Dynamic Changes in Anterior Segment Morphology during the Valsalva Maneuver Assessed with Ultrasound Biomicroscopy

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Purpose. We evaluated dynamic changes in anterior segment morphology during the Valsalva maneuver with ultrasound biomicroscopy (UBM).

Methods. For this prospective observational study, a group of patients with narrow angles and a group of normal subjects were recruited. The anterior segment of subjects was imaged and analyzed quantitatively using UBM before and during the Valsalva maneuver. Changes in anterior segment parameters from baseline and during the Valsalva maneuver, and the differences in parameters between the narrow angle and control groups were analyzed.

Results. Of 151 subjects recruited for the study, 68 (45.0%) were men and 83 (54.9%) had narrow angles. For the overall group, during Valsalva maneuver, the subjects' central anterior chamber depth (ACD) became shallower (from 2.286–2.262 mm, $P < 0.001$), and the anterior chamber angle became narrower (from 14.673–13.370 degrees, $P = 0.004$), the angle opening distance became smaller (from 0.158–0.140 mm, $P = 0.014$), and the peripheral iris thickness became thicker (from 0.494–0.508 mm, $P = 0.041$), while the central iris thickness did not change. Compared to normal controls, narrow angle subjects had shallower ACD and thicker iris at baseline, but there was no significant difference between the 2 groups in dynamic changes in the anterior segment after the Valsalva maneuver.

Conclusions. The Valsalva maneuver, performed frequently in daily activities, can lead to significant narrowing of the angles in subjects with open and narrow angles. This factor may be important in eyes at risk for angle closure glaucoma. (*Invest Ophthalmol Vis Sci.* 2012;53:7286–7289) DOI:10.1167/iovs.12-10497

Primary angle closure glaucoma (PACG) is an important cause of visual loss in Asia. It has been demonstrated that the prevalence of PACG among Asians 40 years and older is between 1.0% and 1.4%.[1,2] PACG also was found to be a leading cause of blindness in East Asian populations.[3,4] Previously reported risk factors for angle closure include shallower central anterior chamber depth (ACD), smaller anterior chamber width (ACW), shorter axial length, and greater iris thickness.[5–7] It has been estimated that only a small proportion of subjects with anatomically narrow angles suffer PACG[8] and, thus, static anatomic risk factors alone cannot explain adequately the pathogenesis of the disease. This suggests that some dynamic factors that induce internal changes in the eye may have a role in PACG.

The Valsalva maneuver is performed frequently in daily life, when moderately forceful attempted exhalation is made against a closed airway. It may be associated with heavy lifting, forceful coughing and sneezing, straining, vomiting, singing, or laughing. The maneuver will elicit various physiologic responses, such as increased intrathoracic pressure, reduced venous return, and increased peripheral venous pressure, and a rise in blood pressure.[9] Especially noteworthy is that some studies have found that the Valsalva maneuver also can lead to a rise in the intraocular pressure (IOP).[10–12]

The aim of our study was to evaluate the dynamic changes in anterior segment morphology during the Valsalva maneuver using ultrasound biomicroscopy (UBM).

Methods

This was a prospective observational study. Study subjects aged 40 years and older were recruited consecutively from the Ophthalmology Department of Beijing Shijitan Hospital, Beijing, China, after obtaining written informed consent. The study was approved by the ethics committee of Beijing Shijitan Hospital and was done in accordance with the tenets of the Declaration of Helsinki.

A group of patients with narrow angles and a group of normal subjects of similar age were examined. Narrow angle patients were recruited from glaucoma clinics and normal controls were recruited from cataract clinics of the same hospital. All eligible subjects underwent a standardized ophthalmic examination, which included assessment of visual acuity, slit-lamp examination, Goldmann applanation tonometry, gonioscopy, fundus evaluation, and visual field examination. An eye was defined to have narrow angles if there was iridotrabecular contact for at least 180° on nonindentation gonioscopy in the primary position.[13] Normal controls had open angles and were without other ocular diseases except for cataract or ametropia. Exclusion criteria included intumescent cataract; use of systemic or eye medications, such as miotic therapy, that may affect the configuration of the anterior chamber; secondary angle closure, such as neovascular or uveitic glaucoma; prior history of laser iridoplasty or intraocular surgery; and cardiovascular or respiratory abnormalities

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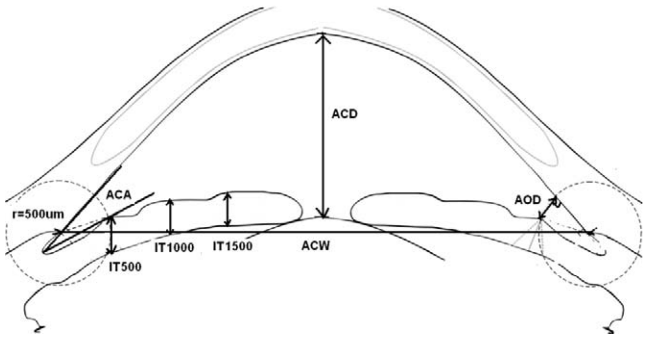

FIGURE. A schematic drawing illustrating the measurements of anterior chamber parameters.

that may render patients unsafe to perform the Valsalva maneuver. If both eyes were eligible, only the right eye was included.

The anterior segment of all subjects was imaged and analyzed quantitatively using UBM (Model SW-3200; Suoer Inc., Tianjin, China). All subjects were imaged in the same dark conditions in an examination room during UBM imaging, and were placed in the supine position. After administering 0.4% benoxinate hydrochloride topical anesthesia (Santen Pharmaceutical Co., Ltd., Osaka, Japan), a plastic eyecup was used and filled with sterilized water for injection before placement of the UBM probe. At baseline, three standard horizontal images of the anterior segment were obtained, with care not to exert pressure on the globe while performing the UBM. Variation in accommodation was minimized by fixation at a target on the ceiling with the contralateral eye. The patient then was asked to perform the Valsalva maneuver. The subject was told to breathe in deeply, then close his/her glottis and hold his/her breath, and to breathe out against the closed glottis for at least 30 seconds. During the Valsalva maneuver, UBM was performed again.

The output of the UBM was stored on a computer for analysis. A single masked observer (B-SW) then performed all analyses using the measurement software of the UBM device. The mean value of the three images was calculated, and the mean of the nasal and temporal values was used for analysis. The following parameters were analyzed (see Fig.):

1. ACD: The perpendicular distance from the center of the corneal endothelial surface to the anterior lens surface.
2. Anterior chamber angle (ACA): First, a circle was drawn with the center at the scleral spur with a radius equal to 500 μm. The corneal endothelial surface and the iris surface intersect the circle at two points. The vertex of the angle was the apex of the peripheral iridocorneal angle. The ACA was formed by two lines drawn from the apex to the two points.
3. Angle opening distance (AOD): The distance along a perpendicular line drawn from the corneal endothelial surface to the iris at 500 μm from the scleral spur.
4. ACW: The distance from the nasal scleral spur to the temporal scleral spur.
5. Iris thickness at 500 μm (IT500): The iris thickness at 500 μm from the scleral spur.
6. Iris thickness at 1000 μm (IT1000, the iris thickness at 1000 μm from the scleral spur)
7. Iris thickness at 1500 μm (IT1500): The iris thickness at 1500 μm from the scleral spur.

Statistical Analysis

Normality assumptions for the measurement values were checked using the Komolgorov-Smirnov 1-sample test. The paired *t*-test was used to evaluate the significance of the difference in the various parameters between the baseline and the Valsalva imaging. The independent-samples *t*-test was used to evaluate the significance of the difference in the various parameters between the narrow angle and control groups. Statistical analysis was performed using SPSS version 12.0 program, and a *P* value of less than 0.05 was considered statistically significant.

TABLE 1. Changes in Anterior Segment Parameters Measured by UBM before and during the Valsalva Maneuver in All Subjects

Variables, mean	Baseline	During Valsalva	Mean Difference	*P* Value
ACD, mm	2.286	2.262	0.024	<0.001
ACA, degree	14.673	13.370	1.304	0.004
AOD, mm	0.158	0.140	0.018	0.014
ACW, mm	11.057	10.938	0.120	0.226
IT500, mm	0.494	0.508	−0.014	0.041
IT1000, mm	0.531	0.529	0.003	0.650
IT1500, mm	0.527	0.531	−0.004	0.510

RESULTS

Of 151 subjects recruited for the study, 68 (45.0%) were men and the mean age ± SD was 64.46 ± 10.70 years (range 41–86 years). Of these subjects, 83 (54.9%) had narrow angles.

Analyses of the differences of the various anterior segment parameters between baseline and during the Valsalva maneuver in all subjects are shown in Table 1. During the Valsalva maneuver, the ACD became shallower (from 2.286–2.262 mm, $P < 0.001$), ACA became narrower (from 14.673–13.370 degrees, $P = 0.004$), and the AOD became smaller (from 0.158–0.140 mm, $P = 0.014$). Also, the IT500 became thicker, but the IT1000 and IT1500 did not change.

Analyses of the differences in the various parameters between the narrow angle and control groups at baseline are shown in Table 2. Compared to normal controls, narrow angle subjects had a smaller ACD, narrower ACA, and thicker iris at baseline.

There was no significant difference in the changes of the anterior segment parameters before and during the Valsalva maneuver between narrow angle and normal control groups (Table 3). However when the relative change in ACD (which was defined as ACD difference/ACD × 100%) was compared in the 2 groups, we found that the Valsalva maneuver induced 1.307% ACD change in the narrow angle group, while it induced 0.692% change in the normal control group ($P = 0.048$).

In addition, during the Valsalva maneuver, there were eight (9.64%) subjects in the narrow angle group (in whom the angle was narrow but open) who had definite iridotrabecular contact in the nasal and temporal meridians, while no subject had

TABLE 2. Comparison of Anterior Segment Parameters Measured by UBM between Narrow Angles and Normal Control Groups at Baseline

Variables, mean	Narrow Angle Group	Control Group	Mean Difference	*P* Value
ACD, mm	2.014	2.663	0.650	<0.001
ACA, degree	7.013	26.774	19.760	<0.001
AOD, mm	0.073	0.289	0.216	<0.001
ACW, mm	10.959	11.188	0.228	0.003
IT500, mm	0.507	0.456	0.051	0.002
IT1000, mm	0.533	0.503	0.031	0.042
IT1500, mm	0.540	0.500	0.040	0.007

Table 3. Comparison of the Changes in Anterior Segment Parameters during the Valsalva Maneuver between Narrow Angle and Normal Control Groups

Variables, mean	Narrow Angle Group	Control Group	Mean Difference	*P* Value
Change in ACD, mm	0.025	0.017	0.008	0.253
Change in ACA, degree	1.635	1.505	0.130	0.908
Change in AOD, mm	0.031	0.017	0.014	0.460
Change in ACW, mm	0.012	−0.013	0.025	0.557
Change in IT500, mm	−0.025	−0.012	−0.013	0.423
Change in IT1000, mm	−0.007	0.009	−0.016	0.281
Change in IT1500, mm	−0.005	−0.005	−0.000	0.998

iridotrabecular contact in the normal control group ($P = 0.001$).

Discussion

When we evaluated the dynamic changes of anterior segment morphology during the Valsalva maneuver with UBM in our study, we found that subjects' central anterior chamber became shallower and the ACA became narrower during this maneuver. The peripheral iris thickness also became thicker. These changes were similar in the narrow angle eyes and normal control groups.

The Valsalva maneuver is performed frequently in daily activities. Especially notable is that the Valsalva maneuver can lead to a rise in IOP as high as 10 mm Hg.[10–12] Sihota et al. also studied the anterior chamber changes during the Valsalva maneuver, and they found results similar to ours in some respects. Their study showed that the ACA recess narrowed, angle recess area diminished, and iris thickness increased. However, they did not find significant changes in AOD or ACD. The possible explanation for these differences is that UBM imaging was performed during the Valsalva maneuver in our study, while UBM was performed right after the procedure in theirs.

A pathologic syndrome named Valsalva retinopathy, which presents as ocular congestion and results in preretinal hemorrhages, also is associated with the Valsalva maneuver.[14] The Valsalva maneuver reduces venous return and increases peripheral venous pressure. It elicits decreased ocular venous return, thus increasing the blood and fluid held in the ocular tissues. Choroidal volume is regulated by choroidal arterial and venous pressure, and permeability of its vessels. Therefore, we speculated that the choroidal volume is increased during the Valsalva maneuver. The filling and expansion of the choroid is a dynamic phenomenon that has been proposed as a risk factor in angle closure.[15] Our study did not assess the choroidal volume directly, but we found that the anterior chamber became shallower during the Valsalva maneuver, suggesting that the iridolenticular diaphragm moved forward during the Valsalva maneuver. This may be due to choroidal volume expansion.

Apart from anatomic differences in ocular dimensions, previous studies have suggested that angle closure may result from dynamic physiologic mechanisms. Friedman et al. found that compared to normal controls, the contralateral eyes of individuals with acute angle closure tended to shallow more when going from light to dark, and tended to open less when given 1 drop of pilocarpine hydrochloride.[16] Quigley et al. showed that angle closure eyes had similar iris volume at baseline compared to controls, but angle closure eyes retained more iris volume with pupil dilation than did controls.[17] However, our study did not find any significant differences in the dynamic changes of the anterior segment parameters before and during the Valsalva maneuver, when comparing narrow angle and normal control groups. Although there was a difference in ACD between narrow angles and normal controls at baseline, there were similar changes in anterior segment parameters in both groups during the Valsalva maneuver. However, these ACD changes may have significant effects in eyes with already narrow angles to begin with. Interestingly, we found that eight patients (9.64%) in the narrow angle group, in whom the angle was narrow but open, had definite iridotrabecular contact during the Valsalva maneuver, thereby compromising trabecular outflow further and potentially causing a rise in intraocular pressure or risk of acute angle closure.

Our study had some limitations. This was not a population-based study. The Valsalva maneuver could not be standardized or quantified in our study subjects. Our sample size was relatively small and some of the differences found may not have been significant due to the limited sample size. In addition, we only imaged the anterior segment in the horizontal meridian due to difficulty in imaging the vertical meridian. Finally, we were unable to measure IOP during the Valsalva maneuver.

In summary, we studied the dynamic changes of anterior segment morphology during the Valsalva maneuver, and we found that during this procedure, subjects' central anterior chamber became shallower and the ACA became narrower. Similar changes were found in the narrow angle and control groups. The possible implications are that frequently performed Valsalva maneuver in daily activities may lead to an increase in IOP and possibly an increased risk of acute angle closure in subjects with anatomically predisposed narrow angles.

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