Correlation between Central Corneal Thickness and Intraocular Pressure in Various Age Groups

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SUMMARY

Introduction The Pascal Dynamic Contour Tonometer (DCT) is an ophthalmic investigational device which directly calculates the dynamic pulsatile fluctuations in intraocular pressure (IOP) using a piezo-electric pressure sensor embedded in the devices tip.

Objective The aim of this study was to compare IOP results obtained with Goldmann applanation tonometer (GAT), and their correlation with central corneal thickness (CCT) in patients of various age groups.

Methods We studied 37 patients (17 male and 20 female), divided into three age groups: younger than 40 years; 40-60 years old, and older than 60 years. In the first and second group there were patients rarely and in the third mostly diagnosed and medicamentously compensated glaucoma. In topical anaesthesia, first we measured CCT, with ultrasound pachimeter, then IOP with DCT and GAT.

Results Statistically significant difference between measurements of IOP with the DCT and GAT appeared in all groups: I mean diff. -1.71±1.27 mm; p<0.0001; II mean diff. -1.19±1.06 mm; p<0.0001; III mean diff. -1.69±1.67 mm; p<0.0001. CCT was in indirect correlation with the values of IOP measured both with the DCT and GAT in the first and third, while it was in the direct correlation with these values in the second group.

Conclusion CCT had no influence on IOP measurements both with the DCT and GAT in none of the groups. The DCT cannot replace GAT, but it is a reliable device for the measurement of IOP particularly in corneal deformations (keratoconus, after corneal refractive surgery, corneal scars, etc.).

Keywords: central corneal thickness; dynamic contour tonometry; Goldmann applanation tonometry; age groups

INTRODUCTION

Accurate measurement of intraocular pressure (IOP) is a fundamental parameter in all ophthalmic examinations. Over the past four decades, Goldmann applanation tonometry (GAT) has become the standard for routine measurements of IOP, as the method has proved to be robust and easy to use with low intra- and interobserver variability [1]. However, the accuracy of GAT depends on many factors, including corneal thickness, corneal curvature, corneal structure and axial length [2]. Especially central corneal thickness (CCT) has been shown to have a substantial effect on IOP readings obtained with the GAT. The effect of CCT on the accuracy of IOP measurements with applanation tonometry was first suggested by Goldmann in 1957 [3]. The management of patients with suspected ocular hypertension or early glaucoma depends on accurate IOP assessment [4]. It is recommended that not only the GAT readings, but also CCT be recorded for a glaucoma work-up [5]. Later reports evaluated this possibility and suggested that Goldmann tonometry may underestimate IOP in eyes with thinner corneas and hyperestimate this parameter in eyes with thicker corneas [6, 7].

However, this requires an ultrasound pachymetry and a reliable nomogram to convert GAT readings and CCT into true IOP. Several nomograms for adjusting GAT readings in normal eyes with varying CCT [8] or in eyes after refractive surgery [9] have been published, but so far none seems to be satisfactory [10].

The Pascal dynamic contour tonometer (DCT) is a nonapplanation contact tonometer designed to be largely independent on the structural properties of the cornea, including CCT (Swiss Microtechnology®) (Figure 1) [11]. DCT

Figure 1. Dynamic Contour Tonometer

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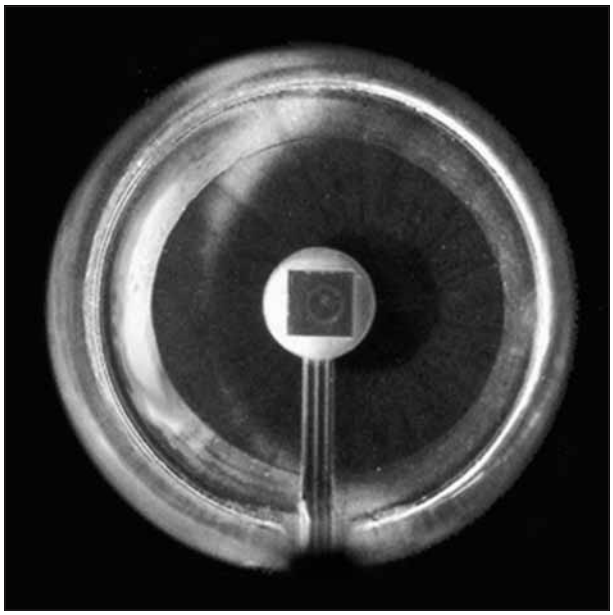

Figure 2. Photo of the examination procedure with DCT

has a specially designed tip with a concave contact surface of 10.5 mm radius that matches the contour of the cornea. Pressure on both sides of the cornea is equalized as the cornea takes the tip contour, and a pressure-sensitive area in the centre of the contour surface with a built-in microprocessor provides a direct and continuous transcorneal measurement of IOP that is independent of corneal properties (Figure 2). All forces exerted on the cornea are compensated by a tight-fitting shell created by the tip of the tonometer. Exposing a miniaturized pressure sensor closely to the contour of such a cornea is thought to measure IOP directly [12]. Theoretically, DCT may measure IOP most accurately in abnormally thinner corneas.

OBJECTIVE

The aim of this study was to evaluate the effect of CCT on IOP readings, measured with DCT and GAT in various age groups, and assess their correlation.

METHODS

Patients

All patients were examined at the Institute of Eye Diseases of the Clinical Centre of Serbia in Belgrade between May and August 2008. All patients were obtained from the Ophthalmology Outpatient Department. The research adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained after explanation of the nature and possible consequences of the study.

We studied 37 patients (74 eyes), 17 male and 20 female, divided into 3 various age groups. The first group was composed of patients aged below 40 years (12 patients, 5 male and 7 female), the second of those between 40-60 years (12 patients, 4 male and 8 female) and the third one was composed of patients aged over 60 years (13 patients, 8 male and 5 female). In the first group there were 2 in the second 3 and in the third 10 patients with diagnosed and medicamentously compensated glaucoma.

Operating technique

All examinations were done under topical anaesthesia (Sol. Tetracaine 1%). First we measured CCT three times consecutively with Ultrasound Pachymetry. IOP was determined three times each consecutively using DCT and Goldmann tonometry. For DCT exam we changed tip preservative before every exam.

DCT displayed, beside IOP data, ocular pulse amplitude (OPA): diastolic – sistolic pressure and quality level (Q) measurements. For DCT measurements we accepted quality level (Q) from 1 to 3 (Figure 3).

We analyzed CCT expressed in μm, IOP measured with the DCT in mm Hg, IOP measured with GAT in mm Hg and OPA in mm Hg.

Statistics

Data are presented as mean value with standard deviation. Normal distribution and homoscedasticity of continuous variables were tested by means of the Kolmogorov-Smirnov test. Statistical evaluations were performed by running the SPSS/PC + software package (SPSS, Chicago, IL) on a personal computer. P values of less than 0.05 were regarded as statistically significant.

RESULTS

In the first group of patients, younger than 40 years, we examined 12 patients (24 eyes) – 5 male and 7 female. Measured parameters were: CCT (mean=559.42±37.55 μm; p>0.05); DCT (mean=17.67±4.47 mm Hg; p>0.05); GTA (mean=15.96±4.20 mm Hg; p>0.05), and OPA

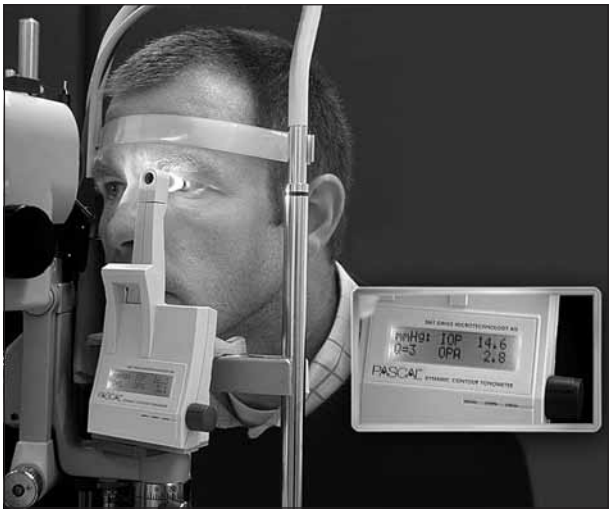

Figure 3. DCT measuring of IOP with presented display data

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(mean=3.1±1.69 mm Hg; p>0.05). Correlations of the observed parameters were between: IOP measurements measured with DCT and GAT (mean diff. -1.71±1.27 mm Hg; p<0.01), (Graph 1); CCT (μm) and IOP measured with DCT (mm Hg), (r=-0.24; inverse (indirect) correlation (↑CCT≈ ↓DCT); p>0.05); CCT (μm) and IOP measured with GAT (mm Hg), (r=-0.15; inverse (indirect) correlation (↑CCT≈ ↓DCT); p>0.05); CCT (μm) and OPA (mm Hg), (r=+0.09; direct correlation (↑CCT≈ ↑DCT); p>0.05).

In the second group, with the patients between 40 and 60 years old, we also examined 12 patients (24 eyes), 4 male and 8 female. Measured parameters were also CCT (mean=570.75±35.75 μm; p>0.05); DCT (mean=20.57±2.32 mm Hg; p>0.05); GTA (mean=19.38±1.84 mm Hg; p>0.05); and OPA (mean=3.95±0.78 mm Hg; p>0.05). Correlations of the observed parameters were also between: IOP measurements measured with DCT and with GAT (mean diff. -1.19±1.06 mm Hg; p<0.01), (Graph 2); CCT (μm) and IOP measured with the DCT (mm Hg), (r=+0.19; direct correlation (↑CCT≈ ↑DCT); p>0.05); CCT (μm) and IOP measured with GAT (mm Hg), (r=+0.35; direct correlation (↑CCT≈ ↑DCT); p>0.05); CCT (μm) and OPA (mm Hg), (r=+0.17; direct correlation (↑CCT≈ ↑DCT); p>0.05).

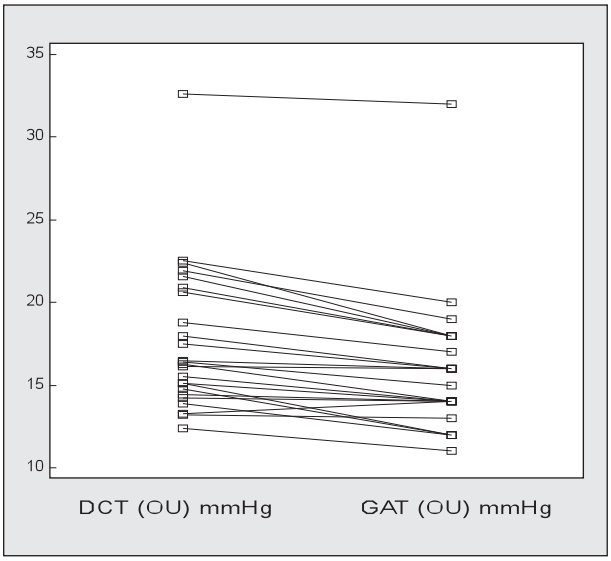
In the third group, with patients older than 60 years, we examined 13 patients (26 eyes), 8 male i 5 female. Measured data were: CCT (mean=569.3±32.75 μm; p>0.05); DCT (mean=20.96±5.1 mm Hg; p>0.05); GTA (mean=19.27±5.51 mm Hg; p>0.05); and OPA (mean=4.03±2.04 mm Hg; p>0.05). Data correlations in this group were also between: IOP measurements measured with DCT and with GAT (mean diff. -1.69±1.67 mm Hg; p<0.01), (Graph 3); CCT (μm) and IOP measured with the DCT (mm Hg), (r=-0.16; inverse (indirect) correlation (↑CCT≈ ↓DCT); p>0.05); CCT (μm) and IOP measured with the GAT (mm Hg), (r=-0.13; inverse (indirect) correlation (↑CCT≈ ↓DCT); p>0.05); CCT (μm) and OPA (mm Hg), (r=-0.26; inverse (indirect) correlation (↑CCT≈ ↓DCT); p>0.05).

We also measured the influence of age on CCT measurements (p>0.05), (Graph 4); and on OPA measurements (p>0.05), (Graph 5); as well as the influence of sex on both, CCT measurements (p>0.05), (Graph 6); and OPA measurements (p>0.05), (Graph 7).

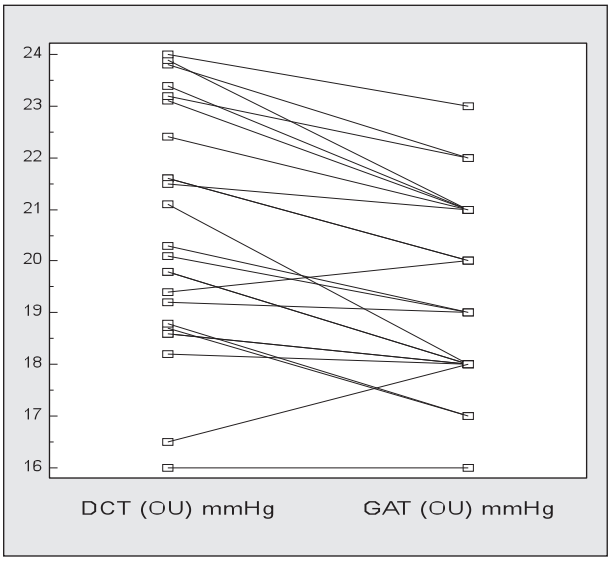
DISCUSSION

In our study all data had normal statistical distribution. The values of CCT in the first group were 511-657 μm, in the second 485-630 μm and in the third group 498-638 μm.

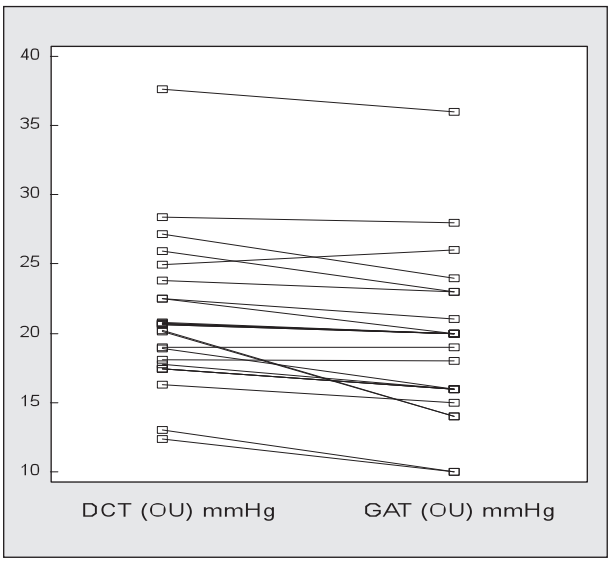
Since the last results of the Ocular Hypertension Treatment Study were published, CCT has received much attention because of its influence on measurement of IOP [17]. Being the golden standard for clinical measurement of IOP, GAT assumes that every cornea has a standard corneal stiffness or resistance that tends to oppose corneal flattening in the determined surface area (Imbert-Fick law) [3].



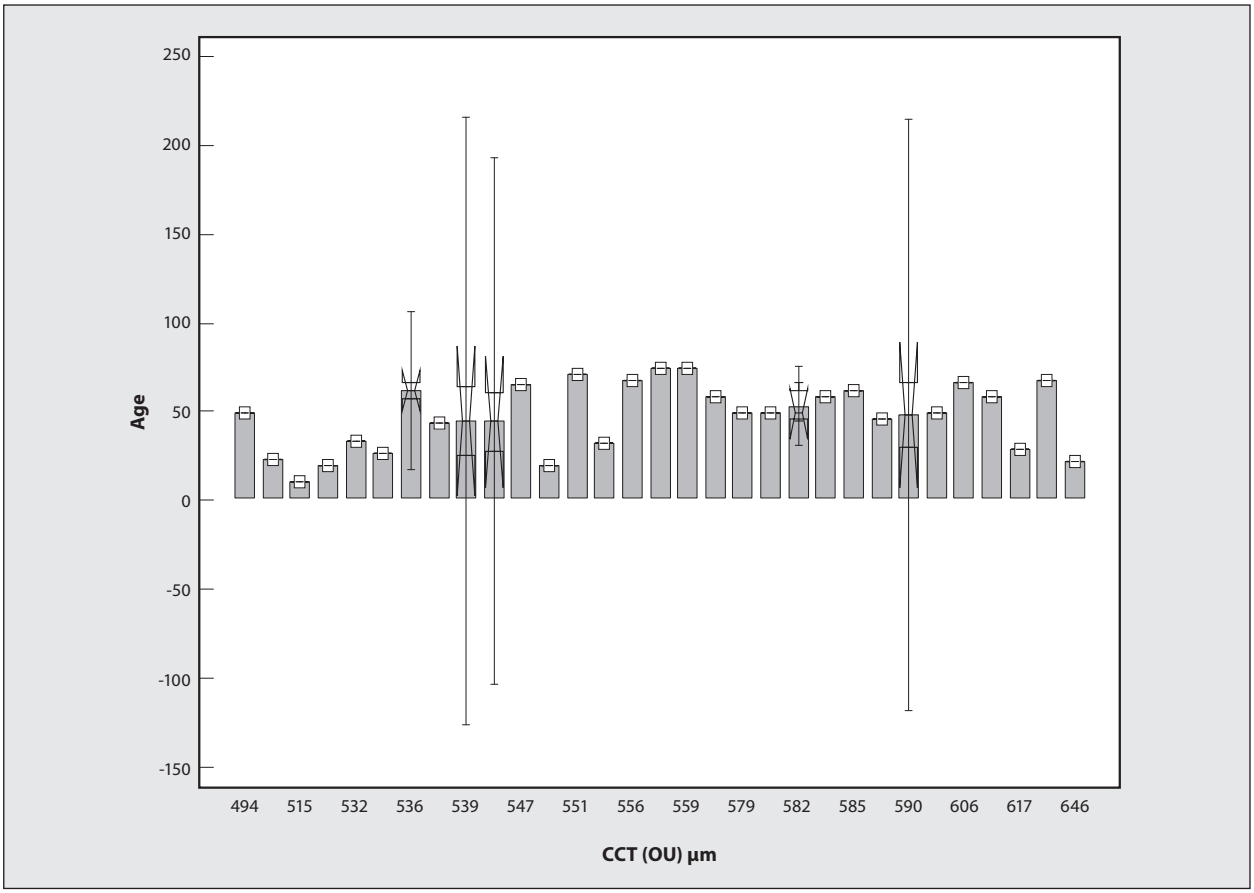
Graph 1. Correlation between IOP measurements measured with DCT and GAT in the first group



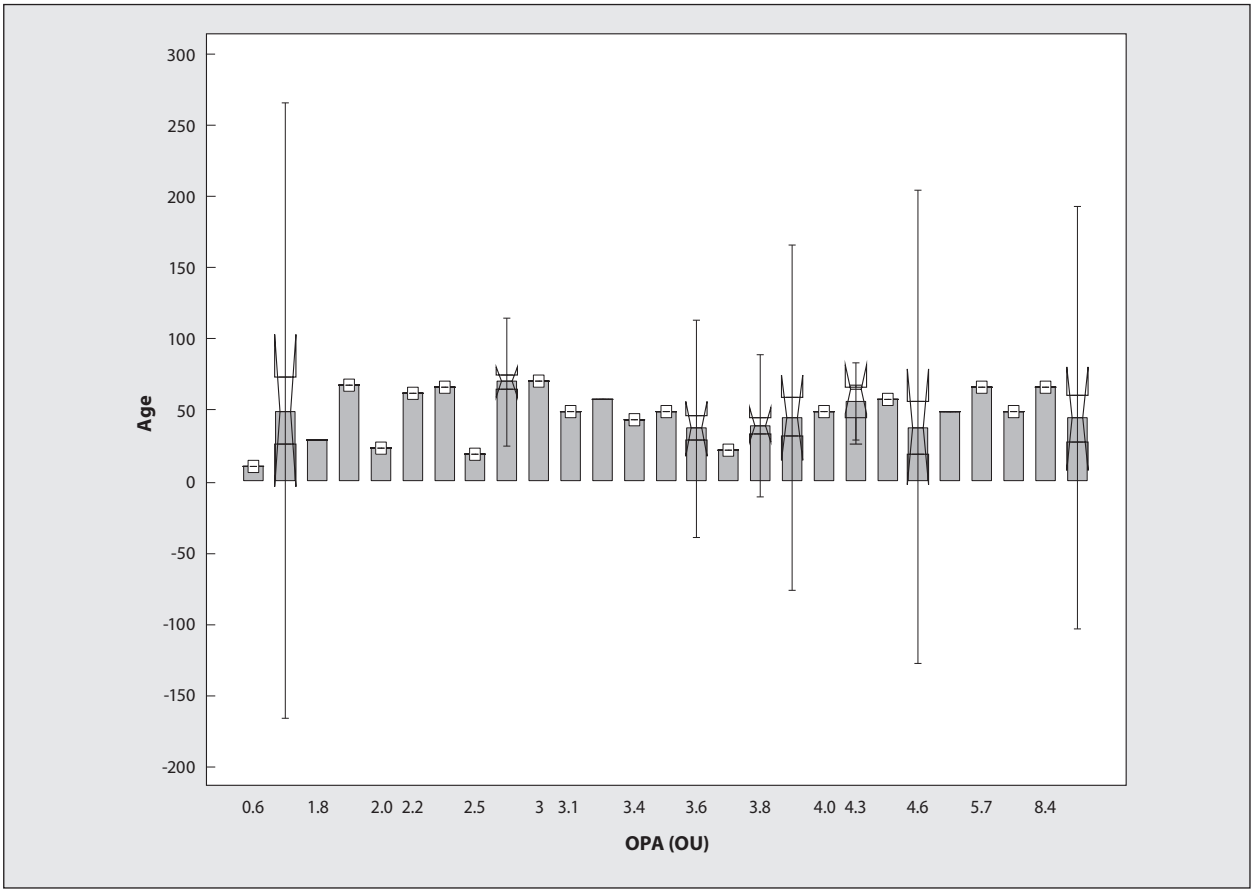
Graph 2. Correlation between IOP measurements measured with DCT and GAT in the second group



Graph 3. Correlation between IOP measurements measured with DCT and GAT in the third group



Graph 4. Influence of age on CCT measurements



Graph 5. Influence of age on OPA measurements

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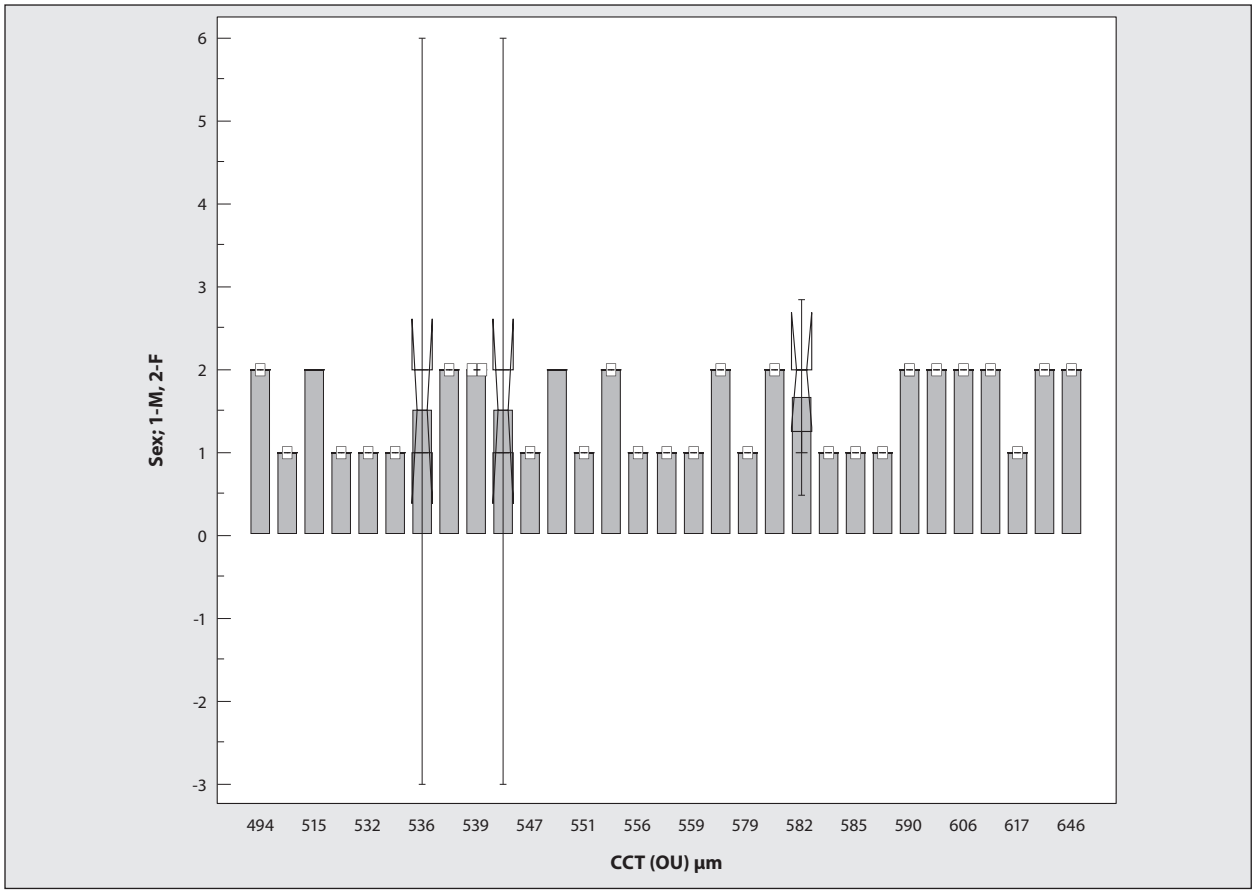
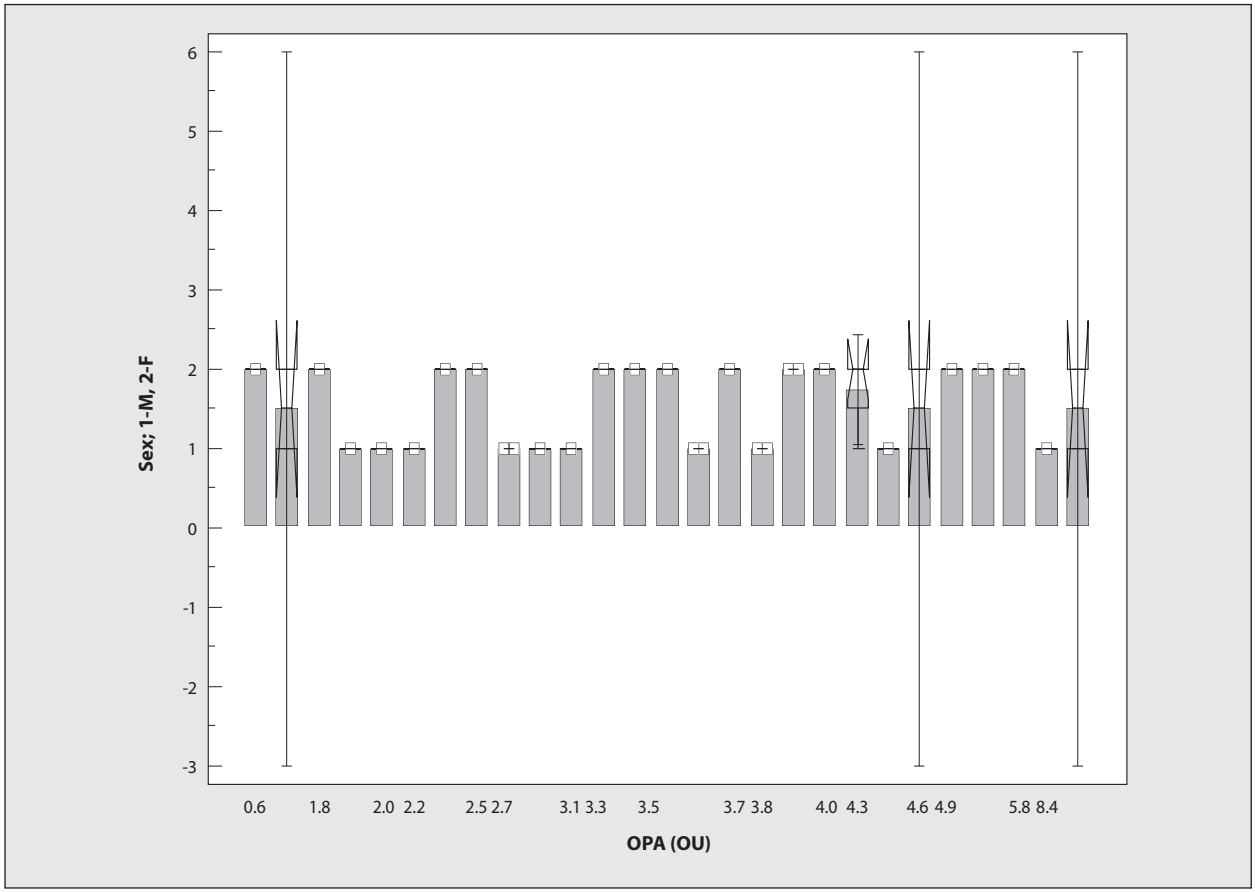


Graph 6. Influence of sex on CCT measurements



Graph 7. The influence of sex on the OPA measurements

However, thinner corneas tend to be more elastic and may lead to underestimation of GAT IOP measurements [6, 7]. Manometric study by Ehlers and Hansen reported an underestimation of IOP in normal thin corneas. The underestimation of IOP measurements was around 5 mm Hg per 70 μm change in CCT [8].

Ultrasonic pachymetry is a widely used technique for the measurement of corneal thickness. Although many different models are available, they all work on the same underlying principle of the recording of time difference between reflection from the anterior and posterior surfaces of the cornea. Studies have shown a high degree of intraobserver and interobserver reproducibility for the given instrument and high reliability coefficients between different instruments [13]. In contrast, significant differences between ultrasonic and optical pachymeters have been found with latter producing generally higher CCT values [6]. This makes comparison of data between different methods problematic. For the purposes of this study, however, a single ultrasonic pachymeter was used relying on a technique that was shown to be both accurate and reliable [13]. The effect of CCT on IOP measurement between different tonometers is therefore unlikely to be affected by the specific pachymeter used in this study.

In our study correlation between CCT and IOP measurements measured both with DCT and GAT was indirect (inverse) in the first and in the third, but direct in the second group. Only in the second group IOP measurements depended on CCT measurements, measured with both tonometers, which match with some reports [14]. There were also studies reporting the influence of CCT on GAT IOP readings and without the influence of CCT measurements on DCT IOP readings [15, 16]. There was no statistical significant relationship between presented data, which corresponds to similar reports [17].

All our patients had not previously undergone corneal surgery (especially refractive) and were without ectatic corneas.

Correlation with OPA was direct in the first and second, but indirect (inverse) in the third group. OPA increases with increasing age. Additionally, OPA is affected by other parameters, e.g. IOP and axial length suggesting that factors connected with increased stiffness of the eye globe wall lead to increase of OPA [18].

In the view of true clinically based IOP measurements, GAT has been accepted as the golden standard technique despite the readings being affected by a number of variables [2].

In our study difference between IOP measurements measured with DCT and GAT was statistically significant in all three groups. IOP measurements were higher with DCT than with GAT, with the mean difference in the first group 1.71 mm Hg, in the second group 1.19 mm Hg and in the third group 1.69 mm Hg, which is in agreement with a similar study [11].

Two published studies found that IOP readings by applanation tonometry to be 1.2 to 2 mm Hg lower than true IOP measured manometrically in human eyes in vivo [19, 20]. Hence, higher readings obtained by DCT as compared with GAT readings were expected, because DCT was calibrated against a manometrically controlled pressure standard rather than GAT pressure readings. To reduce the risk of observer bias, it is recommended that more subjective GAT measurements should be always taken before DCT readings, which thus cannot be influenced by the examiner. In our study we first measured IOP with DCT then with GAT, which we repeated 3 times consecutively. Average measurements were taken into consideration. Our data are in agreement with most published studies. Previous studies have shown that IOP readings decrease with successive GAT measurements, but this effect is absent in the case of rapid repetition of IOP measurements by the same examiner, as in our present study [21].

Additionally, intracameral manometric studies using harvested human eyes have demonstrated very good correlation between true IOP (per manometry) and DCT measurements of IOP [22, 23].

Finally, preliminary results from intracameral, manometric in vivo studies using human eyes suggest that DCT-IOP measurements strongly agree with intracameral IOP measurements [24].

Thus, the published evidence to-date suggests that DCT may be truly capable of overcoming interindividual variation in corneal biomechanical properties resulting in more accurate measurements of IOP compared with GAT.

In the present study DCT was found to be suitable as a routine clinical tool for measuring IOP. Because DCT can be attached to any slit lamp fitted with a normal GAT stand, the new tonometer can be used on most rigs without the need for modification. The examination technique with DCT is similar to the technique used with GAT, except that it does not require occasionally cumbersome tuning of a knob to adjust two oscillating or melting semicircles, which leaves room for observer-dependent interpretation. All examiners involved in this study managed to obtain consistent readings with DCT right from the beginning without any learning curve. Measuring IOP with DCT requires the tip of the tonometer to rest on the patient's cornea for approximately 5 seconds. This is slightly longer than the contact time that an experienced examiner would require with GAT. However, the acoustic signal of DCT that informs the examiner about the correct alignment of the tonometer tip seems to encourage patients to remain still for the time needed. Although several direct comparison studies between the Pascal DCT and GAT have been published [15, 16, 25].

We did not find any significant relationship between either CCT and age, or CCT and sex; and there was no significant relationship between either OPA and age, or OPA and sex, although one must keep in mind that this is a small group of patients for this kind of conclusions.

CONCLUSION

In our study groups, CCT measurements had no influence on IOP measurements measured with both tonometers. With the increase of CCT also increased OPA in the first and in the second group; in the third group composed of

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oldest patients OPA decreased with the increase of CCT. IOP measurements measured with the Dynamic Contour Tonometer were higher than IOP readings measured with the Goldmann Applanation Tonometer, with statistically significant difference in all observed groups.

NOTE

This work was presented at the IX Congress of the Serbian ophthalmologists held in Zlatibor on October 2008, as oral presentation.

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Однос централне дебљине рожњаче и интраокуларног притиска код особа различите старосне доби

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КРАТАК САДРЖАЈ

Увод Паскалов динамички контурни тонометар (*The Pascal Dynamic Contour Tonometer – DCT*) је офталмолошки дијагностички апарат који служи за контактно мерење интраокуларног притиска (ИОП). Овај апарат мери ИОП директно на основу динамичких пулсних флуктуација у ИОП помоћу пиезоелектричног сензора уграђеног у тип којим се додирује рожњача.

Циљ рада Циљ рада је био да се упореде вредности ИОП измерене помоћу *DCT* с вредностима ИОП измереним Голдмановим (*Goldmann*) апланационим тонометром (*GAT*), те установи њихова корелација с вредностима централне дебљине рожњаче (ЦДР) код особа различите старосне доби.

Методе рада Истраживање је обухватило 37 испитаника (17 мушког и 20 женског пола) који су сврстани у три старосне категорије. Прву групу су чинили испитаници млађи од 40 година, другу стари 40-60 година, а трећу старији од 60 година. Испитаници прве и друге групе су били без дијагностикованог глаукома, док су у трећој групи били углавном болесници са дијагностикованим и медикаментно леченим глаукомом. Мерења су вршена у топикалној анестезији, при чему је најпре ултразвучним пахиметром мерен ЦДР, а затим је мерен ИОП помоћу *DCT* и *ГАТ*.

Резултати Статистичка значајност је забележена између мерења ИОП помоћу оба апарата у свим старосним категоријама: у првој -1,71±1,27 *mm* (p<0,0001); у другој -1,19±1,06 *mm* (p<0,0001); у трећој -1,69±1,67 *mm* (p<0,0001). Вредности ЦДР су биле у обрнутој корелацији с вредностима ИОП мереним и помоћу *DCT* и помоћу *GAT* у првој и трећој групи, док су у директној корелацији с истим вредностима биле у другој групи.

Закључак Вредности ЦДР нису значајно утицале на вредности ИОП који је мерен помоћу *DCT* и *GAT* ни у једној старосној категорији. *DCT* не може да замени *GAT*, али је користан код одређених промена на рожњачи када мерење *GAT* није прецизно (кератоконуси, стања након рефрактивне хирургије рожњаче – ЛАСИК, ЛАСЕК, ПРК,...).

Кључне речи: централна дебљина рожњаче; динамичка контурна тонометрија; Голдманова апланациона тонометрија; старосне категорије

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