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The Influence of Central Corneal Thickness on The Intraocular Pressure as Measured by Different Tonometers: Non-Contact Tonometer and Goldmann Applanation Tonometer

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Abstract

Background and objectives: Intraocular pressure plays a crucial role in maintaining vision and preventing eye disease. Beyond its importance in diagnosing and managing glaucoma, intraocular pressure measurements significantly impact the evaluation of postoperative outcomes, complications and optimize patient recovery. This study quantifies the influence of central corneal thickness on intraocular pressure using both Goldmann applanation tonometer and non-contact tonometer.

Methods: In a prospective clinical trial, the subjects were recruited from glaucoma unit at Shahid Dr. Aso Eye Hospital in Sulaimania city/Iraq between January and June 2023. Intraocular pressure measurements were conducted in a randomized sequence for both eyes using both Goldmann applanation tonometry and non-contact tonometry exploring the correlation between measured inter-tonometer discrepancies employing linear regression analysis with central corneal thickness.

Results: The study included 200 eyes of 100 consecutive patients diagnosed with either ocular hypertension or glaucoma. Mean age was 56.8 years, male (55%) and female (45%). Mean central corneal thickness was 533 ± 42 µm and mean intra ocular pressure were 14.9 ± 4.3 mm Hg, 19.3 ± 5.4 mm Hg for Goldmann applanation tonometry and non-contact tonometry, respectively. There is a statistically significant relationship between central corneal thickness and intraocular pressure by Goldmann applanation tonometry (r2 = 0.1, p 0.001) and non-contact tonometry (r^2 = 0.17, p 0.001).

Conclusion: Both Goldmann applanation tonometry and non-contact tonometry are influenced by central corneal thickness. However, non-contact tonometry was significantly more sensitive to central corneal thickness variations compared to Goldmann applanation tonometry.

Keywords: Central corneal thickness, Goldmann applanation tonometry, Intraocular pressure, Non-contact tonometry

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Introduction

Intraocular pressure (IOP) plays a crucial role in maintaining optimal vision and preventing disease. Beyond its importance in diagnosing and managing glaucoma, IOP measurements significantly impact the evaluation of postoperative outcomes following specific intraocular surgical interventions, such as cataract surgery. By closely monitoring IOP changes, we can identify potential complications early and optimize patient recovery.[1, 2] For nearly five decades, Goldmann applanation tonometry (GAT) as widely been regarded as a reliable method for intraocular pressure evaluation, grounding its principles in the Imbert–Fick principle. The Imbert-Fick principle states that the pressure inside a perfectly elastic sphere with a thin, dry wall equals the force required to applanate its surface divided by the area of applanation. This principle is crucial for understanding GAT, as it forms the theoretical basis for its operation by relating the applanation force applied to the cornea to the intraocular pressure. Noteworthy advancements in tonometry include pneumotonometry, where the central cornea is flattened by a directed jet of air rather than a prism. This technique, devoid of ocular contact and the necessity for topical anesthesia, proves particularly advantageous for community screening. Nevertheless, the abrupt air jet may startle patients, necessitating careful consideration during implementation. Central corneal thickness (CCT) emerges as a critical variable in accurate intraocular pressure assessment. Calculations by Goldmann applanation tonometer presuppose a standard central corneal thickness of 520 μm, assuming minimal normal variation. Deviations from this norm, either towards thinness or thickness, introduce the potential for underestimation or overestimation of intraocular pressure, respectively.[3] The inherent structural alterations in the cornea following refractive surgeries further compound this challenge. Seeking to overcome limitations of traditional methods like GAT, which are susceptible to central corneal thickness dependence and applanation-induced intraocular pressure changes. The objective of this study is to quantify the influence of central corneal thickness on intraocular pressure measurements using both GAT and non-contact tonometer (NCT) by comparing the accuracy and reliability of these tonometers in a diverse patient population, we aim to provide valuable insights into the limitations of current intraocular pressure measurement. Ultimately, our findings may inform the development of more personalized and accurate methods for assessing intraocular pressure, potentially improving early glaucoma detection and optimizing postoperative care.

Patients and methods

In a prospective clinical trial, the subjects were recruited from a glaucoma unit at Shahid Dr. Aso Eye Hospital in Sulaimania city/Iraq between January and June 2023. They met specific inclusion (glaucoma and ocular hypertension)/exclusion criteria (Patients with any corneal abnormality, such as scars or Fuchs dystrophy, were excluded.) and comprised a total of [100] participants. Intraocular pressure measurements were conducted in a randomized sequence for both eyes of each selected participant. Intraocular pressure was measured using both the Goldmann applanation tonometer (topical anesthetic applied, applanation plate touched gently to central cornea) and the non-contact tonometer (patient gazes at fixation target, instrument emits air puff). This ensured that each eye received both types of measurements. The CCT was measured using optical biometer (Zeiss; IOL Master 700). The IOP as measured in all patients using GAT (Keeler 2009) and NCT (CT-80 non-contact tonometer; Topcon Corp., Tokyo,

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Japan). All variables were measured twice and the means were calculated, the subsequent analysis delved into exploring the correlation between measured intraocular pressure values and inter-tonometer discrepancies, employing linear regression analysis to discern any discernible relationships with central corneal thickness. This study's methodological approach, fosters a comprehensive investigation into the intricate interplay between central corneal thickness and the accuracy of intraocular pressure measurements obtained through these distinct tonometric modalities. Ethical approval taken from Kurdistan Higher Council of Medical Specialties (KHCMS)/Research Protocol Ethics Committee), issued in 26/11/2023 by issue number (9). For statistical analysis a p-value of less than 0.05 was considered statistically significant. To assess the relationship between intraocular pressure and central corneal thickness, Pearson's correlation coefficients were calculated for both GAT and non-contact tonometer measurements.

Results

The study included 100 consecutive patients diagnosed with either ocular hypertension or glaucoma. This resulted in a total of 200 eyes for analysis, as some participants had both conditions in both eyes. The mean age of participants is 56.8 year ranging from (18-82) years. Fifty-five percent of them (105 eyes) being male and the remaining forty-five (95 eyes) female. The recorded mean central corneal thickness was 533 ± 42 µm, demonstrating a range from 448 to 676 µm.

In terms of intraocular pressure measurements, the mean readings and standard deviations were shown in Table (1).

Table (1): Mean intraocular pressure measurement with standard deviation by different tonometry.

Tonometry method	Mean Intraocular pressure (mmHg)	Standard deviation (SD)
Goldman applanation	14.9	4.3
Non-contact tonometry	19.3	5.4

Goldman applanation tonometer readings on average 4.5 mm Hg higher than non-contact tonometer. There is a statistically significant relationship between central corneal thickness and intraocular pressure measurement by GAT (r2 = 0.1, p 0.001) and non-contact tonometry (r2 = 0.17, p 0.001) respectively as shown in Figure (1, 2).

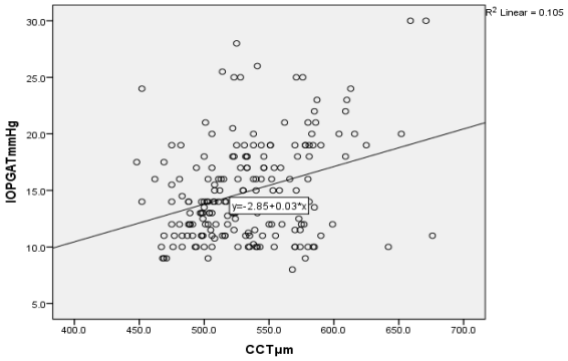

Figure (1): This figure describes central corneal thickness correlation with intraocular pressure using GAT.

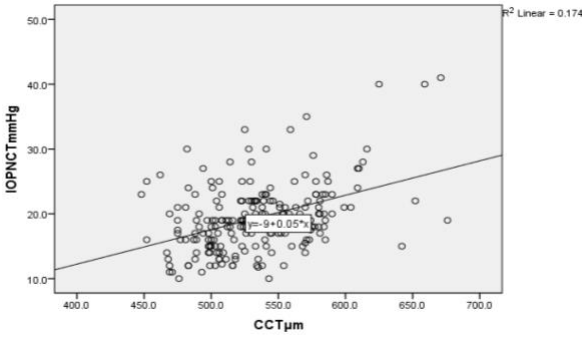

Figure (2): This figure describes central corneal thickness correlation with intraocular pressure using non-contact tonometry.

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Discussion

Intraocular pressure remains a continuous risk factor for glaucoma development, despite not always exceeding the statistically normal range of [e.g., 10-21 mmHg] in primary open-angle glaucoma patients. This lack of absolute correlation presents a significant challenge, further complicated by the existence of ocular hypertension. Defined by elevated IOP without glaucomatous visual field or optic disc damage, ocular hypertension affects a substantial proportion of individuals with only a subset progressing to glaucoma development. This highlights the limitations of using intraocular pressure alone to predict glaucoma risk and underscores the need for additional diagnostic tools. [4] GAT historically considered the leading method for intraocular pressure measurement, presents limitations such as dependence on central corneal thickness, applanation-induced intraocular pressure changes, and potential risks of corneal abrasions, infection and discomfort for patients. These limitations have motivated the exploration of alternative methods like non-contact tonometer's, seeking to enhance the accuracy and reliability of intraocular pressure assessment and the requirement for local anesthesia renders it less favorable for certain patient populations. Goldmann applanation tonometer suffers from accuracy limitations due to factors like central corneal thickness, curvature, axial length, and structural rigidity. These factors can introduce variations in IOP readings. This poses significant challenges for its effectiveness in mass screening programs, where diverse patient populations and cost-effectiveness are crucial considerations.[5-8] non-contact tonometer offers several user-friendly advantages, particularly in community screening programs. Unlike GAT, it employs an air puff to measure corneal deformation caused by a controlled air pressure, eliminating the need for direct corneal contact. This significantly reduces the risk of corneal abrasion and infection, making it highly suitable for mass screenings with diverse populations.[9] However, challenges arise in patients with fixation loss, and non-contact tonometry has been noted to show lower readings at lower intraocular pressure and higher reading at higher intraocular pressure.[10] Our study found that GAT measurements on average 4.5 mmHg higher ($p < 0.001$) than non-contact tonometry readings. This aligns with observations by Moseley et al, who reported that non-contact tonometry tends to overestimate intraocular pressure at low pressures (e.g., below 9 mmHg) and underestimate them at higher pressures (e.g., above 19 mmHg) compared to GAT. While our findings show a similar trend, the magnitude of overestimation/underestimation appears slightly smaller in our study population.[11] Meta-analysis results for central corneal thickness in adult human eyes indicated a slightly higher mean value (535 ± 31 μm) compared to our study's result (533 ± 42 μm), possibly influenced by the shift towards ultrasound pachymetry in literature reports.6 This study identified a strong, positive correlation between central corneal thickness and intraocular pressure with a significantly greater influence of central corneal thickness on intraocular pressure measurements obtained by non-contact tonometry compared to GAT This aligns with Wollensak et al.'s explanation, where the prolonged flattening time during Goldmann tonometry measurements compared to the instantaneous applanation in non-contact air puff likely leads to distinct interactions with corneal biomechanics, influencing the observed relationships.[12]

Conclusion

This study demonstrates that both GAT and non-contact tonometry are influenced by central corneal thickness. However, non-

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contact tonometry was significantly more sensitive to central corneal thickness variations compared to GAT. This highlights the crucial importance of considering individual central corneal thickness values, when interpreting intraocular pressure measurements, especially for accurate glaucoma diagnosis and management in patients with diverse corneal characteristics.

Conflict of interest

There is nothing to declare.

Acknowledgment

There is nothing to declare.

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