction of faciocraniosynostoses by monobloc frontofacial advancement with distraction osteogenesis. *J Craniofac Surg*. 2007;18(2):355—360.
4. Alyamani A, Kessler P, Abuzinada S. Management of exorbitism using midface distraction osteogenesis. *J Maxillofac Oral Surg*. 2012;11(1):119—124.
5. Nugent RA, Belkin RI, Neigel JM, et al. Graves orbitopathy: correlation of CT and clinical findings. *Radiology*. 1990;177(3):675—682.
6. McGurk M, Whitehouse RW, Taylor PM, Swinson B. Orbital volume measured by a low-dose CT scanning technique. *Dentomaxillofac Radiol*. 1992;21(2):70—72.

7. Cooper WC. A method for volume determination of the orbit and its contents by high resolution axial tomography and quantitative digital image analysis. *Trans Am Ophthalmol Soc*. 1985;83:546−609.
8. Acer N, Sahin B, Ergur H, Basaloglu H, Ceri NG. Stereological estimation of the orbital volume: a criterion standard study. *J Craniofac Surg*. 2009; 20(3):921−925.
9. Moss AA, Friedman MA, Brito AC. Determination of liver, kidney, and spleen volumes by computed tomography: an experimental study in dogs. *J Comput Assist Tomogr*. 1981;5(1):12−14.
10. Weaver AA, Loftis KL, Tan JC, Duma SM, Stitzel JD. CT based three-dimensional measurement of orbit and eye anthropometry. *Investig Ophthalmol Vis Sci*. 2010;51(10):4892−4897.
11. Osaki TH, de Castro DK, Yabumoto C, et al. Comparison of methodologies in volumetric orbitometry. *Ophthalmic Plast Reconstr Surg*. 2013; 29(6):431−436.
12. Szucs-Farkas Z, Toth J, Balazs E, et al. Using morphologic parameters of extraocular muscles for diagnosis and follow-up of Graves' ophthalmopathy: diameters, areas, or volumes? *Am J Roentgenol*. 2002;179(4): 1005−1010.
13. Mourits MP, Bijl H, Altea M, et al. Outcome of orbital decompression for disfiguring proptosis in patients with Graves' orbitopathy using various surgical procedures. *Br J Ophthalmol*. 2009;93(11):1518−1523.
14. Barretto RL, Mathog RH. Orbital measurement in black and white populations. *The Laryngoscope*. 1999;109(7 Pt 1):1051−1054.