Comparison of Dynamic Contour Tonometry with Goldmann Applanation Tonometry

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PURPOSE. The dynamic contour tonometer (DCT; Pascal tonometer) is a novel tonometer designed to measure intraocular pressure (IOP) independent of corneal properties. The purpose of this study was a comparison of the DCT with the Goldmann applanation tonometer (GAT) with respect to mean of IOP readings, the influence of ocular structural factors on IOP readings, and both intra- and interobserver variability, in a large group of healthy subjects.

METHODS. In a prospective study of 228 eyes, IOP measurements by GAT and DCT were compared, and the effects of central corneal thickness (CCT), corneal curvature, axial length, and anterior chamber depth were analyzed. To evaluate intra- and interobserver variability, IOP was measured in eight eyes by four observers.

RESULTS. There was a high concordance between the IOP readings obtained by DCT and GAT. However, IOP readings were consistently higher with DCT than with GAT (median difference: +1.7 mm Hg, interquartile range [25th–75th percentile] = 0.8–2.7 mm Hg). In contrast to GAT, multivariable regression analysis showed no significant effect of corneal thickness, corneal curvature, astigmatism, anterior chamber depth, and axial length on DCT readings. For repeated measurements the intraobserver variability was 0.65 mm Hg for the DCT and 1.1 mm Hg for the GAT (P = 0.008). Interobserver variability was 0.44 mm Hg for the DCT and 1.28 mm Hg for the GAT (P = 0.017).

CONCLUSIONS. IOP measurements by DCT are highly concordant with IOP readings obtained from GAT but do not vary in CCT and have a lower intra- and interobserver variability. DCT seems to be an appropriate method of tonometry for routine clinical use. (Invest Ophthalmol Vis Sci. 2004;45:3118–3121) DOI:10.1167/iovs.04-0018

Accurate measurement of intraocular pressure (IOP) is a fundamental parameter in any ophthalmic examination. Over the past four decades, Goldmann applanation tonometry (GAT) has become the standard for routine measurement of IOP, as the method has proven 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 management of patients with suspected ocular hypertension or early glaucoma depends on an accurate IOP assessment.3 It is recommended that not only the GAT readings but also CCT be recorded for a glaucoma work-up.4 However, this requires an ultrasound pachymeter and a reliable nomogram to convert GAT readings and CCT into true IOP. Several nomograms for adjusting GAT readings in normal eyes with varying CCT5–7 or in eyes after refractive surgery8,9 have been published, but so far none seems to be satisfactory.10

With the dynamic contour tonometer (DCT), a new digital tonometer has been introduced as an alternative to adjustments of application tonometry readings based on CCT. The so-called contour-matched tonometer tip has a concave surface that allows the cornea to assume the shape that it naturally assumes when pressure on both sides of the cornea is equal and distortion of the cornea is minimal. Exposing a miniaturized pressure sensor closely to the contour of such a cornea is thought to measure IOP directly (i.e., without systematic errors resulting from force-to-pressure translations; Kanngiesser H, et al. IOVS 2002;43:ARVO EAbstract 301). In a pilot study on patients before and after corneal refractive surgery (LASIK) DCT has been shown to measure IOP accurately, independent of corneal thickness.11

The purposes of this study were to compare the IOP readings obtained by DCT with those of GAT, to evaluate the ocular structural factors influencing IOP measurements obtained from both tonometers and to determine intra- and interobserver variability in a group of nonsurgical healthy subjects.

METHODS

One hundred fifty healthy volunteers from the hospital staff with normal eyes on slit lamp examination and no history of previous ocular diseases, trauma, or surgery contributed 228 eyes that were evaluated in a prospective single-center study. Informed consent, according to the tenets of the Declaration of Helsinki, was obtained from each volunteer.

All measurements were taken by the same examiner in the following order: biometry, pachymetry, GAT, and DCT. First, axial length, corneal curvature, and anterior chamber depth were measured with an optical biometry system (IOL Master; Carl Zeiss AG, Feldbach, Switzerland). Second, CCT was measured with an ultrasonic pachymeter (model SP-2000; Tomey Corp., Cambridge, MA). The pachymeter probe was placed on the center of the cornea over an undilated pupil and the mean of three readings within a range of ±5 μm was calculated for each eye. Third, GAT was performed on a slit lamp (Haag-Streit, Köniz, Switzerland) with a tonometer calibrated according to the manufacturer's guidelines. Before each reading, the measuring drum was reset to approximately 2 mm Hg, and the mean of three consecutive readings was recorded.

Fourth, DCT was performed using a technically identical prototype of the model launched in November 2003 (Pascal dynamic contour tonometer; Swiss Microtechnology AG, Port, Switzerland; slit-lamp-mounted, self-calibrating, 1 g appositional force, 100 Hz sampling rate, 7 mm tip diameter, 1.2 mm pressure sensor diameter). As DCT provides a digital readout of the IOP on a liquid crystal display (LCD), prior knowledge of the GAT result would not influence the result and made it unnecessary to randomize the order of IOP measurements (always

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Submitted for publication January 8, 2004; revised May 14, 2004; accepted June 9, 2004.

Disclosure: C. Kaufmann, None; L.M. Bachmann, None; M.A. Thiel, None

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GAT followed by DCT) or to mask the investigator. However, for the study of the intra- and interobserver variability, all four investigators were fully masked to all results. For this part of the study, three GAT readings followed by three DCT readings were taken in eight participants by each investigator, resulting in 192 measurements. The delay between readings by different investigators was kept as short as possible (<30 seconds).

Data are presented as medians and 25th to 75th percentile limits. Comparisons in pressure measurements were performed using the nonparametric Wilcoxon signed ranks test to account for the skewed and nonsymmetrical distribution of data points. *P* < 0.05 was considered significant. To correct for related data, when two eyes of the same subject were entered into analysis, we performed clustered analyses, using the subject identifier as the cluster variable. We fitted models in which DCT and GAT, respectively, acted as the dependent variable. To adjust for the skewed data distribution, DCT and GAT were transformed into their logarithms. Corneal thickness, corneal curvature, astigmatism, anterior chamber depth, and axial length were entered as continuous independent variables. First each independent variable was assessed in a univariate analysis. Then all independent variables were fitted into two multivariable models (one for GAT and one DCT).

To study the variability between the different investigators and the two measurement readings, we performed analyses of variance (ANOVAs). We used the variance components procedure to estimate the contribution of an independent variable (observer, test, subjects, observer subject interaction, and residual error) to the variance of the dependent variable (pressure measurement). Based on the variance components, we calculated the intraclass correlation coefficients (ICC) for GAT and DCT using the variance component of the subjects in the numerator and the sum of all variances in the denominator. To test for significant differences between the ICCs, we calculated the sum of variance of all noise components for the two tests (all variance components except the subjects variance component). The division of the two noise components was bootstrapped and tested using a one-sample *t*-test.

To assess the intra- and interobserver variability of DCT and GAT, we calculated the interobserver variability for each of the two tests as the sum of the variance components of the investigator and the investigator–subject interaction. The variance component of the residual error was used as the intraobserver variability.

Statistical analysis was performed on computer (SPSS statistical software, ver. 10; SPSS Inc., Chicago, IL).

**RESULTS**

The study included 228 healthy eyes with a corneal thickness ranging from 439 to 642 μm, a corneal curvature between 40.02 and 46.47 D with a corneal astigmatism of up to 5.6 D, an anterior chamber depth between 2.25 and 4.29 mm, and an axial length between 21.08 and 29.83 mm.

The IOP measurements obtained by DCT and GAT demonstrate a high concordance between the two techniques (Fig. 1). IOP readings obtained by DCT were consistently higher.
The interobserver variability for each of the two tests can be calculated as the sum of the variance components of the investigator and the investigator × subjects interaction. The variance component of the residual error is the intraobserver variability.

Table 1. Variance Components for GAT and DCT Measurements

<table>
<thead>
<tr>
<th>Technique</th>
<th>Variance Components</th>
<th>Estimates (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAT</td>
<td>Investigators</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>7.37</td>
</tr>
<tr>
<td></td>
<td>Investigator × subjects interaction</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Residual error</td>
<td>1.10</td>
</tr>
<tr>
<td>DCT</td>
<td>Investigators</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>8.52</td>
</tr>
<tr>
<td></td>
<td>Investigator × subjects interaction</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Residual error</td>
<td>0.65</td>
</tr>
</tbody>
</table>

The interobserver variability for each of the two tests can be calculated as the sum of the variance components of the investigator and the investigator × subjects interaction. The variance component of the residual error is the intraobserver variability.

In summary, this study found IOP measurements taken with the new DCT to have an excellent concordance with measurements obtained by the GAT. In the subjects studied, IOP measurements with the DCT did not depend on corneal thickness, corneal curvature, or axial length. With regard to increasing awareness of the effect of corneal thickness on IOP readings by GAT and the increasing number of patients with a history of corneal refractive surgery, DCT may offer some clinically relevant advantages over conventional Goldmann-type applanation tonometers for screening and management of patients with suspected or known glaucoma.

References


