Original article

Normative values and contralateral comparison of anterior chamber parameters measured by Pentacam and its correlation with corneal biomechanical factors

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Abstract

Purpose: To evaluate the normative values of anterior chamber parameters measured by Pentacam and corneal hysteresis (CH) and corneal resistance factor (CRF) measured by Ocular Response Analyzer (ORA) and their relationship.

Methods: In an observational cross-sectional study, patients aged 18–35 years were included. Exclusion criteria were history of any intraocular or corneal disease, anomaly or surgery; hyperopic spherical refraction more than +3, and myopic spherical refraction less than −5.00 diopters (D) or cylindrical refraction more than 2.00 D. ORA was used to measure CH and CRF. Corneal volume (CV), anterior and posterior Q value (QA and QP), anterior and posterior elevation (AE and PE), central corneal thickness (CCT), corneal thinnest thickness (CTT), anterior chamber depth (ACD), anterior chamber volume (ACV) and anterior chamber angle (ACA) were measured with Pentacam.

Results: This study evaluated 506 eyes of 253 cases (182 females) with a mean age of 28.43 ± 6.36 years. The average CH and CRF were 10.07 ± 1.61 and 10.33 ± 1.68 mmHg. CH and CRF were not correlated with PQ, AQ, AE and PE. CH and CRF were significantly correlated with CCT ($r = 0.499$, $p < 0.0001$ and $r = 0.591$, $p < 0.0001$ respectively), CTT ($r = 0.469$, $p < 0.0001$ and $r = 0.593$, $p < 0.0001$ respectively) and CV ($r = 0.443$, $p < 0.0001$ and $r = 0.526$, $p < 0.0001$ respectively).

Conclusion: A significant positive correlation was found between CH and CRF, and CCT, CTT and CV. This study also provided data about wide range normative values of corneal parameters.

Keywords: Pentacam, Ocular response analyzer, Corneal hysteresis, Corneal resistance factor

Introduction

In many fields of ophthalmology, the examination of anterior segment structures and determining the accurate measurement of its indexes are fundamental. It is crucial to assess the anterior chamber volume (ACV) and anterior chamber angle (ACA) in order to precisely diagnose a corneal disease or estimate the risk of glaucoma and also the preoperative plan of refractive surgeries.[1] Anterior chamber depth (ACD) that is defined as the distance from the corneal endothelium to the anterior surface of the lens, is an essential value for intraocular lens power calculation.[2] Corneal thickness is another index which needs to be accurately assessed for the diagnosis of keratoconus, corneal ectasia and exact

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measurement of intraocular pressure (IOP).[3,4] There are a number of methods for assessing the anterior segment parameters, one of them being the Pentacam-Scheimpflug camera. Employing a Scheimpflug rotating camera, Pentacam is a non-contact optical system that captures the images of the anterior segment. A three-dimensional model of the anterior segment of the eye is then constructed via the device software.[5]

Assessing the biomechanical status of the cornea is another key factor for the diagnosis and management of several ophthalmological conditions such as glaucoma or a number of corneal disorders like keratoconus and pellucid marginal degeneration.[6] Corneal hysteresis (CH) and corneal resistance factor (CRF) are the commonly used measures that provide the qualitative information about biomechanical status of cornea.[7] Ocular Response Analyzer (ORA) is a clinical device capable of quantifying mechanical properties of the cornea is used to assess CH and CRF.[8]

Since there are a variety of normal parameters among different ethnic groups the current study was designated to measure anterior segment parameters in normal Iranian young population. Additionally we determined the correlation of CH and CRF with various normal corneal characteristics in the same population.

Methods

Study population

A total of 506 normal eyes of 253 volunteer subjects aged 18–35 years were evaluated. Patients were enlisted among those referring for refractive surgery from March 2010 till February 2011. Patients were visited by an anterior segment subspecialist to have normal eye history and physical exam except for refractive errors. Exclusion criteria were history of any corneal disease such as keratoconus, corneal dystrophy, an irregular corneal topography pattern, any history of prior surgery; hyperopic spherical refraction more than +3.00 diopters (D), and myopic spherical refraction less than −5.00 D or cylindrical refraction more than 2.50 D.

Examination

In order to measure CH and CRF values ORA was used. Patients were asked to look at a fixed target (a red blinking light) in ORA while sitting in a chair. The ORA device, while activated, released an air puff from a non-contact probe and detected the air reflex signal from the eye. The CH and CRF were displayed on the monitor and the average of 3 time measurements was considered as each eye CH and CRF values.

Anterior segment was imaged using a rotating Scheimpflug camera (Pentacam). The patients were asked to sit in front of the camera with the chin on the chinrest and the forehead on the forehead strap. The device automatically takes the images within 1.5–2 s while the alignments are achieved. All the imaging procedures were performed by the same examiner. Anterior chamber depth (ACD), anterior chamber volume (ACV), anterior chamber angle (ACA), Corneal volume (CV), anterior and posterior Q value (AQ and PQ), anterior and posterior elevation (AE and PE), central corneal thickness (CCT), and corneal thinnest thickness (CTT) were extracted by the analyzer software.

Data analysis

Statistical analyses were performed using SPSS Windows version 16 (SPSS, Inc., Chicago, IL). The variables are expressed as mean ± SD and Student's t test was used to compare differences. The Pearson correlation coefficient was calculated and linear regression analysis was applied to the data to investigate the relationship between age and the parameters. The level of significance was set at p value of 0.05 or less.

Ethical consideration

Informed consent was obtained from each participant after the nature of the examinations had been explained. The research followed the tenets of the Declaration of Helsinki and was approved by the Mashhad University of Medical Sciences Research Ethics Committee.

Results

The current study was performed on 506 eyes of 253 participants including 182 women and 71 men with the mean age of 28.43 ± 6.36 years. Normative parameters of anterior segment chamber that have been measured by Pentacam are as follows: Mean ACA was 42.07 ± 5.6° (range: 14.40–69.90). The average values for ACV and ACD were 207.93 ± 36.04 mm^3 (range: 118–361 mm^3) and 3.25 ± 0.28 mm (range: 2.35–4.57 mm), respectively. The mean for Pentacam findings for each eye and total average with corresponding standard deviation and range have been illustrated in Table 1. However, analysis with dependent T test showed no significant difference between the normative parameters of left and right eye.

The comparison of Pentacam and ORA findings is demonstrated in Table 2. The statistical analysis showed AE and PE to be significantly higher in women. Moreover, statistically significant difference between CH and CRF among genders has been found. Although there were some disparities in the other parameters between male and female individuals, the statistical analysis revealed no significant difference.

According to the fact that the mean values for each eye was not statistically different, we merely evaluated the right eye for the correlation study. The result of correlation analysis of Pentacam findings revealed a significant association between ACD, ACV and ACA ($r = 0.89$ and $r = 0.43$, respectively). However a medium correlation was found between ACA and ACV ($r = 0.34$) and ACA and ACV had a weak but significant correlation with CV, CTT and CCT.

The mean CH and CRF was 10.07 ± 1.61 and 10.33 ± 1.68 mmHg, respectively. Age did not show any correlation with CH and CRF (p value: 0.83, 0.98 respectively). The mean value for CV was 75.95 ± 3.7 mm^3 (range: 23.9–68.9). CV was found to have a significant correlation with CH and CRF ($r = 0.443$, $p < 0.0001$ and $r = 0.526$, $p < 0.0001$ respectively). Nevertheless the association between CV and CRF seemed to be stronger than CH. The mean values for CTT and CCT were 531.8 ± 32.68 μm (range:

Table 1. Total and contralateral comparison eye's mean of normative value with the corresponding p value. (ACD: anterior chamber diameter, ACA: anterior chamber angle, ACV: anterior chamber volume, CV: corneal volume, CTT: corneal thinnest thickness, CCT: corneal central thickness, CH: corneal hysteresis, CRF: corneal resistance factor.)

	Mean ± SD	Range (min-max)	OD	OS	p value
ACD	3.25 ± 0.28	2.35–4.57	3.15	3.25	0.85
ACA	42 ± 5.6	14.4–69.9	44.4	41	0.08
ACV	207 ± 36	118–361	176	207	0.65
CV	59.8 ± 3.7	23.1–68.9	207	208	0.62
CTT	531 ± 32	443–688	539	531	0.92
CCT	533 ± 34	270–623	533	533	0.98
Ant. elevation	5.13 ± 2.7	1–27	5.73	5.54	0.13
Post. elevation	9.17 ± 5.64	−4.50 to 38	9.87	9.50	0.24
Ant Q value	−0.33 ± 0.16	−0.70 to 0.82	−0.21	−0.18	0.23
Post Q value	0.11 ± 0.21	−0.70 to 0.70	0.09	0.13	0.069
CH	10.07 ± 1.6	15.7–5.3	10.54	9.61	0.669
CRF	10.34 ± 1.6	16.7–6.2	10.54	10.1	0.342

Table 2. Comparison of Pentacam and ORA findings among genders. Data are illustrated as mean ± standard deviation. (ACD: anterior chamber diameter, ACA: anterior chamber angle, ACV: anterior chamber volume, CV: corneal volume, CTT: corneal thinnest thickness, CCT: corneal central thickness, CH: corneal hysteresis, CRF: corneal resistance factor.)

	Men	Women	p value
ACD	3.29 ± 0.27	3.23 ± 0.26	0.98
ACA	4.95 ± 0.64	5.46 ± 0.44	0.609
ACV	213.98 ± 35	204.85 ± 33	0.86
CV	58.81 ± 3.3	60.02 ± 3.2	0.74
CTT	526.25 ± 32	533.01 ± 33	0.65
CCT	528.47 ± 32	534.60 ± 31	0.95
Ant Q value	−0.18 ± 0.15	−0.22 ± 0.14	0.98
Post Q value	0.08 ± 0.2	0.10 ± 0.22	0.48
Ant elevation	5.23 ± 2.7	5.92 ± 3.01	<0.000*
Post elevation	8.82 ± 6.06	10.24 ± 6.08	0.014*
CH	9.99 ± 1.4	10.73 ± 1.5	<0.000*
CRF	10.17 ± 1.5	10.66 ± 1.7	0.004*

$p < 0.0001$) and CTT ($r = 0.595$, $p < 0.0001$) with a stronger association with CTT. CH and CRF did not show significant correlation with PQ, AQ, AE and PE. Table 3 shows detailed correlation coefficients and significance levels among measured anterior segment parameters, CH and CRF.

Discussion

The current investigation is a cross-sectional observational study that measured normative values of anterior segment ACD, ACV, ACA, CV, CTT, CCT, AE, PE, AQ value and PQ value by Pentacam and CH and CRF by ORA and demonstrated their correlation in 253 young Iranian populations. Additionally we determined the key indicators of corneal biomechanics: CH and CRF that were revealed to have a moderate positive correlation with CV, CTT and CCT. Correlation of CV, CTT and CCT seemed to be stronger with CRF than CH.

Static resistance component of the viscoelastic properties of cornea is characterized by CRF which is defined as the deformation in proportionate to applied force. CH is measured by estimating the difference between the inward and outward applanation pressure that is created by the air puff.

443–668 μm) and 533.04 ± 34.22 μm (range: 270–623), respectively.

CH significantly correlated with CCT ($r = 0.414$, $p < 0.0001$) and CTT ($r = 0.449$, $p < 0.0001$). However the correlation between CH and CTT was slightly stronger than CCT. Similarly, CRF was related to CCT ($r = 0.533$,

Table 3. Correlation of anterior segment parameters measured by Pentacam and corneal resistance factors. (ACD: anterior chamber diameter, ACA: anterior chamber angle, ACV: anterior chamber volume, CV: corneal volume, CTT: corneal thinnest thickness, CCT: corneal central thickness, CH: corneal hysteresis, CRF: corneal resistance factor.)

		CH	CRF	ACD	ACV	ACA	CV	CTT	CCT
CH	Pearson correlation		0.87*	−.198*	−.211*	−.066	0.424*	0.449*	0.414*
	Sig. (2-tailed)		<0.000	<0.000	<0.000	0.180	<0.000	<0.000	<0.000
CRF	Pearson correlation	0.87*		−.160*	−.175*	−.390	0.458*	0.595*	0.533*
	Sig. (2-tailed)	<0.000		<0.01	<0.000	0.436	<0.000	<0.000	<0.000
ACD	Pearson correlation	−.198*	−.160*		0.890*	0.430*	−.235*	−.139*	−.197*
	Sig. (2-tailed)	<0.000	<0.01		<0.001	<0.001	<0.000	<0.004	<0.000
ACV	Pearson correlation	−.211*	−.175*	0.890*		0.348*	−.317*	−.138*	−.182*
	Sig. (2-tailed)	<0.000	<0.000	<0.001		<0.001	<0.000	<0.005	<0.000
ACA	Pearson correlation	−.066	−.390	0.430*	0.348*		.019	−.081	−.110*
	Sig. (2-tailed)	0.180	0.436	<0.001	<0.001		0.7	0.100	<0.001
CV	Pearson correlation	0.424*	0.458*	−.235*	−.317*	.019		.691*	.688
	Sig. (2-tailed)	<0.000	<0.000	<0.000	<0.000	0.7		<0.000	<0.001
CTT	Pearson correlation	0.449*	0.595*	−.139*	−.138*	−.081	.691*		.881*
	Sig. (2-tailed)	<0.000	<0.000	<0.004	<0.005	0.100	<0.000		<0.000
CCT	Pearson correlation	0.414*	0.533*	−.197*	−.182*	−.110*	.688	.881*	
	Sig. (2-tailed)	<0.000	<0.000	<0.000	<0.000	<0.001	<0.001	<0.000	

* Significant p value or correlation.

Due to corneal viscoelastic properties, these two pressures are not the same, the difference being dependent on the force magnitude and velocity of the force application.[9,10]

There is an increased tendency toward investigation of corneal indices in the recent studies considering their effect on the outcome of refractive surgery and preoperative evaluation of patients with keratoconus.[11,12] The first investigation of corneal biomechanical properties was performed by Luce who measured CH in normal individual along with patients with keratoconus, Fuch's dystrophy and the post-laser in situ keratomileusis patients (LASIK). CH comprises a wide range of 1.8–14.6 mmHg, only weakly correlated with corneal thickness.[8] Touboul et al. evaluated the correlation of CH and CRF with IOP measured with Goldman applanation tonometry and ultrasonic CCT. They revealed that CH showed a modest positive correlation with CCT and IOP. Furthermore, the mean CH in LASIK and keratoconus groups was found to be lower than normal subjects.[13]

Correlation of CH and CRF with CCT in normal subjects has also been the key concern of several investigations.[14–16] The findings of these studies were mostly concordant to our results and CH and CRF were demonstrated to have a moderate association with CCT. In fact CH and CRF are related to corneal shape and thickness and measure different biomechanical aspects of corneal rigidity which provide additional useful measurement to CCT while assessing IOP.[15,16]

Previously it has reported that a significant correlation between CH and CRF with CV at 3, 5, 7 and 10 mm zones[17] which is in concordance with our recent findings. Mannion et al. have revealed a significant decrease in CV in patients with keratoconus especially in central and paracentral zones due to the loss of corneal tissue.[18] With regard to the reduction of CH and CRF in patients with keratoconus and their association with CV, these indices of biomechanical status of cornea can offer valuable data in diagnosis and screening of such patients.

According to our results AE, PE, AQ and PQ are not correlated with CH and CRF. Corneal elevation indices are important for early diagnosis of keratoconus, to differentiate keratoconus-suspect eyes from normal[19] and to diagnose early corneal ectasia after refractive surgery.[20] However, our results showed that viscoelastic characteristics of cornea measured by ORA are not related to these topographic features of the cornea.

In conclusion our results provide novel epidemiologic data of normal anterior chamber parameters in young Iranian population and reveal association of Pentacam findings with CH and CRF. ORA and Pentacam measure different aspects of corneal status and therefore provide a better concept before planning for corneal surgery.

Conflict of interest

No author has a financial or proprietary interest in any material or method mentioned.

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