J Nepal Health Res Counc 2025 Jan-March; 23 (66): 94-100

Central Corneal Thickness and Intraocular Pressure Measured with Goldmann Applanation Tonometer among Patients with Normal Intraocular Pressure

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ABSTRACT

Background: Intraocular pressure measurement is one of the important and commonly performed examination in Ophthalmology. Goldmann applanation tonometer has been gold standard for measurement of Intraocular pressure. Intraocular pressure measurement is known to be affected by Central corneal thickness. It has been stated that thinner cornea leads to false low Intraocular pressure while thicker cornea leads to false high Intraocular pressure interpretations.

Methods: A total of 920 patients of forty and above years with no any anterior segment pathology like corneal diseases, corneal oedema and opacities, uveitis, ocular surgery, ocular trauma or evidence of glaucoma were included. This was cross sectional, descriptive, hospital based study. Ultrasonic pachymeter was used to measure Central corneal thickness and Goldmann applanation tonometer was used to measure Intraocular pressure. A correction factor was applied and corrected Intraocular pressure values were calculated.

Results: The mean Central corneal thickness was 538.70 ± 29.17 µm and Intraocular pressure was 14.72 ± 2.58 mmHg. The mean Central corneal thickness of the females was thinner and mean corrected Intraocular pressure was higher than male. There were statistical significant differences in the mean Central corneal thickness and corrected Intraocular pressure between genders (p= 0.029, p=0.04) respectively. There was a significance difference in mean Central corneal thickness between different age groups (p= <0.001). Corrected Intraocular pressure is negatively correlated with Central corneal thickness (r= - 0.49, p= <0.001). In this study there was a significant association between Central corneal thickness and Intraocular pressure, age, gender and refractive error.

Conclusions: A thick cornea leads to an overestimation of Intraocular pressure while thin cornea leads to an underestimation of Intraocular pressure. We recommend that Intraocular pressure measurement should be associated with a pachymetry correction to avoid inaccurate readings.

Keywords: Central corneal thickness; corrected intraocular pressure; intraocular pressure.

INTRODUCTION

GAT is considered as the gold standard for measuring IOP in clinical practice. Measurements of IOP with GAT are affected by CCT, as thinner corneas underestimate and thicker corneas overestimate the IOP value.[1] A thicker cornea requires greater force to applanate and a thinner cornea is easily flattened. Depending on the thickness, there is a need to adjust IOP values taking CCT into consideration as it may change the treatment decisions and affect patient outcomes.[2] The GAT is based on the Imbert-Fick principle, which states that the pressure within a sphere is approximately equal to the external force needed to flatten a portion of the sphere divided by the area of the sphere that is flattened.[3] The average CCT is between 520µm and 540µm, however, it may range from 470 to 630 µm. CCT is an important parameter in the diagnosis and treatment planning of many ocular conditions. So the objective of this study was to determine the distribution of CCT and its association with IOP, age, gender, ethnicity, refractive error and systemic diseases.

METHODS

The study was conducted in Ophthalmology OPD at Nepal Medical College from July 2023 to June 2024. This was a cross-sectional, based study. Sample size

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was taken using the formula Finite size n= n_0 / 1+n_0 / N = 14266/1+14266/950= 14266/1+15= 14266/16=891. Sampling technique was consecutive so total 920 participants were included in this study. Informed and verbal consent was taken from each participant. Ethical clearance was taken from Nepal Medical College-Institutional Review Committee (NMC-IRC Ref. No. 16-080/081). All patients ≥ 40 years without any evidence of any anterior segment pathology like corneal diseases, corneal opacities, uveitis, and glaucoma attending Ophthalmology OPD between 9 am to 12 pm were included to reduce the bias of time-based variation of IOP. Patients with evidence of any ocular pathology like corneal diseases, corneal oedema and opacities, uveitis, patients on antiglaucoma drugs, history of glaucoma, glaucoma suspects, ocular hypertension , history of intraocular surgery or trauma were excluded. All patients received an ophthalmic examination including visual acuity, anterior segment by slit lamp examination and evaluation of posterior segment using +90 Diopter lens with the slit lamp. IOP was measured by GAT during morning hours to reduce the bias of time-based variation of IOP. CCT was measured with Nidek ultrasonic contact pachymeter. Patients was instructed to look straight ahead at a fixation target located at 3 m and asked to blink before starting the procedure to avoid dryness of cornea. The probe tip was gently positioned to touch the patient's cornea at its centre. The pachymeter probe was kept perpendicular to the apex of the cornea. The mean value of three consecutive measurements was recorded for the statistical analysis. Corrected IOP was recorded after doing corneal ultrasonic pachymetry. Correction of IOP was done based on Modified Ehler's formula.[4] Measured IOP need to be corrected because the GAT is calibrated for corneas with a CCT value of 520 µm.[5] Corneas with CCT <520µm was considered as thin, 520 to 560µm as normal and >560µm was considered as thick corneas.[6]

Data was statistically analyzed using software SPSS version 17. Quantitative variables were reported as mean with standard deviation. One way Analysis of variance (ANOVA) was applied for comparing difference of means between variables. Paired sample t test was used to compare between variables. Pearson coefficient correlation (r) was used to determine the correlation between IOP and CCT. P value <0.05 was considered as significant.

RESULTS

A total of 920 patients were included in the study. The mean age was 55.13 ± 11.04 years with a range of 40 to 98 years (Table 1). The mean age of male was 56.59 ±11.52 years (40-87 years) and female was 54.31 ± 10.68 years (40-98 years). Younger participants (40 to 50 years) had mean CCT of 543.71 ± 28.39 µm, 51-60 years had CCT of 539.37 ± 29.02 µm, 61-70 years had 535.08 ± 27.19 µm, 71- 80 years had 524.45 ± 32.59 µm, 81-90 years had 517.25 ± 23.13 µm and 91-100 years had 505.00 ± 0 µm. We noted that younger participants presented with thicker CCT than older. As the age increases the CCT decreases in thickness which was statistically significant (F= 8.50, p= < 0.001) (Table 2). The mean uncorrected IOP in age group 40 to 50 was 14.63 ± 2.20 mm Hg and in age 51-60 was 14.34 ± 2.43 mm Hg which showed significant difference between age and uncorrected IOP (F=5.53, p=<0.001). However, there was no significant difference between age and mean corrected IOP (F= 0.51, p=0.76) (Table 2). This study revealed that there was significant difference in mean CCT and uncorrected IOP with age but no significant difference in mean corrected IOP with age. In present study, regarding ethnicity Tibetomongolian were 531 (57.7%) and 389 (42.3%) were Indoaryan. The mean CCT in Tibetomongolian was 538.86 ± 28.04 µm and mean IOP was 14.78 ± 2.57 mm Hg. Similarly, in Indoaryan the mean CCT was 538.50 ± 30.67 and IOP was 14.64 ± 2.59mm Hg which showed no significant difference in mean CCT and IOP with ethnicity (F= 0.034, p = 0.853 and F= 0.672, p=0.413).

Out of 920 patients, the mean CCT in right eye (RE) was 538.70 ± 29.17 µm (range 450 to 660 µm) (Table 1) and in the left eye (LE) was 539.82 ± 29.12 µm (range 450 to 656 µm) which had difference of 1.1µm between two eyes.

In present study, 330 (35.9%) were males and 590 (64.1%) were female. The mean CCT in the RE among males was 541.51 ± 29.04µm (range 451 to 660µm) and among females the mean CCT was 537.14 ± 29.15µm (range 450 to 650µm). There was a statistically significant difference in the mean RE CCT between males and females (F = 4.76, p =0.029) (Table 3). The mean CCT among males in LE was 542.29 ± 29.30µm (range 450 to 656µm) and in female was 538.44 ± 28.96µm (range 450 to 647µm) which showed significant difference in mean LE CCT between males and females (F=3.72, p=0.05). We noted that female had thinner CCT in compare to male in both eyes.

The mean uncorrected IOP was 14.33 ± 2.32 mmHg in RE (range 8 to 22 mmHg) and was 14.54 ± 2.28 mmHg in LE (range 9 to 22 mmHg). The mean corrected IOP of RE was 14.72 ± 2.58 mmHg (range 7 to 24mm Hg)

and LE was 14.86 ± 2.57 mm Hg (range 7 to 23 mm Hg) (Table 1). There was a statistically significant difference between uncorrected and corrected mean IOP in RE (t= -5.8, p=<0.001) and LE (t= -4.5, p=< 0.001) respectively. This study showed low negative correlation between CCT and corrected IOP (r= - 0.49, p= <0.001) and low positive correlation between CCT and uncorrected IOP (r= 0.32, p=<0.001).

The mean corrected IOP in the RE among males was 14.50 ± 2.63 mm Hg (range 7 to 22 mm Hg) and among females the mean corrected IOP was 14.85 ± 2.54 mm Hg (range 9 to 24 mm Hg). There was a statistically significant difference in mean corrected IOP between males and females (F= 4.07, p=0.044) (Table 3). In LE among male the mean corrected IOP was 14.60 ± 2.61 mm Hg (range 7 to 21 mm Hg) and in female was 15.0 ± 2.54 mm Hg (range 9 to 23 mm Hg) which showed statistically significant difference in mean corrected IOP among male and female (F= 4.99, p=0.026) in LE (Table 3). However there was no significant difference in mean uncorrected IOP and gender (F=0.05, p=0.81). In female corrected IOP was higher than male in both RE and LE. There was a significant difference in mean CCT and corrected IOP between male and female participants.

Although the observations were made in both eyes of all participants, the RE of each subject was included for statistical analysis as very similar results were obtained when analysis was done for LE.

Out of total 920 participants, 229 (24.9%) had thin CCT (< 520 µm), 502 (54.6%) had average CCT (520 to 560 µm) and 189 (20.5%) had thick CCT (> 560 µm). Based on CCT readings, 307 (33.4%) had the IOP reduced while 464 (50.4%) had their IOP increased and 149 (16.2%) had the same IOP. IOP adjustment ±1mmHg was done in 418 (45.43%), ± 2mmHg was done in

148 (16.08%), ± 3mmHg in 97 (10.54%), ± 4mmHg in 78 (8.47%), ±5 mmHg in 13 (1.41%), ± 6mmHg in 15 (1.63%) and ±7 mmHg in 2 (0.21%) participants. The mean uncorrected IOP was higher in individuals with thicker cornea and lower in thinner cornea and after correction the mean IOP was lower in thicker cornea and higher in thinner cornea which was statistically significant (p=<0.001) (Table 4). There was a statistically significant difference in mean CCT and corrected IOP (F= 46.45, p=<0.001) (Table 5).

Mostly 355 (38.6%) presented with vertical CDR of 0.25 to 0.3:1 followed by 301 (32.7%) with CDR ≤ 0.2:1. The mean CDR was 0.3:1 ± 0.12 (range 0.1:1 to 0.6:1) (Table 1). There was no statistically significant difference in mean CCT, uncorrected IOP and corrected IOP with vertical CDR (F= 0.86, p=0.48), (F= 1.48, p=0.20) and (F= 1.23, p= 0.29) respectively.

The mean CCT in simple myopia, simple myopic astigmatism and compound myopic astigmatism was found to be 534.73 ± 27.97 µm, 540.58 ± 30.73 µm and 538.03 ± 30.70 µm respectively. In simple hyperopia, simple hyperopic astigmatism and compound hyperopic astigmatism the mean CCT was 531.92 ± 27.66 µm, 563.0 ± 47.63 µm and 546.80 ± 18.75 µm respectively and in emmetropic the mean CCT was 541.08 ± 28.88 µm. There was significant difference in mean CCT and different types of refractive error (F=2.53, p=0.019). However there was no significant difference in mean uncorrected and corrected IOP with refractive error (F=1.28, p= 0.263) and (F=1.49, p=0.177) respectively.

In current study, 399 (43.4%) had no systemic illness, 298 (32.4%) had hypertension, 130 (14.1%) had diabetes, 88 (9.6%) had both hypertension and diabetes, 3 (0.3%) had thyroid disease and 2 (0.2%) had COPD. The mean CCT in diabetic patients was 543.0 ± 29.95 µm, hypertension was 537. 99 ± 31.29 µm, who had both HTN and DM was 541.37 ± 26.85 µm and in patients without any systemic disease was 537.17 ± 27.77 µm. There was no significant difference in mean CCT and IOP in relation to the systemic diseases (F=1.32, p= 0.253) (F= 1.32, p=0.250) respectively.

Table 1. Demographic characteristics of the participants.

Characteristics	Mean ± Standard Deviation
Age (years)	55.13 ± 11.04 years (range 40-98 years)
CCT (µm)	538.70 ± 29.17µm (range 450-660µm)
Uncorrected IOP (mmHg)	14.33 ± 2.32mmHg (range 8 - 22 mmHg)
Corrected IOP (mmHg)	14.72 ± 2.58mmHg (range 7 - 24mmHg)
Vertical CDR	0.3:1 ± 0.12:1 (range 0.1:1-0.6:1)

Table 2. Age wise comparison of mean CCT and IOP.

Age group (years)	N	Mean CCT (µm)	Uncorrected Mean IOP (mmHg) ± S.D	Corrected Mean IOP (mmHg) ± S.D
40-50	377	543.71 ± 28.39	14.63 ± 2.20	14.72 ± 2.46
51-60	266	539.37 ± 29.02	14.34 ± 2.43	14.67 ± 2.80
61-70	190	535.08 ± 27.19	14.18 ± 2.24	14.80 ± 2.44
71-80	70	524.45 ± 32.59	13.15 ± 2.22	14.55 ± 2.57
81-90	16	517.25 ± 23.13	13.56 ± 2.85	15.43 ± 3.14
91-100	1	505.00 ± 0	14.00 ± 0	17.00 ± 0
F		8.50	5.53	0.51
P value		<0.001	<0.001	0.76

Table 3. Gender wise comparison between mean CCT and corrected IOP between RE and LE.

Gender	RE mean CCT µm ±SD	LE mean CCT µm ±SD	RE corrected IOP mmHg ± SD	LE corrected IOP mmHg ± SD
Male	541.51 ± 29.04 (range 451-660)	542.29 ± 29.30 (range 450-656)	14.50 ± 2.63 (range 7-22)	14.60 ± 2.61 (range 7 to 21)
Female	537.14 ± 29.15 (range 450-650)	538.44± 28.96 (range 450-647)	14.85 ± 2.54 (range 9-24)	15.0 ± 2.54 (range 9-23)
F	4.76	3.72	4.07	4.99
P value	0.029	0.05	0.044	0.026

Table 4. Comparison of mean uncorrected and corrected IOP with CCT.

IOP	CCT µm	N	Mean IOP ± SD (mmHg)	F value	P value
Uncorrected IOP	< 520 µm	229	13.39 ± 2.18	54.53	<0.001
	520-560 µm	502	14.26 ± 2.23		
	>560 µm	189	15.64 ± 2.12		
Corrected IOP	< 520 µm	229	16.40 ± 2.33	94.92	<0.001
	520-560 µm	502	14.49 ± 2.38		
	>560 µm	189	13.31 ± 2.28		

Table 5. Comparison of mean CCT with corrected IOP.

Corrected IOP (mmHg)	N	Mean CCT (µm) ± SD	F value	P value
≤ 10 mmHg	47	564.36 ± 22.93	46.45	<0.001
11-12mmHg	141	556.38 ± 27.76		
13-14mmHg	224	545.80 ± 26.27		
15-16mmHg	275	535.30 ± 25.84		
17-18mmHg	172	523.77 ± 22.48		
19-20mmHg	52	512.46 ± 27.27		
≥ 21mmHg	9	492.33 ± 26.59		

Table 6. Comparison of CCT and IOP in various Nepalese studies.

Study	Type of study	Participants, n (eye)	Mean CCT±SD	CCT range	Mean IOP(mmHg)
Thapa SS[12] et al	Population based	2330 (right eyes)	539 ± 34µm	472-606µm	13.33±2.26
Godar ST[13] et al	Hospital based	152 (right eyes)	538 ± 32µm	530-554µm	12.39±2.34
Agrawal L[14] et al	Hospital based	382 (both eyes)	530.06± 23µm	500-549µm	17.24±2.57
Present study	Hospital based	920 (right eyes)	538 ± 29µm	450-660µm	14.72 ±2.58

DISCUSSION

The variation in CCT was not taken into consideration as GAT assumes a standard 520 µm for all cornea.[7] When all else is equal, a CCT above this level theoretically will overestimate the true tension and vice versa. This has developed the correction factors to adjust applanation IOP based on deviation from normal CCT by Ehlers et al[4], Doughty and Zaman[8] as well as Orssengo and Pye.[9] CCT can affect the accuracy of IOP measurements by applanation tonometry.[4] Studies on CCT and its impact on applanation tonometry have shown that CCT does affect the accuracy of the IOP reading, with thinner corneas giving a falsely low reading while thicker corneas yield a falsely high reading.[10] Previous studies have revealed the positive relationship between CCT and IOP among adults. Every 10 µm increase in CCT leads to 0.15-1.0 mmHg increase in IOP.[11]

In present study the mean CCT was 538.70 ± 29.17 µm ranging from 450 to 660 µm which was similar to Thapa SS et al [12] and Godar ST et al[13] studies whereas CCT was 530. 06 ± 23µm in Agrawal L study[14] which was slightly different from this study (Table 6). In normal eyes the mean CCT was very similar to our result which was 536.6 ± 28.9 in Adhikary P et al study.[15] In various other studies the mean CCT was similar 539 ± 32 in Day AC[16], 531.71 ± 21µm in Kamath et al study.[17] In some studies the mean CCT was lesser in compare to our results, 511 ± 34 in Lingam V[18], 514 ± 33µm in Nangia V[19] and 522 ± 37µm in Chebil A study.[20]

In this study, the mean CCT among males was 541.51 ± 29.04µm and among females was 537.14 ± 29.15µm. There was a statistically significant difference in the mean CCT between gender (F = 4.76, p =0.029). We noted that male had thicker CCT in compare to female. The mean CCT among males was 540.3 ±22.7µm and among females 524.6 ±17.3µm, which was statistically significant (p<0.05) in Kamath M et al study.[17] Similarly, CCT in males (515.6±33.8µm) was significantly (*P* = 0.0001) greater than females (508.0±32.8µm) in Lingam V et al.[18] Males have thicker corneas compared to females.[21, 22] However in some studies there was no significant association between gender and CCT.[13, 20]

We noted that younger participants presented with thicker CCT than older. As the age increases the CCT decreases in thickness which was statistically significant (F= 8.50, p= < 0.001). CCT showed an average decrease of 2.67µm per decade increase in age.[12] CCT decreased with increasing age was noted in some other studies as well.[13, 19, 23] However, in some studies there was no association between CCT and age.[20, 22,24] The density of keratocytes decreases with age, so the collagen fibers are broken down. These changes are the most likely reasons for the observed reduction in CCT with age.[25]

In this study, 307 (33.4%) had the IOP reduced while 464 (50.4%) had their IOP increased and 149 (16.2%) had the same IOP after correction. The mean uncorrected IOP was higher in individuals with thicker cornea and lower in thinner cornea and after correction the mean IOP was lower in thicker cornea and higher in thinner cornea which was statistically significant (p=<0.001). Thick cornea gives falsely high IOP and thin cornea gives low IOP. IOP readings increased significantly (P<0.001) with higher CCT.[19] CCT and IOP are directly proportional to each other as increase in CCT leads to an increase in IOP.[21] A thick cornea leads to an overestimation of IOP while thin cornea leads to an underestimation of IOP.[26] An adjustment of IOP values by a correction factor is required for many patients in Eballe AO et al study.[27]

In present study, the mean corrected IOP of RE was 14.72 ± 2.58 mmHg and LE was 14.86 ± 2.57 mm Hg which was closer to the value obtained by Thapa SS[12] which was 13.33 ±2.26 mmHg. In other studies, the mean IOP was 15.61 ± 2.68mmHg[23] and 13.01 ± 2.97mmHg in both eyes[27] which was closer to our values. In contrast to our results, in Godar ST et al[13] the IOP was lower 12.39 ± 2.34mmHg and in Agrawal L et al[14] it was higher 17.24 ± 2.57mmHg.

In this study, there was a statistically significant difference between uncorrected and corrected mean IOP in RE (t=-

5.8, p=<0.001) and LE (t= -4.5, p=< 0.001) respectively. There was a statistically significant difference between IOP measurements when corrected with pachymetry than when it is uncorrected in Awoyesuku E study.[28] This study showed low negative correlation between CCT and corrected IOP (r= - 0.49, p= <0.001) and low positive correlation between CCT and uncorrected IOP (r= 0.32, p= <0.001). Similar to our results, a significant negative correlation was found between corneal thickness and corrected IOP values.[29] This study has similarity with other studies where IOP was significantly correlated with CCT.[13,14,18,22,23,26] However Nemisure B study didn't find significant correlation between CCT and IOP.[30]

In various studies there was variation in CCT of different ethnic populations, but in this study there was no variation in CCT in different ethnicity (p=0.85). No significant association was seen between central corneal thickness and ethnicity (p=0.19).[13, 23]

In this study CCT was significantly associated with refractive error (p=0.01) but in some studies there was no statistical association between CCT and refractive error.[19, 20]

This study showed no significant association between CCT and vertical CDR (p= 0.48) and systemic diseases (p=0.25). Similar to our study, CCT was not significantly associated with systemic factors but CCT was greater in larger vertical CDR which was statistically significant.[24] This was hospital based study with limited number of participants. Inter observer variability might affect the findings.

CONCLUSIONS

The mean CCT of the females was thinner than that of the males and the mean corrected IOP was slightly higher than male. There were statistical differences in the mean CCT and IOP between genders. As the age increases, thinner was the CCT. There was significance difference in mean CCT between different age groups. There was a statistically significant correlation between IOP and CCT. There was no association between CCT and IOP in different vertical CDR, ethnicity and systemic diseases. So, this study concluded that CCT and corrected IOP measurement can influence in the management of the patients. CCT is one factor that is necessary to adjust IOP to achieve a more accurate IOP and thus avoid under and over treatment of the patients. Implementation of routine central corneal thickness measurement could change in patient management.

ACKNOWLEDGMENTS

We express our gratitude towards patients for their participation and department of Ophthalmology for the help during this study.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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