Diffusion Changes in the Vitreous Humor of the Eye during Aging

I Meral and Y. Bilgili

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BACKGROUND AND PURPOSE: The inability to image the vitreous humor of the eye adequately hinders a complete understanding of its normal structure and the changes occurring in aging and disease. The purpose of the present study was to reveal normative data and age-related changes of the vitreous humor by using DWI.

MATERIALS AND METHODS: A total of 160 patients were enrolled in the present study. Patients were divided into 8 groups according to decade of age, and each group was of equal size with 20 patients. The ADCs were determined for each vitreous humor. Each determination was obtained by using average regions of interest of 50 ± 2 mm². ADC values were then plotted against age.

RESULTS: The ADC values obtained from group 0 (0–10 years of age) were statistically different from those of all other groups (P < .05). Group 1 (11–20 years of age) was statistically different from groups 3, 5, 6, and 7 (P < .05). A trend toward increased ADC values with increasing age was not statistically significant.

CONCLUSIONS: Besides the statistically significant difference between pediatric and adult patients, a statistically insignificant trend of increased ADC values among aging adults has been demonstrated. These normative data contribute to our understanding of how DWI can aid in the diagnosis of age-related changes in eye health and function.

ABBREVIATIONS: ADC = apparent diffusion coefficient; DWI = diffusion-weighted imaging; OCT = optical coherence tomography; SLO = scanning laser ophthalmoscopy

Duke-Elder once described the structure of the vitreous humor of the eye as “composed of loose and delicate filaments surrounded by fluid,” a description that is remarkably close to an understanding of present day concepts.

The vitreous gel, maintained by a low-attenuation network of collagen fibrils, is homogeneous, with no liquefaction at all in the eyes at infancy, but undergoes age-related changes that increase its liquefaction. The mechanism involves a breakdown of the network of collagen fibrils, and this appears to be crucial for the age-related liquefaction of the human vitreous humor.

Classic and modern histologic examinations, dark-field slit microscopy, clinical slit-lamp biomicroscopy, standard laser ophthalmoscopy and SLO, sonography, OCT, combined OCT-SLO, MR imaging, Raman spectroscopies, and dynamic light scattering are all techniques that have been reported in the study of the structure and function of the vitreous humor. Thus, DWI may be able to detect age-related changes in the vitreous humor. Therefore, there is a rationale for the exploration of new methods.

DWI is an MR imaging technique that provides image contrast related to the random microscopic motion of water protons. Diffusion depends on a variety of biophysical properties in tissue, including cell organization, attenuation, microstructure, and microcirculation, all of which change with age in the vitreous humor. Thus, DWI may be able to detect age-related changes in the vitreous humor.

The purpose of this study was to obtain normative data detailing the ADC of the vitreous humor in children and adults across a spectrum of ages.

Materials and Methods

The ethics committee of our university approved the protocol for the involvement of human subjects in this study. Informed consent was obtained from subjects or their legal guardians.

First, we defined 8 decadal age groups and then enrolled patients until we had 20 patients in each group, so a total of 160 patients were prospectively included in the present study. They were selected from patients undergoing clinical imaging studies.

The medical history of each patient was recorded. Patients were excluded from the study if their history included any of the following: vitreous hemorrhage, glaucoma, uncontrolled hypertension, or diabetes mellitus.

Also 2 radiologists (Y.B., I.M.) independently determined that MR imaging findings of each orbit were normal in all subjects.

All experiments were performed by using a head coil in conjunction with a 1.5T whole-body imager (Infinion; Philips Healthcare, Cleveland, Ohio) with a maximum gradient amplitude of 50 mT/m and a maximum gradient slew rate of 100 mT/m/s. The head coil had an inner diameter of 27 cm. Before DWI, conventional T1- and T2-weighted images were obtained in the transverse plane.

DWI was performed by using a single-shot spin-echo echo-planar sequence. During the MR imaging studies, the 2 radiologists (M.Y.K.B., I.M.) evaluated the quality of DWIs and selected, by consensus, the images for further analysis that had a minimum of distortion from susceptibility artifacts and ghosting. We selected b-values of 0 and 1000 s/mm² for calculation of ADC in this study. DWIs were obtained during 43 seconds. DWI was performed with the following
The study population consisted of 160 patients, 74 males and 86 females, ranging in age from 2 months to 84 years. The mean age of all patients was 40 ± 17 years. The internal control group consisted of 20 patients, 8 males and 12 females, ranging in age from 16 to 63 years with a mean age of 36.7 ± 12 years. The mean ADC value obtained from the CSF of the frontal horn of the lateral ventricles was 3.48 ± 0.07 mm²/s (range, 2.35–4.31 × 10⁻³ mm²/s) and, for the vitreous, 3.35 ± 0.02 × 10⁻³ mm²/s (range 2.88–3.77 × 10⁻³ mm²/s). While the mean ADC value of the vitreous was lower than that of the CSF, the difference was not statistically significant (P > .05).

The Table presents the mean (plus the measure of variation) of the ADC values obtained for all study patients organized into decadic age groups. Post hoc analysis of the mean ADC values revealed that those of group 0 (0–10 years) were statistically different from the mean ADC values of all other age groups (P < .05) (Fig 1A, -B). The mean ADC value observed in age group 1 (11–20 years) was found to be different from those of groups 3, 5, 6, and 7 as well (P < .05). While the mean ADC values of groups 2 and 4 were seen to be higher than that in group 1, this difference was not statistically significant.

Differences in the ADC values between the right and left eyes of each patient were assessed and found not to be significantly different (P > .05). Moreover, there were no statistically significant differences in the inter- or intraobserver ADC value determination (α: 0.82 and 0.86, respectively). While a trend could be observed in that ADC values increased with healthy patient age, the statistical significance of this correlation could not be established.

Discussion

The vitreous humor of the eye is composed of a transparent gel consisting almost entirely of the constituents that describe tissue extracellular matrix. It is composed largely of water with small amounts of essential structural macromolecules. The gel state of the vitreous humor is maintained by a low-attenuation network of long thin collagen fibrils. The vitreous gel, which is quite compositionally homogeneous with no relative liquefaction in infancy, undergoes noticeable age-related changes with the progress of years. Morphologically, 2 distinct structural alterations can be observed. On the 1 hand, there is a progressive increase in the volume of liquefied spaces (synchysis), and on the other, there is an increase in optically attenuated areas (syneresis). Collagen fibrils are an essential component of the vitreous gel structure, and with time, they break down into smaller fragments that are involved in the mechanism of the age-related liquefaction of the vitreous humor. With aging, these collagen fibrils progressively aggregate due to a loss of collagen components on the fibril surface necessary for maintaining a nonliquefied gelatinous state. In particular, hyaluronic acid is a major component of the vitreous gel, which contributes to gel viscosity, and both this substance and proteoglycans decrease in the

![Fig 1. A, ADC values obtained from the vitreous of a 4-year-old girl (W 1524/L 762). B, ADC values obtained from the vitreous of a 54-year-old man (W 1528, L 764).]
ischemic homonymous hemianopsia, indeterminate orbital litis, acute optic nerve infarction, endophthalmitis, acute inflammatory syndrome, orbital lymphoid lesion, orbital cellu-
differential diagnosis of orbital pathologies such as orbital in-
tortuosity, intracellular restrictions, membrane permeability,
active processes across membranes, relaxation rates, or aniso-
tropic morphology.17 A low ADC value implies a limited or
restricted diffusion, and this is observed in tissues that are
highly cellular. A high ADC value is more likely seen in struc-
tures in which tissue fluid has relatively free diffusion, in those
with low cellularity, or in those that are cystic.15,16

Diffusion can be quantitatively evaluated by using ADC,
expressed in square millimeters per second. The ADC reflects
diffusion properties within the tissue and depends on many
physiologic parameters such as volume fractions, extracellular
tortuosity, intracellular restrictions, membrane permeability,
active processes across membranes, relaxation rates, or aniso-
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DWI has been a complementary technique useful in the
differential diagnosis of orbital pathologies such as orbital in-
flammatory syndrome, orbital lymphoid lesion, orbital cellu-
litis, acute optic nerve infarction, endophthalmitis, acute
ischemic homonymous hemianopsia, indeterminate orbital
masses, and optic neuritis.18–23 Also, Politi et al24 recorded the
ADC of the vitreous humor in healthy subjects as part of a
normative data collection for a larger study of orbital masses
and found a mean vitreal ADC that is significantly lower than
that in our results; the difference might be due to different
methods used in the studies.

According to our results, ADC values within first decade are
statistically significantly different from those in all other age
groups, and those in the second decade are statistically different
from several but not all other age groups. Also, there is a statisti-
cally insignificant trend of increased ADC values with aging.

Studies using microscopy have shown progressively larger vitreal
spaces with age, and age-related increase in vitreal ADC values
might be expected due to increased movement of fluid through
these spaces. Also, it is widely believed that increased fluid viscos-
ity is partially responsible for the low ADC observed in abscess
cavities, and changes in viscosity likely account for the age-related
changes in vitreal ADC observed in this study.25

However, on the basis of the results that are provided, be-
yond a certain degree of vitreal liquefaction that occurs by the
end of the second decade, DWI is unable to further character-
ize changes in the vitreous. This seems to be a limitation of the
study. However, this normative data does have potential use
for assessing patients with eye disease.

Conclusions
A better understanding of the normal physiology and structure
of the vitreous humor of the eye and how changes in
structure and function occur during aging and disease is nec-
essary to develop more effective therapies and preventative
care.5 Our use of DWI gave results that indicated a trend,
though not statistically significant, showing increases in ADC
values with advancing age, and we did find statistically signif-
icant difference between decadal age groups, namely between
pediatric and adult patients. While DWI is unable to further
characterize changes in the vitreous humor occurring by the
end of the second decade of life, the normative data of the
vitreous humor may play a complementary role not only for
the differential diagnosis of ocular pathologies but also in con-
tributing information to a large data base looking at how aging
affects the vitreous humor.

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References
14(suppl 4):6
2. Itakura H, Kishi S, Kotajima N, et al. Decreased vitreal hyaluronan levels with
3. Bishop PN. Structural macromolecules and supramolecular organisation of the
4. Los LI, van der Worp RJ, van Luyk MJ, et al. Age-related liquefaction of the
human vitreous body: LM and TEM evaluation of the role of proteoglycans
5. Sebag J. To see the invisible: the quest of imaging vitreous. Dev Ophthalmol
2008;42:5–28
7. Le Bihan D, Breton E, Lallemand D, et al. Separation of diffusion and perfusion
2003;45:169–84
9. Bishop PN, Holmes DF, Kadler KE, et al. Age-related changes on the surface of
malian vitreous by freeze etch/rotary shadowing electron microscopy. Micro-
ron 2001;32:301–06
1982:45–57
12. Szent-Gyorgyi A. Untersuchungen uber den Bau des Glaskorpers des Men-
schen. Arch Anat 1917;89:324–86
13. Eisner G. Postmortem slitlamp study of the vitreous body. II. Pattern of vitre-
ous structures made visible by the slitbeam. Allbrecht Von Graefes Arch Klin Exp
Ophthalmol 1971;182:8–22
Exp Ophthalmol 1997;225:89–93
15. Charles-Edwards EM, deSouza NM. Diffusion-weighted magnetic resonance
imaging and its application to cancer. Cancer Imaging 2006;6:135–43
with background body signal suppression (DWIBS): features and potential
17. Meier C, Dreher W, Leibfritz D. Diffusion in compartmental systems. I. A

Fig 2. ADC values for age groups.