Doi: 10.47572/muskutd.1482491

Age-Related Diffusion Changes in The Corpus Vitreum And Aqueous Humor of The Ocular Bulb

Bulbus Okulinin Korpus Vitreumu ve Hümör Aközünde Yaşa Bağlı Difüzyon Değişiklikleri

Bünyamin GÜNEY[1], Ferda BACAKSIZLAR SARI[2], Emrah DOĞAN[1]

[1]Muğla Sıtkı Koçman University Faculty of Medicine Department of Radiology, Muğla
[2]Department Muğla Training and Research Hospital Radiology Department, Muğla

Öz

Bulbus okuli, anteriorda hümör aköz (HA) ve posteriorda vitröz hümör (VH) olmak üzere iki ana sıvı içerikli anatomik yapıdan oluşur. Bu çalışmada, farklı biyokimyasal içeriğe sahip bu iki yapıda yaşlanmaya bağlı olarak oluşan difüzyon değişikliklerini manyetik rezonans görüntüleme kullanarak araştırdık Yaşlarına göre 8 farklı gruba ayrılan toplam 128 hastanın gözünde VH ve HA difüzyon değerleri hesaplandı. Elde edilen sonuçlar yaş, cinsiyet ve sağ-sol ayrımına göre karşılaştırıldı. Hem VH hem de HA için elde edilen difüzyon değerlerinde cinsiyetler arasında ($p=0.397$, $p=0.383$) ve sağ ve sol gözler arasında ($p>0.568$, $p>0.717$) istatistiksel olarak anlamlı fark saptanmadı. Ancak ilk dekat yaş grubu her iki yapı için de en düşük difüzyon değerlerine sahipti ($p<0.001$). Yaşlanmaya bağlı olarak gözün VH ve HA'de difüzyon değerlerinde meydana gelen değişiklikler, her iki yapının biyokimyasal içeriğinin yaşlanmayla birlikte değiştiğini göstermektedir.

Anahtar Kelimeler: 3 Tesla, ADC, Difüzyon MR, Hümör Aköz, Vitröz Hümör

Abstract

The bulbus oculi consists of two main fluid-containing anatomical structures: the aqueous humor (AH) at the anterior and the vitreous humor (VH) at the posterior. In this study, we investigated the diffusion changes that occur due to aging in these two structures with different biochemical contents using magnetic resonance imaging. VH and HA diffusion values were calculated in the eyes of a total of 128 patients divided into 8 different groups according to their ages. The results obtained were compared according to age, gender and right-left distinction. There was no statistically significant difference in the diffusion values obtained for both VH and HA between genders ($p=0.397$, $p=0.383$) and between right and left eyes ($p>0.568$, $p>0.717$). However, the first decade age group had the lowest diffusion values for both structures ($p<0.001$). Changes in the diffusion values of the eye in VH and HA due to aging show that the biochemical contents of both structures change with aging.

Keywords: 3 Tesla, ADC, Diffusion MRI, Aqueous Humor, Vitreous Humor

Introduction

The ocular bulb contains two fluids that are anatomically distinct and have different chemical compositions (1). Humor aqueous (HA), which fills the anterior and posterior chambers anterior to the bulbus oculi, has a transparent, low-viscosity structure consisting of ions, carbohydrates, amino acids, urea, oxygen, carbon dioxide, glutathione and water (2-4). In the posterior part of the bulbus oculi, just behind the lens, there is the vitreous humor (VH), which has a gel-like form and is surrounded by the chorioretinal complex and constitutes approximately 80 percent of the eye (1). VH, the largest structure of the eye, consists of water, collagen and hyaluronic acid groups, and its viscosity is higher than HA (5). Deterioration of homogeneity in VH due to aging is called liquefaction, and liquefaction may result in vitreous detachment and retinal tear and/or detachment (6). Although the chemical content of both HA and VH and changes due to aging can be evaluated by invasive methods (such as VH or HA fluid sampling), these methods also bring complications such as infection, hemorrhage and detachment (6-8). The chemical content of both structures and changes due to aging can be evaluated with magnetic resonance imaging (MRI), a non-invasive method (9-11). Diffusion-weighted imaging (DWI), one of the advanced MRI methods, is an imaging method that evaluates the random microscopic movement of water protons and depends on the biophysical properties of the examined tissue (12,13). Aging changes water content, microcirculation, microstructure and perfusion in tissues, and these changes can be evaluated with DWI (13,14). In the literature, there are studies on diffusion changes in VH due to aging in normal cases and diffusion changes in pathological conditions (9,15). However, according to our limited knowledge, there are not enough studies on the diffusion properties of HA. The aim of this study is to reveal age-related diffusion changes in HA and VH, which have different chemical contents.

	ORCID No
Bünyamin GÜNEY	0000-0002-0853-4184
Ferda BACAKSIZLAR SARI	0000-0002-6293-9481
Emrah DOĞAN	0000-0002-9446-2294

Başvuru Tarihi / Received: 29.05.2024
Kabul Tarihi / Accepted : 21.08.2024

Adres / Correspondence : Bünyamin GÜNEY
Muğla Sıtkı Koçman University Faculty of Medicine Department of Radiology, Muğla
e-posta / e-mail : bunyaminguney@mu.edu.tr

Material and Method

Patient Selection

This retrospective study was approved by the local Ethics Committee (21.12.2023 date / 118 no). Patient information was kept confidential throughout the study and patient privacy was taken into

consideration. Among the cases who underwent brain MRI examination including a diffusion sequence using a standard head coil for different reasons between September 2022 and November 2023, those without pathological imaging findings were included in our study. Cases with glaucoma, uncontrolled hypertension and/or diabetes in the file scan were excluded from the study. In addition, cases with previous retinal detachment, posterior vitreous detachment, intraocular bleeding, trauma, infection clinics and cases with artificial images were excluded from the study.

Review and Evaluation of MRI Images

All MRI examinations were performed with a 3 Tesla (Magnetom Skyra, Siemens, Erlangen, Germany) scanner. DWI consisted of axial slices (b-values of 0 and 1000 s/mm2 for calculation of ADC, TR/TE 6400/98 ms, FOV 220 x 220 mm, slice thickness 4 mm). Average apparent diffusion coefficient (ADC) values were measured by placing a region of interest (ROI) in front and behind the lens using an axial section passing through the middle point of the lens on the axial ADC map (Figure 1). All radiological measurements were made on a Siemens workstation (syngo via) with the consensus decision of two radiologists with over 10 years of experience. A total of 8 groups were created considering age and gender (according to decades, the first group is 1-10 years old and the eighth group is over 70 years old).

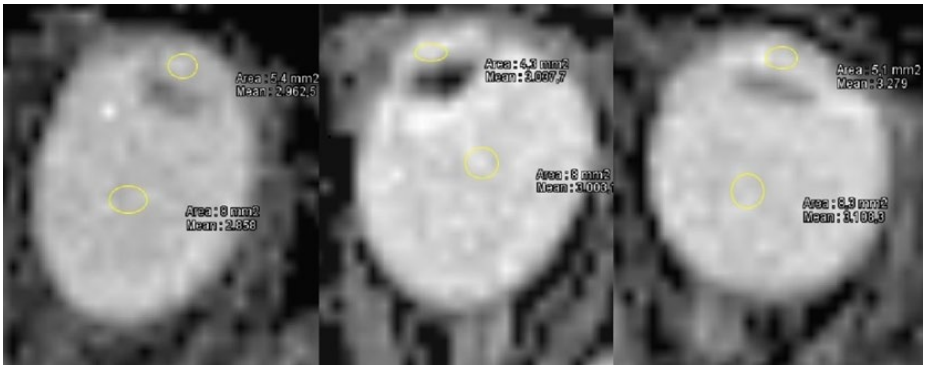

Figure 1. Axial ADC images. Average ADC values measured in normal cases aged 8 years (Figure A), 17 years (Figure B) and 55 years (Figure C). HA measurement in the anterior ROI and VH measurement in the posterior ROI.

Statistical Analyses

IBM SPSS version 20.0 software (IBM Corp, Armonk, NY, USA) was used for statistical evaluation and normal distribution was checked using Kolmogorov-Smirnov test. Data are presented as mean±standard error of mean or mean±standard deviation. Comparison of right and left VH and HA ADC values and VH and HA ADC values was performed by paired samples t-test. Comparison of VH and HA according to gender was performed with Independent T-test. One-way ANOVA test was used to evaluate the statistical differences between groups formed according to age. Multiple comparisons were made with the Tukey test and a p value of 0.05 was considered statistically significant.

Results

A total of 128 patients (59 males, 69 females) were included in the study. The mean age was 40.84±23.04 (range 4-94). The mean ADC value (x 10^{-6} mm^2/sn) for VH was 3147±165 (range 2800-3599) on the right side and 3143±160 (range 2765-3552) on the left side. There was no statistical difference between right and left side VH (p=0.568). There was no statistical difference between the genders for mean, right and left VH (p=0.397, p=0.487 and p=0.261, respectively**) (**Table 1). Mean ADC values for HA were 3239±205 on the right and 3243±216 on the left. There was no statistical difference between right and left in terms of HA (p=0.717). There was no statistical difference between the genders for mean, right and left HA (p=0.383, p=0.494 and p=0.449, respectively) (Table 1). Additionally, according to Table 1, the ages of men and women are similar (p=0.715).

The distribution of mean VH and HA according to age groups are given in Table 2. Among the age groups, the values of the first group in terms of mean, right and left VH were lower than the other groups (Table 2) (p<0.001). Among the age groups, the values of the first group in terms of mean, right and left HA were lower than the other groups (Table 2) (p<0.001). The values of the second group in terms of mean, right and left VH were lower than the 5th and 7th groups (Table 2) (p<0.01). The values of the second group in terms of mean, right and left HA were lower than the 5th and 7th groups (Table 2) (p<0.01). The values of the 3th group in terms of mean, right and left HA were lower than the 5th group (Table 2) (p<0.01).

In Table 2, the effect size obtained as a result of the posterior power analysis performed according to the descriptive statistics of the average VH variable was calculated as 1.038 and the achieved power was calculated as 99%.

Table 1. The distribution of age, mean and both sides vitreous humor and aqueous humor in according to sexes.

	Group A (n=59)	Group B (n=69)	p value
Age	40.03±3.01	41.54±2.79	0.715
Mean VH	3142±22.5	3147±17.7	0.871
Right VH	3134±22.6	3158±19.2	0.414
Left VH	3151±23.1	3136±17.6	0.602
Mean HA	3250±27.3	3233±23.2	0.628
Right HA	3251±26.7	3227±24.9	0.515
Left HA	3249±30.1	3238±24.7	0.780

Descriptive statistics are shown as mean±standard error. VH: Vitreous humor, HA: Aqueous humor

Discussion

According to the results of our study, there was no statistically significant difference between the mean ADC values of VH and HA as well as between the right and left eyes, when gender is taken into account. However, the mean ADC value of HA was higher than that of VH in both the right and left eyes. Additionally, in the first decade, ADC values of both HA and VH were lower than other age groups.

DWI is a radiological modality that creates imaging through the microscopic random movement of water molecules in tissues. In general, relatively increased diffusion is encountered in cystic tissues with high water content, necrotic tissues with impaired membrane integrity, and tissues with low number of nuclei (containing fewer cells) (16,17). The diffusion property of the tissue is measured quantitatively via ADC images, and tissues with high water content and low cell content have higher ADC values (17,18).

MRI is successfully used in diagnosis and follow-up treatment for many orbital pathologies (19-22). Regarding the use of diffusion-weighted MRI in orbital pathologies, the ADC values of normal cases and ocular adnexal lymphoma (OAL) cases were compared in the study conducted by Politi et al. (23). In this study, it was found that the average ADC values in orbital tissues with OAL were lower than the ADC values in orbital tissues in normal cases, and the ADC values of tissues that responded to treatment increased. As a result, DWI was found to be useful in estimating the correct diagnosis and post-treatment therapeutic response in OAL cases.

A study by Itakura et al. showed a decrease in the amount of hyaluronic acid in VH due to aging (24). In the study conducted by Meral et al., it was found that ADC values in VH increased with aging in normal cases (9). According to the results of both studies, the decrease in eye VH in hyaluronic acid groups due to aging and the increased ADC values due to the increase in water content in VH (liquefaction) with age are parallel to the values we found in our study. However, unlike the study conducted by Meral et al., in our study, the average VH ADC values measured in the 2nd decade were found to be lower than the 5th and 7th decade age groups.

In one of the studies showing the changes in the content of the aqueous humor that occur with aging, it was shown that the immunological environment of the anterior chamber becomes more pro-inflammatory and pro-angiogenic from childhood to adulthood (25). Although there are studies in the literature showing changes in the content and dynamics of the aqueous humor due to aging and glaucoma, there are not yet sufficient studies on DWI features (26-29). According to our study, HA mean ADC values increase with age, similar to VH ADC values, and the lowest was measured in the first decade.

Our study has some limitations, the first of which is that interobserver variability was not taken into account. Moreover, the area measured for HA is small and although the measurement is avoided as much as possible, the ADC values of the surrounding tissues may have contributed to the calculated ADC value. However, we think that these age-related normal data for VH and HA in normal cases have the potential to be used in the evaluation of eye diseases.

Table 2. The distribution of age, mean and both sides vitreous humor and aqueous humor in according to age groups.

	0-10 y (n=16)	11-20 y (n=16)	21-30 y (n=14)	31-40 y (n=19)	41-50 y (n=14)	51-60 y (n=17)	61-70 y (n=15)	>70 y (n=17)
Age (years)	7.3±0.4	14.9±0.7	25.8±0.8	35.8±0.7	44.5±0.8	54.7±0.7	65.9±0.7	75.7±1.5
Mean VH	2928±91*	3072±93£	3149±119	3171±101	3245±136	3203±182	3183±136	3210±158
Right VH	2923±90*	3074±97£	3157±138	3156±110	3244±132	3202±180	3183±142	3238±43££
Left VH	2933±97**	3070±94£	3140±108	3186±99	3247±143	3204±192	3183±147	3182±164
Mean HA	2966±116	3145±91***	3217±127	3279±139	3427±171	3269±190	3345±173	3290±213
Right HA	2970±121**	3143±96***	3216±131£££	3259±106	3412±177	3287±189	3348±219	3289±205
Left HA	2962±115*	3147±95***	3218±127	3299±208	3443±212	3252±210	3342±157	3292±217

Data are n of participants, mean±SD. VH: Vitreous humor, HA: Aqueous humor. *: Group 1 is different from other age groups ($p<0.05$). **: Group 1 is different from other age groups except group 2. ***: Group 2 is different from groups 5 and 7. £: Group 2 and group 5 are different from each other. ££: Group 8 is different from group 2. £££: Group 3 is different from group 5.

Conclusion

In order to obtain better results in the diagnosis and treatment of eye diseases, it is necessary to understand the changes that occur with aging in the two main fluids of the bulbus oculi. According to our study, the lowest mean ADC values of both HA and VH were detected in the first decade and increased with age. For both structures, the values obtained in the 2nd decade were found to be lower than those in the 5th and 7th decades. Although these findings show that there are changes in HA and VH content depending on age, we believe that larger studies should be conducted on this subject.

Acknowledgements

There is no specific person to whom we would like to thank regarding the research.

Conflict of interest statement

The authors declare that there is no conflict of interest.

Ethics Committee Approval: Muğla Sıtkı Koçman University Medical and Health Sciences Ethics Committee**,** 21.12.2023 date / 118 no.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Hermsen VM, Dreyer RF. Ophthalmic anatomy. Prim Care. 1982;9(4):627-45.
2. Benham GH, Duke-Elder WS, Hodgson TH. The osmotic pressure of the aqueous humour in the normal and glaucomatous eye. J Physiol. 1938;92(3):355-60.
3. De Berardinis E, Tieri O, Polzella A, et al. The chemical composition of the human aqueous humour in normal and pathological conditions. Exp Eye Res. 1965;4(3):179-86.
4. Goel M, Picciani RG, Lee RK, et al. Aqueous humor dynamics: a review. Open Ophthalmol J. 2010;4:52-9.
5. Bishop PN. Structural macromolecules and supramolecular organisation of the vitreous gel. Prog Retin Eye Res. 2000;19(3):323-44.
6. Murthy KR, Goel R, Subbannayya Y, et al. Proteomic analysis of human vitreous humor. Clin Proteomics. 2014;11(1):29.
7. Garg A, Rewri P. Comparison of aqueous humor ascorbic acid level in smokers and non-smokers. Exp Eye Res. 2023;226:109302.
8. Jünemann AGM, Michalke B, Lucio M, et al. Aqueous humor selenium level and open-angle glaucoma. J Trace Elem Med Biol. 2018;50:67-72.
9. Meral I, Bilgili Y. Diffusion changes in the vitreous humor of the eye during aging. AJNR Am J Neuroradiol. 2011;32(8):1563-6.
10. Sebag J. To see the invisible: the quest of imaging vitreous. Dev Ophthalmol. 2008;42:5-28.
11. Sebag J. Imaging vitreous. Eye (Lond). 2002;16(4):429-39.
12. Gupta L, Peterson EL, Williams C, et al. Diffusion-weighted imaging of the orbit: a case series and systematic review. Ophthalmic Plast Reconstr Surg. 2023;39(5):407-18.
13. Bammer R. Basic principles of diffusion-weighted imaging. Eur J Radiol. 2003;45(3):169-84.
14. Le Bihan D, Breton E, Lallemand D, et al. Separation of diffusion and perfusion in intravoxel incoherent motion MR imaging. Radiology. 1988;168(2):497-505.
15. Hwang M, Shin SS, Thimm MA, et al. Apparent Diffusion Coefficient (ADC) of the vitreous humor and Susceptibility Weighted Imaging (SWI) of the retina in abused children with retinal hemorrhages. Clin Imaging. 2017;44:38-41.
16. Charles-Edwards EM, deSouza NM. Diffusion-weighted magnetic resonance imaging and its application to cancer. Cancer Imaging. 2006;6(1):135-43.
17. Kwee TC, Takahara T, Ochiai R, et al. Diffusion-weighted whole-body imaging with background body signal suppression (DWIBS): features and potential applications in oncology. Eur Radiol. 2008;18(9):1937-52.
18. Meier C, Dreher W, Leibfritz D. Diffusion in compartmental systems. I. A comparison of an analytical model with simulations. Magn Reson Med. 2003;50(3):500-9.
19. Micevych PS, Horton JC. Postoperative magnetic resonance imaging of the inferior oblique muscle. J AAPOS. 2024;28(1):103826.
20. Tsutsumi S, Kawai S, Sugiyama N, et al. Diameters of the optic sheath and superior ophthalmic vein can expand and contract at positional changes: a magnetic resonance imaging study. Surg Radiol Anat. 2024;46(2):153-8.
21. Uysal C, Yilmaz T, Ozkan H, et al. The refractory secondary hyperparathyroidism presenting with retro-orbital brown tumor: a case report. BMC Nephrol. 2024;25(1):15.
22. Kapur R, Sepahdari AR, Mafee MF, et al. MR imaging of orbital inflammatory syndrome, orbital cellulitis, and orbital lymphoid lesions: the role of diffusion-weighted imaging. AJNR Am J Neuroradiol. 2009;30(1):64-70.
23. Politi LS, Forghani R, Godi C, et al. Ocular adnexal lymphoma: diffusion-weighted MR imaging for differential diagnosis and therapeutic monitoring. Radiology. 2010;256(2):565-74.
24. Itakura H, Kishi S, Kotajima N, et al. Decreased vitreal hyaluronan levels with aging. Ophthalmologica. 2009;223(1):32-5.
25. Zheng Y, Rao YQ, Li JK, et al. Age-related pro-inflammatory and pro-angiogenic changes in human aqueous humor. Int J Ophthalmol. 2018;11(2):196-200.
26. Toris CB, Yablonski ME, Wang YL, et al. Aqueous humor dynamics in the aging human eye. Am J Ophthalmol. 1999;127(4):407-12.
27. Gabelt BT, Kaufman PL. Changes in aqueous humor dynamics with age and glaucoma. Prog Retin Eye Res. 2005;24(5):612-37.
28. Inada K, Murata T, Baba H, et al. Increase of aqueous humor proteins with aging. Jpn J Ophthalmol. 1988;32(2):126-31.
29. Gabelt BT, Gottanka J, Lütjen-Drecoll E, et al. Aqueous humor dynamics and trabecular meshwork and anterior ciliary muscle morphologic changes with age in rhesus monkeys. Invest Ophthalmol Vis Sci. 2003;44(5):2118-25.