Measurement of Eyelid and Orbital Fat Volume in Different Age Groups by Computed Tomography

Gözkapağı ve Orbita Yağ Hacminin Farklı Yaş Gruplarında Bilgisayarlı Tomografi ile Ölçülmesi

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ABSTRACT Objective: To compare the eyelid and orbital fat volume in different age groups. **Material and Methods:** Sixty seven orbits of 39 subjects with normal orbital computed tomography (CT) scans with an age range of 18-82 years were included in the study. Three dimentional (3D) connected threshold region growing algorithm as a plugin to Image J, an image analysis software package developed by National Institute of Health (NIH) (U.S. Department of Health and Human Services, USA) was used to measure the orbital and eyelid fat volume on axial computed tomography sections. Measurements were compared in three different age groups. **Results:** There were 16 orbits in the first group (18-34 years), 33 in the second (35-60 years) and 18 in the third group (61 and up). Total volume (Orbit + eyelid) and total fat volume (Orbital+ eyelid) was noted to increase with age (p= 0.0021). Eyelid fat volume also increased with age (p=0.0013). Total fat volume/Total volume (p= 0.0041) and Eyelid fat volume/Total volume (p= 0.0033) was noted to increase with age. Eyelid fat volume/Total fat volume also increased with age (p= 0.0042). Orbital fat volume showed a trend of increase with age but this was not found to be statistically significant. (p= 0.072) The proportion of mean orbital fat volume within mean total volume (p= 0.688) did not show any change with age. **Conclusion:** The total fat volume and eyelid fat volume as well as their percentage of the total volume increased with age. Percentage of eyelid fat volume of the total fat volume increased with age as well. These observations suggest that orbital fat expansion may occur with aging and fat excision may have a role in blepharoplasty for treatment of upper and lower eyelid prominence. This technique may be useful in further future studies regarding the anatomy and distribution of eyelid and orbital fat.

Key Words: Eyelids; orbit; adipose tissue; aging

ÖZET Amaç: Bu araştırmada farklı yaş gruplarında göz kapağı ve orbita yağ hacminin karşılaştırılması amaçlanmıştır. **Gereç ve Yöntemler:** Onsekiz ile 82 yaşları arasındaki 39 kişinin 67 normal orbita bilgisayarlı tomografisi (BT) araştırmaya dahil edilmiştir. Gözkapağı ve orbita yağ hacmi, Ulusal Sağlık Enstitüsü (NIH) (A.B.D. Sağlık Bakanlığı bünyesinde) tarafından geliştirilmiş bir görüntü analizi programı olan Imaj J ile birlikte üç boyutlu büyüyen bağlantılı eşik bölge algoritması kullanılarak aksiyel BT kesitlerinde ölçülmüştür. Bulunan ölçümler üç ayrı yaş grubunda karşılaştırılmıştır. **Bulgular:** Birinci grupta (18-34 yaş) 16 orbita, ikinci grupta (35-60 yaş) 33 ve üçüncü grupta (61yaş ve üzeri) 18 orbita bulunmaktaydı. Total hacim (Orbita + göz kapağı) ve total yağ hacminin (Orbita + göz kapağı) yaş ile beraber arttığı görülmüştür (p= 0.0021). Gözkapağı yağ hacminin de yaş ile beraber arttığı izlenmiştir (p= 0.0013). Total yağ hacmi/Total hacim (p= 0.0041), Gözkapağı yağ hacmi /Total hacim (p= 0.0033) ve Gözkapağı yağ hacmi/Total yağ hacmi (p= 0.0042) oranlarının da yaş ile beraber arttığı gözlenmiştir. Orbita yağ volümü yaşla beraber bir artış göstermiş fakat istatistiksel olarak anlamlı bulunmamıştır. (p= 0.072) Orbita yağ hacmi/Total hacim (p= 0.688) oranının yaş ile beraber değişmediği izlenmiştir. **Sonuç:** Total yağ hacmi ve göz kapağı yağ hacmi ile bunların total hacime oranlarının yaşla beraber arttığı gözlenmiştir. Gözkapağı yağ hacminin de total yağ hacmine oranının yaşla arttığı görülmüştür. Bu bulgular yaşla beraber orbita yağ dokusunun genişleme gösterebilecegini ve üst/alt kapak blefaroplastisinde yağ dokusu çıkartılmasının rolünü desteklemektedir. Bu yöntem, gelecekteki orbitanın anatomisi ve orbita ve göz kapağı yağ dokusunun dağılımı ile ilgili çalışmalarda kullanılabilecek faydalı bir tekniktir.

Anahtar Kelimeler: Gözkapağı; orbita; yağ dokusu; yaşlanma

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Computer tomographic (CT) digital data and special off-line automatic or semi-automatic CT image processing techniques have been used to measure volumes of orbital soft tissue, extraocular muscle, orbital fat and total bony orbit with accurate and reproducible results.[1-4] To our knowledge, there is only one study which analyzed the volume of different orbital components in normal subjects without classification in different age groups.[1] Recently, Darcy et al. evaluated magnetic resonance imaging characterization of orbital changes with age and associated contributions to lower eyelid prominence.[5] One limitation of that study is the extrapolation of orbital volume from an area measurement of a single sagittal magnetic resonance imaging slice.

In our study, we measured eyelid and orbital fat volume in different age groups using digital image analysis based on orbital CT scans. A three-dimentional (3D) connected threshold region growing algorithm as a plugin to Image J, an image analysis software package developed by National Institute of Health (NIH), was used to measure the orbital and eyelid fat volume on axial computed tomography sections.

MATERIAL AND METHODS

Sixty seven orbits of 39 subjects with normal orbital computed tomography (CT) with an age range of 18-82 years were included in the study. Only the orbital CT scans (Multislice spiral CT scanner, HiSpeed Adv SYS#MSC1, GE Medical Systems, Waukesa, WI, USA) that were performed in our Radiology Department between July 2000- July 2002 and reported as normal by the neuroradiologists were obtained from the database and included in the study. All CT scans were performed when the patients in supine position. These orbital CT scans were re-evaluated by one of the authors of the study (AA) and they were confirmed to be normal. If an orbital pathology was noted in one orbit, that side was excluded from the study, otherwise, both orbits of the same subject were included in the study. The patients' charts were reviewed and patients with primary ophthalmologic diseases, infection, and a history of thyroid disease and previous operation around the periorbital region were excluded. Other exclusion criterias included congenital craniofacial abnormalities, bilateral facial trauma, intracranial hemorrhage, and tumor involving the midface.

3D connected threshold region growing algorithm as a plugin to Image J, an image analysis software package developed by NIH, was used to measure the orbital and eyelid fat volume on 3 mm-thick axial computed tomography sections (512x512 matrix)

The original images were transferred to NIH ImageJ program in our research computer system (IBM Thinkpad T23,utilizing Windows 2000 OS). The total of orbital and eyelid soft tissue volume was designated as total volume. The total volume was measured by 3D connected threshold region growing algorithm after manually tracing the medial and lateral orbital wall including the eyelid soft tissues (Figure 1). The borders of the orbit was determined with the following landmarks: frontal bone superiorly, frontozygomatic suture laterally, inferior orbital rim inferiorly and anterior lacrimal crest medially.[7] Anterior orbital boundary is defined by a line passing from the most anterior aspects of the medial lateral orbital walls.[7-9] The

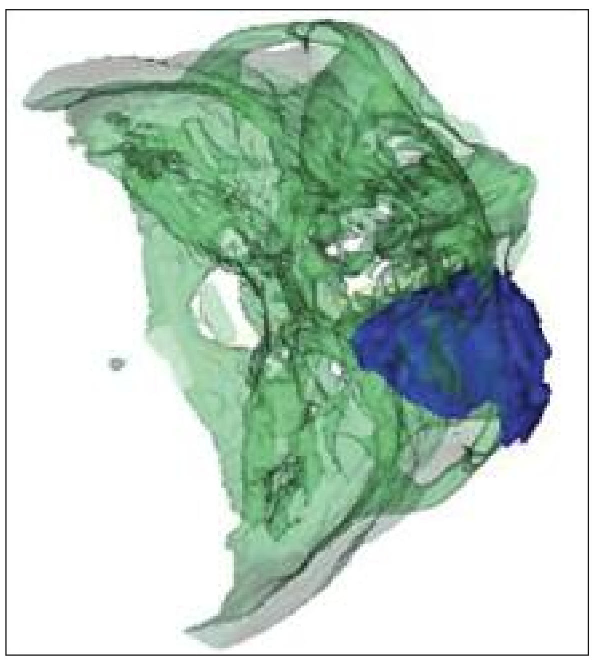

FIGURE 1: Total volume including orbital and eyelid soft tissue volume

posterior limit was defined by a line connecting the medial and lateral walls of the optic foramen within the orbit, thus excluding the optic canal for volume measurements.[8] The sum of orbital and eyelid fat volume was designated as total fat volume. It was measured by a 3D connected threshold region growing algorithm within the borders of the space designated as total volume (Figure 2). Eyelid fat volume was again measured by the same method after manually tracing the medial and lateral orbital wall in every slice, the posterior limit being a straight line (also manually traced in every slice) passing from the most anterior aspects of the medial and lateral orbital walls (Figure 3).[7-9]

For measurement of eyelid or total fat volume, ten different points inside the fat within the defined space were identified. These points served for threshold determination of the intensity of fat for that specific CT scan. Then a point was seeded into the orbital fat to serve as the 'starting point' for the 3D connected threshold growing algorithm. The algorithm "expands" this point in three dimensions including only those pixels within the predetermined intensity threshold in the manually drawn region of interest. The total of orbital and eyelid soft tissue volume was calculated in a similar fashion. The program generates a pixel count of the designated space in each slice of the scan and then adds the values from each slice to obtain the volume. The total number of pixels in the designated space is multiplied by a conversion factor representative of the dimension of a single voxel. Each voxel (elementary unit of volume) is 0.37 mm^3 in dimension. The volume was calculated by multiplying the number of voxels in every slice with the volume of each voxel. A separate calculation was done for total volume, total and eyelid fat volume.

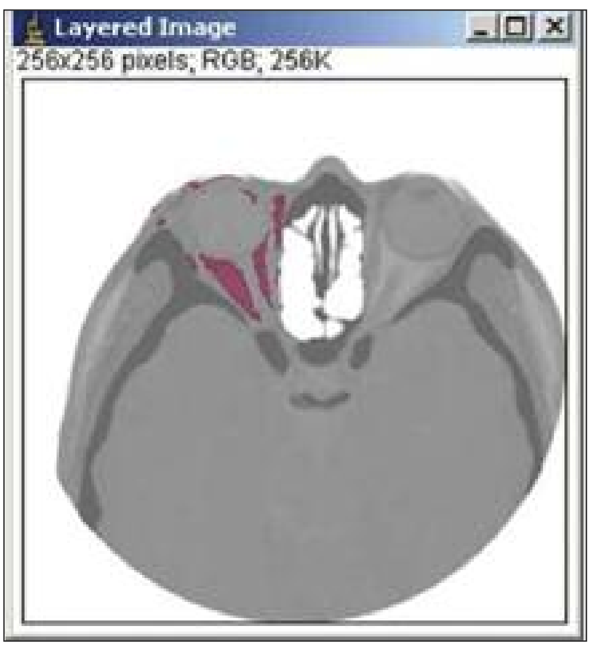

FIGURE 2: Total fat volume shown as red including orbital and eyelid fat volume. It was measured by 3D connected threshold region growing algorithm within the borders of the space designated as total volume

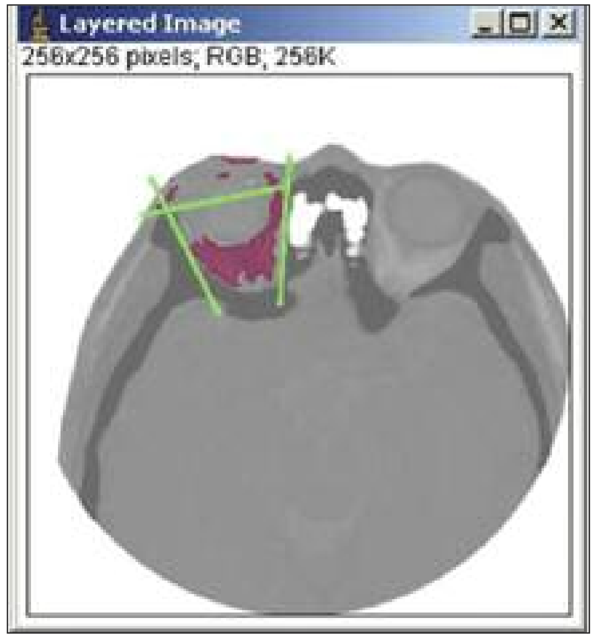

FIGURE 3: Eyelid fat volume shown as red measured by 3D connected threshold region growing algorithm after manually tracing the medial and lateral orbital wall, the posterior limit being a straight line connecting the lateral and media orbital walls

The reproducibility of the measurements was confirmed by taking three different measurements and the average of three measurements was used for calculation. Measurements were compared in three different age groups. Statistical analysis was performed by analysis of variance (ANOVA). Comparison of means between three age groups were performed using Tukey's honestly significant difference (HSD) test.

RESULTS

There were 16 orbits in the first group (18-34 years), 33 in the second (35-60 years) and 18 in the third group (61 and up). The total volume (Orbit + eyelid) (Table 1) (By using Tukey's test the total volume in age 60+ group was found to be significantly higher than the total volume in age 18-34 group as well as 35-60 group) and total fat volume (Orbital+ eyelid) was noted to increase with age (p=0.0021) (Table 2) (with Tukey's test total fat volume in age 60+ group was found to be significantly higher than the total fat volume in age 18-34 group). Eyelid fat volume also increased with age (p=0.0013) (Table 3) (with Tukey's test eyelid fat volume in both age 35-60 and age 60+ groups was found to be significantly higher than the eyelid fat volume in age 18-34 group).

The proportion of mean total fat volume within mean total volume (p=0.0041) (Table 4) (with Tukey's test, the proportion of mean total fat volume within mean total volume in age 60+ group was found to be significantly higher than age 18-34 group) and the proportion of mean eyelid fat volume within mean total volume (p=0.0033) was noted to increase with age (with Tukey's test the proportion of mean eyelid fat volume within mean total volume in both age 35-60 group and 60+ group was found to be significantly higher than age 18-34 group). The proportion of eyelid fat volume within total fat volume also increased with age (p=0.0042) (Table 5) (with Tukey's test the proportion of eyelid fat volume within total fat volume in both age 35-60 and 60+ groupb was found to be significantly higher than the proportion in age 18-34 group). Orbital fat volume showed a trend of increase with age but this was not found to be statistically significant. (p= 0.072) (Table 6). The proportion of mean orbital fat volume within mean total volume (p=0.688) did not show any change with age. (With Tukey's test comparison of means among three age groups were not found to be statistically significant).

DISCUSSION

Various methods to measure orbital volumes have been used in the past, including linear measurements, stereoradiography, radiographic tomography, and in vitro dye studies in animals. These studies have been limited to bony orbit volumes, dry-skull in vitro determinations, or gross estimates of in vivo bony orbit volume from plain radiographic linear measurements. Linear methods suffer from gross estimates of the irregular polymorphic and slightly ellipsoid shape of the bony orbit, and they led to volumetric determinations of filler materials in dry skulls. Although useful for estimating bony orbit volume, none of these methods could evaluate soft-tissue orbital contents or be used for practical in vivo study of clinical subjects. This has now been made possible using late-generation computed tomographic scanners and off-line com-

TABLE 1: Mean total volume (orbit+eyelid) in three different age groups.

Age (yr)	Mean total volume (cm^3)
18-34	31.275 ± 2.5
35-60	33.01212 ± 2.9
61-	35.44444 ± 4.4

TABLE 2: Mean total fat volume (orbit+eyelid) in three different age groups.

Age (yr)	Mean total fat volume (cm^3)
18-34	9.9 ± 1.0
35-60	11.5 ± 2.4
61-	12.7 ± 2.4

TABLE 3: Mean eyelid fat volume in three different age groups.

Age (yr)	Total eyelid fat volume (Mean) (cm^3)
18-34	0.9 ± 0.3
35-60	1.9 ± 1
61-	2.1 ± 0.7

TABLE 4: The proportion of mean total fat volume within mean total volume in three different age groups

Age (yr)	Total fat volume/ Total volume
18-34	0.31 ± 0.03
35-60	0.34 ± 0.05
61-	0.35 ± 0.04

TABLE 5: The proportion of mean eyelid fat volume within mean total fat volume in three different age groups

Age (yr)	Eyelid fat volume/Total fat volume
18-34	0.09 ± 0.01
35-60	0.15 ± 0.03
61-	0.16 ± 0.03

TABLE 6: The proportion of mean orbital fat volume within mean total fat volume in three different age groups

Age (yr)	Eyelid fat volume/Total fat volume
18-34	0.28 ± 0.03
35-60	0.28 ± 0.04
61-	0.29 ± 0.03

puter imaging processing. Bony orbital volume, total soft tissue orbital volume, globe volume, total fat volume and total neuromuscular tissue volume were measured with this method.[1] In the study of Forbes et al. upper limits of normal values were reported as 30.1 cm^3, 20.0 cm^3, 14.4 cm^3, 6.5 cm^3 for the adult bony orbit, soft tissue exclusive of the globe, orbital fat and muscle respectively in 29 patients (58 orbits).[1] There were small differences between men and women as well as right and left orbits of the same person. The accuracy of techniques was established as 7-8% for the orbit structural volumes in physical phantoms and in simulated silicone orbit phantoms in dry skulls. We calculated the total volume including the orbit and eyelid to decrease the errors due to difficulty to define the anterior border of the orbit, and used these values as denominators in our calculations. In the study of Forbes et al. mean orbital fat volume was reported as 10.10 cm^3 and 11.19 cm^3 in females and males, respectively.[1] These values are slightly smaller than ours since we calculated the total fat volume including the eyelid fat.

Ramieri et al. used commercially available software (Mimics; Materialise, Louvain, Belgium) to calculate orbital bony volume (OV) and fat volume (FV) in patients with enophthalmia after blow out fractures.[7] Recently, Regensburg et al. validated this method and assessed the intraobserver and interobserver variability of their calculations of bony orbital volume, orbital fat volume and extraocular muscle volume on CT scans of humans.[6] They also used manual segmentation and region growing (computer-assisted separation of different tissues) method, the same method that we used in our study. They concluded that calculating orbital soft tissue volume using this technique from CT scans was reliable and accurate.

We evaluated the total and eyelid fat volume in different age groups. The study by Forbes et al. did not analyze the measurements in different age groups. We noted an increase in total fat volume and eyelid fat volume with aging. Since race and gender may play a role in these measurements and potentially cause errors, we also measured the proportion of mean total fat volume within mean total volume, the proportion of mean eyelid fat volume within mean total volume and the proportion of eyelid fat volume, within total fat volume which were also noted to be increased with aging.

Increase in mean eyelid fat volume with aging is an expected finding which goes along with the herniated fat pads seen in elderly population. The overall increase in total fat volume is in contrast with the common concept of the orbital fat decreasing with age.[10] Recently Darcy et al. evaluated MRI images of 40 subjects and found that inferior periocular soft-tissue area anterior to the anteroposterior globe axis increased with aging.[5] The largest contributor to this size increase was fat expansion. They also found that total orbital fat increased with aging. They concluded that fat excision had a clear role in the lower eyelid blepharoplasty for the treatment of lower eyelid prominence. The major limitation of this study is the extrapolation of orbital volume from an area measurement of a single sagittal magnetic resonance imaging slice. In our study, although a trend of increase was noted in orbital fat volume with aging, it did not reach a statistical significance. This may be due to our sample size. The proportion of orbital fat volume within the total volume did not show any change with aging. The largest contributor to increased total fat volume was the preseptal fat in our study. Recenly another study showed increased curvature of the lower eyelid fat with aging using CT scan. Exact measurement of fat volume was not the objective of their study.[11]

Although the observed increase in orbital fat is the opposite of what is clinically observed with other subcutaneous fat tissues of the face, the physiology of orbital fat is different from other subcutaneous adipocytes of the body. Castanares reported multiple dissections of subjects who died as a result of starvation or malnutrition still had a "normal" amount of orbital fat.[12] Sires et al. demonstrated that orbital fat had a different lipolytic rate when compared to subcutaneous fat, with a higher percentage of unsaturated fat.[13] The observed increase in orbital fat may be caused by adipocyte hyperplasia/hypertrophy that is grossly unaffected by the state of body nourishment. Another possible explanation is chronic fluid accumulation in the orbital fat, such as lymphedema, because normal orbital fat is devoid of lymphatics, leaving it especially prone to fluid accumulation.[14]

The findings of this study will probably not answer the debate regarding whether the eyelid fat needs to be removed or not during lower eyelid blepharoplasty. As in any other cosmetic procedures, individualization is still the best approach for the surgeons. Facial aging is a summation of both hard and soft tissue changes which occur throughout life.[15,16] Pessa et al. reported that the craniofacial skeleton remodels throughout adulthood and changes in the skeletal architecture impart their effects on the overlying soft tissues.[15] They showed that, with aging, the orbital rim moves posteriorly relative to the anterior cornea. They stated that overresection of orbital fat during lower blepharoplasty might accentuate the proptotic appearance of the eye which occurs naturally with aging due to orbital remodeling. They suggested that the individuals with a negative vector can be identified preoperatively by the clinical triad of scleral show, prominent medial fat, and a prominent nasojugal crease. These individuals likewise exhibit maxillary hypoplasia and may be more prone to complications after blepharoplasty.

In conclusion, this technique for orbital and eyelid fat volume measurements on axial computed tomography sections using 3D connected threshold region growing algorithm as a plugin to Image J is easy and reproducible. It can be used in future studies regarding the anatomy and distribution of eyelid and orbital fat, Grave's disease and other orbital disorders. The total fat volume and eyelid fat volume as well as their percentage in the total volume were noted to increase with aging. These observations suggest that orbital fat expansion may occur with aging and fat excision may have a role in blepharoplasty for treatment of upper and lower eyelid prominence. As in any other cosmetic procedures, individualization is still the best approach for the surgeons.

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