Central Corneal Thickness of Caucasians and African Americans in Glaucomatous and Nonglaucomatous Populations

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Objective: To determine whether there is a difference in central corneal thickness between African American and Caucasian patients. If present, a difference might alter the measurement of intraocular pressure and potentially the assessment and management of glaucoma in these populations.

Methods: Central corneal thickness was measured by means of ultrasound pachymetry in African American (N=56) and Caucasian (N=32) patients with suspected or confirmed glaucoma and control populations of African American (N=26) and Caucasian (N=51) subjects in whom there was no evidence of elevated intraocular pressure or glaucomatous optic nerve damage. Measurements of central corneal thickness were then compared between different subpopulations by means and population distribution analysis.

Results: A statistically significant difference was noted between the mean (±SD) central corneal thickness of all African American (including those with and without glaucoma) (right eye, 531.0±36.3 µm; left eye, 530.0±34.6 µm) and all Caucasian (including those with and without glaucoma) (right eye, 558.0±34.5 µm; left eye, 557.6±34.5 µm) patients. Similar results were found when subpopulations were tested. Distribution analysis of central corneal thickness measurements noted the largest cluster of African American patients around 520 to 540 µm, whereas the largest cluster of Caucasian patients was between 580 and 600 µm.

Conclusions: African Americans were found to have thinner central cornea thickness measurements than Caucasians. This finding in African Americans may lead to lower applanation intraocular pressure readings compared with those of Caucasians, potentially resulting in an underestimation of the actual level of intraocular pressure.


SUBSTANTIAL EVIDENCE supports the assertion that primary open-angle glaucoma (POAG) has different clinical characteristics in African American than in Caucasian patients. Indeed, the Baltimore Eye Survey, the largest American study to examine this issue, demonstrated this disease to be the leading cause of irreversible blindness in African Americans. Roughly 6 times as many African Americans as Caucasians are diagnosed with glaucoma. They are about 10 years younger on initial diagnosis, and both disc and field damage are noted to progress more rapidly. No single cause has been attributed to this difference in initial diagnosis and progression of this disease between the racial groups.

The literature on the intraocular pressure (IOP) measurement in various racial groups at the time of initial examination is conflicting. The Baltimore Eye Survey found a significantly lower IOP in untreated African Americans (21.48 mm Hg) than in untreated Caucasians (24.15 mm Hg). Another large study that examined this issue was the Barbados Eye Study. Their survey of an Afro-Caribbean population disclosed a significantly higher IOP (25 mm Hg) in black patients than did the Baltimore Eye Survey.

Although IOP is an essential element in diagnosing and assessing the management of glaucoma, there are several potential sources for error in measurement. Goldmann applanation tonometry has long been the gold standard for the clinical measurement of IOP. The Goldmann equation is based on a modification of the Imbert-Fick principle, which describes the case of an ideal, dry, thin-walled sphere. However, the corneal surface of the eye exhibits properties that deviate from the ideal theoretical constructs.

Numerous studies have demonstrated the importance of corneal thickness in determination of readings with the Goldmann applanation tonometer.
PATIENTS AND METHODS

One hundred sixty-five consecutive male patients examined at the Houston Veterans Affairs Hospital Eye Clinic, Houston, Tex, between March 1 and May 31, 1999, were included in the study. Eighty-three of these patients were Caucasian and 82 were African American. Race was self-reported by the patient and confirmed by demographic information found in the patient's medical record. Exclusion criteria included any substantial corneal abnormality and intraocular surgery within the past 3 months. All patients were informed of the study and gave verbal consent to undergo corneal thickness measurements by pachymetry.

Primary open-angle glaucoma was defined as gonioscopically open angles, typical visual field and/or optic nerve changes, and a history of IOP greater than 21 mm Hg by Goldmann applanation tonometry. Glaucoma suspects were patients with optic nerve appearance suggestive of glaucoma without typical visual field changes, IOP of 21 mm Hg or less, and open angles on gonioscopy. Ocular hypertension was defined as IOP greater than 21 mm Hg by Goldmann applanation tonometry, with normal-appearing optic nerves and visual fields, and open angles on gonioscopy. Normal-tension glaucoma was defined as typical optic nerve and visual field changes consistent with glaucoma, a history of IOP that never exceeded 21 mm Hg, and open angles on gonioscopy.

Central corneal thickness was measured with an ultrasonic pachymeter (DGH-2000 or DGH 500 “Pachette”; DGH Technology Inc, Frazer, Pa). The pachymetry measurement recorded for each eye separately was the lowest of 5 measurements. This value was believed to represent the most accurate measurement, as it was likely to be closest to perpendicular to the corneal surface. Intraocular pressure was measured twice in each eye by the same examiner before the pachymetry measurement, and the mean was recorded. The patient’s age, race, number of glaucoma medicines, and any history of glaucoma surgery were also recorded. Two examiners (F.A.L.R. or Lisa Hausler, COA) took all pachymetry and IOP measurements. Cross-validation found the examiners to have consistent readings. The CCT measurements were averaged after collection and are presented as mean ± SD. Two-tailed t test was then used to assess statistical significance of the results. In addition, distribution analysis is presented with the use of bin ranges (groups [bins]) of 20 μm (Excel, version 5.0; Microsoft Corp, Redmond, Wash).

Ehlers et al8 calculated the instrument to be accurate at a central corneal thickness (CCT) of 520 μm, with a cornea 70 μm thicker resulting in intraocular pressure readings that were 5 mm Hg higher, and a cornea 70 μm thinner resulting in a reading that was 5 mm Hg lower. Whitacre et al9 showed that the extremes of underestimation and overestimation span a range of almost 16 mm Hg, indicating that measuring CCT may well have important implications with regard to IOP measurement. Patients with a clinical diagnosis of normal-tension glaucoma (NTG) have been shown to have significantly thinner corneas than either healthy volunteers or patients with POAG.10 Argus11 showed that patients with a clinical diagnosis of ocular hypertension (OHT) had significantly thicker corneas than a control population of patients with POAG.11 Copt et al12 were able to reclassify 56% of patients previously followed up for OHT as being normotensive on the basis of CCTs that were greater than average. Conversely, they were able to reclassify 31% of patients followed up for NTG as having elevated IOP after correcting for corneas that were thinner than normal. Specifically, actual IOP may be underestimated in eyes with thinner CCT or overestimated in eyes with thicker CCT.

Another implication of the importance of corneal thickness on IOP measurement is that IOP measurements are also modified by both photorefractive keratectomy and laser in situ keratomileusis.13,14 This may be a confounding factor when patients with glaucoma who have undergone one of these procedures are followed up.

The present study was performed to determine whether there was a difference in CCT between African American and Caucasian patients that could lead to misinterpretation and inaccurate measurement of IOP readings in African Americans and, thus, potentially change the diagnosis and management of glaucoma in that population.

RESULTS

A total of 165 patients were enrolled. The demographic and baseline characteristics of the patients are presented in Table 1.

Table 1. Patient Demographics*

<table>
<thead>
<tr>
<th>Population</th>
<th>No. of Patients</th>
<th>Age, y</th>
<th>No. of Medications</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>165</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>83</td>
<td>65.8 ± 10.5</td>
<td>0.30 ± 0.77</td>
</tr>
<tr>
<td>African American</td>
<td>82</td>
<td>63.3 ± 12.5</td>
<td>0.66 ± 1.10</td>
</tr>
<tr>
<td>Control</td>
<td>51</td>
<td>65.2 ± 10.3</td>
<td>0</td>
</tr>
<tr>
<td>African American</td>
<td>26</td>
<td>63.1 ± 11.8</td>
<td>0</td>
</tr>
</tbody>
</table>

‡Normal intraocular pressure and optic nerve suggestive of glaucoma.
†Includes all patients with POAG, NTG, normal-tension glaucoma, and OHT, ocular hypertension.

*POAG indicates primary open-angle glaucoma; NTG, normal-tension glaucoma; and OHT, ocular hypertension.

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The average age difference between the Caucasian population and the African American population in this study was small, 2.5 years, and not statistically significant ($P = .17$). In the patients with glaucoma, IOP was managed with both surgery and medication, with no statistically significant differences in IOP readings after treatment between all Caucasians and all African Americans ($P = .51$). African American patients were using approximately twice as many medications as Caucasians ($P < .05$).

The average CCT of all subgroups is presented in Table 2. The average difference in CCT between Caucasians and African Americans in all subgroups was statistically significant. In all subpopulations, African American patients had smaller CCT values. In all patient subpopulations together, the CCT difference was 27.3 µm ($P < .001$); in the control subjects, 21.9 µm ($P < .01$); in the glaucomatous populations taken as a whole (including POAG, suspects, OHT, and NTG), 32.2 µm ($P < .001$); in the POAG population, 30.65 µm ($P < .05$); in the glaucoma suspect group, 28.0 µm ($P < .05$); and in the NTG group, 42 µm ($P < .05$). With distribution analysis, the largest cluster of CCT values in African American patients was 60 µm lower than the peak frequency in Caucasian patients when all groups were compared (Figure).
In this study of the racial difference in corneal thickness, we found that there is a statistically significant difference, with thinner corneas being present in African American patients. This difference may impact the evaluation of IOP measurement, as it could lead to misdiagnosis and mismanagement of glaucoma in the African American patients. To our knowledge, this is the first attempt at examining racial differences in CCT. The literature has several examples of race-specific corneal thickness measurements. These examples are a by-product of the location of the institutions where the studies are conducted rather than a specific attempt at categorization based on racial heritage. Thus, although the CCT results of these studies in various racial groups are important, they only indirectly address, and do not answer, the question of whether race is a contributing factor in differences between CCT because they do not compare the groups. Studies such as that by Copt et al, performed in Switzerland, would seemingly represent a relatively homogeneous group of European Caucasians, with an average CCT reported in their control population of 552±35 µm, similar to our Caucasian control group average of 556±32 µm. They did not study other racial groups. Mixed populations such as that in the United States provide an important opportunity to address these questions with the same investigators, in the same clinical setting, with the same pachymeters.

The Goldmann applanation tonometer is theoretically only accurate for CCT at 520 µm, and yet, as with our study, virtually all studies using modern ultrasound pachymetry have noted a mean CCT significantly thicker than this value. Indeed, the study by Morad et al (conducted on an Israeli population), detailing the significantly thinner corneas of patients with NTG, showed an average CCT of 521±37 µm, while their control population had a CCT of 555±32 µm. Almost all population surveys that have defined the “normal” range of IOP, if recalculated with CCT, might be lower.

Control populations were recruited for each category to ensure that our data were not merely a reflection of the types of patients with glaucoma we were able to recruit. Because we were able to include sufficient control patients, this is extremely unlikely because of the nearly identical statistically significant differences between African Americans and Caucasians in our control population and all the glaucoma subpopulations examined.

Thinner corneas in African Americans may represent an important difference that needs to be considered in the management of glaucoma. The adjustment of IOP readings by corneal thickness may lead to more accurate assessment of IOP control in patients with thinner or thicker corneas. In addition, in patients with the thickest corneas, adjusted pressure reading may lead to fewer medications or a less-frequent need for surgery. Although in this report we have shown a statistically significant difference in CCT among different racial groups, it certainly does not explain all differences between the natural history of glaucoma in African Americans and Caucasians. For example, why are there 6 times as many African Americans with the disease as Caucasians? A thinner cornea alone does not address this issue. Why is the diagnosis of glaucoma made at an average age of 10 years younger in African Americans? Our data suggest that screening programs based on IOP alone would miss the diagnosis in more African Americans, on the basis of thinner corneas, and thus lead to an older age at detection. Issues that may be related to the underestimation of IOP are the faster rates of nerve and field progression and the higher incidence of irreversible blindness in African Americans. It is also conceivable that clinicians are more comfortable with lower pressures leading to progression of glaucoma in African Americans than in Caucasians, and thus these patients may not be as aggressively treated.

Although all efforts were undertaken to control for variables that might affect the data in this study, as in most clinical studies, some were beyond our control. The fact that this study was limited to male patients is a potential bias. There is no reason to believe that women would have a different distribution or average value, and no study to date, to our knowledge, has found a sex-related difference in CCT; however, this remains as a potential limitation of our study. In addition, racial backgrounds in the United States are well known to be mixed heritage. We understand that purely phenotypic and demographic categorization of patients has limitations, but we would expect this source of error to blur any significant findings rather than accentuate the outcomes. It is possible that if more precise mechanisms for assessing racial background were to be devised, the difference in CCT might be even greater than was found in this study.

Also, the Goldmann equation assumes not only corneal thickness but also corneal rigidity or elasticity. These factors may also play a role in true IOP measurement along with corneal thickness. Future studies should be devised to examine this area.

This study raises the possibility that CCT may need to be taken into account to accurately assess the actual IOP for the diagnosis and management of glaucoma in African Americans. Furthermore, it highlights the dearth of knowledge regarding CCT in virtually all populations throughout the world. This includes racial and geographic variation as well as age differences and the impact of corneal refractive procedures as they become more widely used. Measurement of CCT may evolve to play an important role in the clinical measurement of IOP and suggest that, just as one would perform baseline gonioscopy, a baseline CCT may need to be obtained for all patients with glaucoma.

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REFERENCES


A look at the past...

Arthur Jacob, 1790-1874, was the first Irish ophthalmologist and the founder of 2 eye hospitals in Dublin. He was also a professor of anatomy and physiology at the Royal College of Surgeons in Ireland. The medal shown, which was engraved by W. Woodhouse, was presented to Jacob in commemoration of eminent services rendered to the medical profession in Ireland in 1860 on the occasion of his 70th birthday. The obverse, Figure 1, depicts the bust of Jacob facing left. The reverse, Figure 2, depicts an inscription surrounding and within a tied laurel wreath.

Courtesy of: Jay M. Galst, MD, 30 E 60th St, New York, NY 10022.