COMPARISON OF INTRAOCULAR PRESSURE (IOP) ESTIMATION BY PERKINS TONOMETER DONE BY OPHTHALMIC ASSISTANT AND GOLDMANN APPLANATION TONOMETER DONE BY OPHTHALMOLOGIST

DISSERTATION

SUBMITTED TO THE TAMILNADU

DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI

In partial fulfilment of
the requirements for the degree of

MS Ophthalmology

BRANCH – III

THE TAMILNADU
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CERTIFICATE

This is to certify that this dissertation entitled **"COMPARISON OF INTRAOCULAR PRESSURE (IOP) ESTIMATION BY PERKINS TONOMETER DONE BY OPHTHALMIC ASSISTANT AND GOLDMANN APPLANATION TONOMETER DONE BY OPHTHALMOLOGIST "** submitted to the Tamil Nadu Dr MGR Medical University is a bonafide work done by **Dr.LAKSHMI MALAR.R ,** under our guidance and supervision in the Glaucoma department of Aravind Eye Hospital and Post Graduate Institute of Ophthalmology, Madurai during the period of his Postgraduate training in Ophthalmology for May 2018 – May 2020.

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DECLARATION

I, **DR.LAKSHMI MALAR.R** hereby declare that this dissertation entitled, "**COMPARISON OF INTRAOCULAR PRESSURE (IOP) ESTIMATION BY PERKINS TONOMETER DONE BY OPHTHALMIC ASSISTANT AND GOLDMANN APPLANATION TONOMETER DONE BY OPHTHALMOLOGIST"** is being submitted in partial fulfilment for the award of MS degree in Ophthalmology by The Tamilnadu Dr.MGR Medical University in the examination to be held in May 2020. I declare that this dissertation is my original work and has not formed the basis for the award of any other degree or diploma award to me previously.

Place:

Date:

Dr. LAKSHMI MALAR.R

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Date –

Place– Madurai **Dr. Lakshmi Malar.R**

CONTENTS

PART I

INTRODUCTION

Glaucoma refers to a group of disorders that have in common a characteristic optic neuropathy associated with visual field loss with elevated intraocular pressure(IOP) as one of the primary modifiable risk factor.

Glaucoma is one of the second most common cause of blindness worldwide.WHO has reported thatdue to glaucoma around4.5 million people are blind.Glaucoma is the leading cause of irreversible blindnessinIndiawith 12 million people affected and nearly 1.2 million people blind from the disease.Majority of Glaucoma cases approximately 90 % of remains undiagnosed in the community[1.]

Jacob A. et al, in their study conducted in Vellore, found that the prevalence of POAG in South India were 4.1 per 1000.

The Andhra Pradesh eye disease survey (APEDS) reported a prevalence of 1.62% for POAG, 0.32% for OHT, and 0.71% for manifest PACG in those 30 years of age or older.

Aravind comprehensive eye survey (ACES) reported a prevalence of 1.7% for POAG and 0.5% for primary angle closure glaucoma (PACG).

George et al have reported that there are approximately 11.2 million persons aged 40 years and older with glaucoma in India. An additional 28.1 million people have Ocular Hypertension , Primary Angle Closure Suspect, or Primary Angle Closure. Every eighth individual or nearly 40 million of the estimated 309 million people, aged 40 years or older in the country have glaucoma or are at risk of developing glaucoma.

Access to a comprehensive eye examination in India is limited by insufficient trained human resources and inequitable distribution of professionals[2].At present ophthalmologists bear much of the burden of providing comprehensive eye care in India.The ophthalmologist to population ratio in urban India is 1:25,000[3].However, in the rural areas of India, the ratio is close to 1:219,000 population.Seventy percent of the ophthalmologists are located in urban areas where approximately 23% of the population of India reside[4].This discrepancy indicates the pressing need for rural eye care professionals.It is imperative to establish a cadre of eye care professionals/ophthalmic assitants to work in conjunction with ophthalmologists to deliver comprehensive eye care. To eliminate vision impairment and avoidable blindness, adequate standardized and regulated training of eye care personnel is essential.

In Barrett,C.(2017) Optometric case finding for glaucoma in Ireland: an investigation of current practice patterns,Chapter 3 and 4 report on a national survey. The results show that optometrists are well equipped to carry out the traditional glaucoma case finding triad.Chapter 7 results highlight key areas for clinical practice reforms such as uptake of Goldmannapplanation tonometry, pacymetry and disc size measurement by optometrists. This will allow for better use of resources in secondary care and more detailed referral information can facilitate more accurate triage in ophthalmology services[5].

Since Intraocular Pressure is the only modifiable factor of Glaucoma and justifiably the primary target of glaucoma management[6],training of Midlevel Ophthalmic assistant in measuring reliable intraocular pressure reduces the burden of Ophthalmologists to address the issues of avoidable vision impairment and blindness due to Glaucoma.

The purpose of this study is therefore to assess the reliability of Intraocular pressure measurement by Midlevel Ophthalmic assistant compared to Ophthalmologists.

INTRAOCULAR PRESSURE (IOP)

The intraocular pressure (IOP) in the population is normally distributed with a skew towards right. The mean IOP in normal adult populations is estimated to be 15-16 mmHg, with a standard deviation of nearly 3.0 mm of Hg[1-10]. Normal IOP has been defined as two standard deviations above the normal IOP, i.e. 21 mmHg, and any IOP above this level is considered to be elevated. The IOP level is a major risk factor for the development of glaucoma and its progression. For example, the risk of having glaucoma for those with Intraocular Pressure of 26 mmHg or greater is estimated to be 12 times higher than that for those with IOP within the normal range[1]. IOP diurnal variations can be substantial and are larger in glaucoma patients than in healthy individuals. Evaluating the IOP at different times of the day are useful in selected patients[7-16.]

GOLDMANN EQUATION

Goldmann equationsummarises the relationship between the factors influencing aqueous humor dynamics and IOP in the normal eye . [17].It is represented as

$$P = \left(\frac{F}{C}\right) + P$$

Where P represents IOP in millimeters of mercury (mm Hg)

F representsthe rate of aqueous formation in microlitres per minute(microlitre/min),

C represents the facility of outflow in microlitres per minute per mm of mercury (microlitre/min/mmHg).

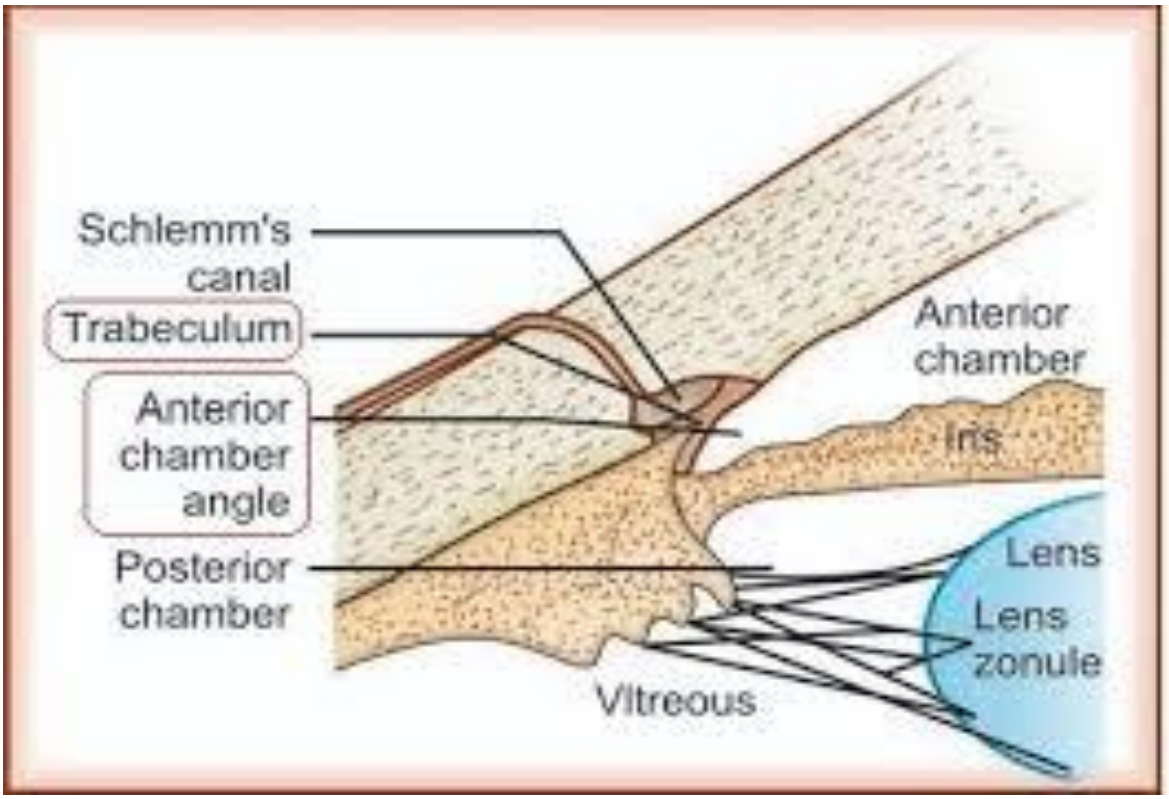
Pv represents the episceleral venous pressure in millimeters of mercury,Resistance to outflow (R) is the inverse of facility (C)[28]

Intraocular pressure (IOP) measurement plays an important role in any comprehensive ophthalmic examination, and is particularly important in any patients above 40 years and in patients at risk of developing glaucoma. IOP is the most important risk factor for development of glaucomatous optic neuropathy. It is the best evidenced target for management[18–23].Goldmannapplanation tonometry (GAT) is regarded as the gold standard method for the measurement of IOP.[24] It is recommended as part of the UK National Institute for Health and Clinical Excellence (NICE) guidelines Glaucoma.[25]

Perkins hand-held tonometry is a hand held applanation tonometry which is useful in measuring intraocular pressure in screening, or where a person may have difficulty being examined on a slit lamp (for example with curvature of the spine).Multiple studies revealed that Perkins Tonometer is equivalent to slit lamp mounted GAT[26].

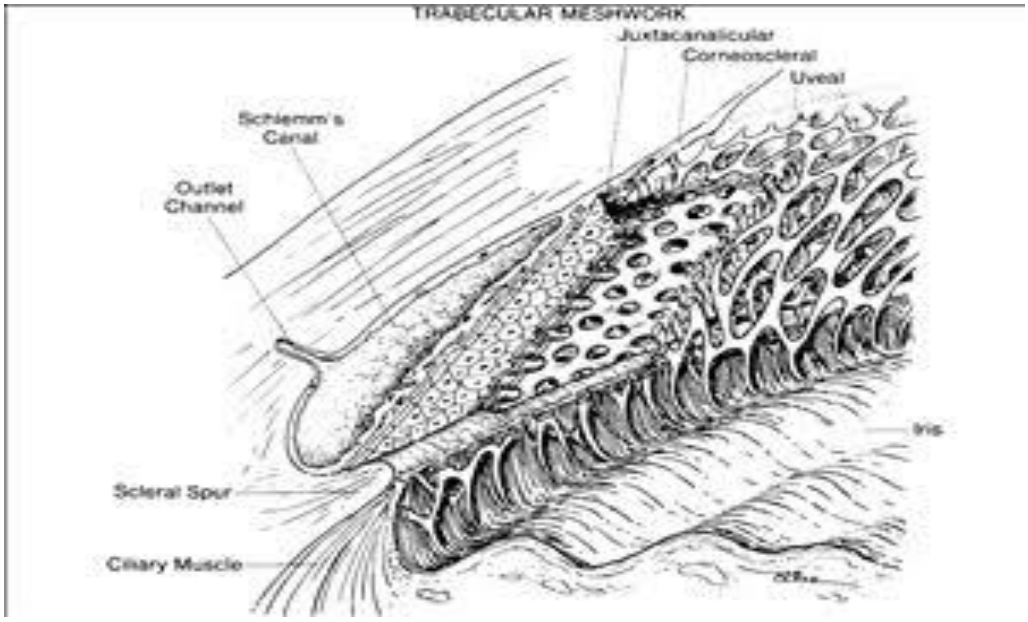
ANATOMY

The two main structures related to aqueous humour dynamics are the ciliarybody,which is the site for aqueous humor production,and the limbalregion,which includes the trabecular meshwork, the principal site of aqueous humor outflow.



The limbus is the transition zone between the cornea and the sclera.On the inner surface of the limbus is an indentation,thescleralsulcus,which has a sharp posterior margin,the sclera spur,and a sloping anterior wall that extends to the peripheral cornea.

A sievelikestructure,the trabecular meshwork,bridges the sclera sulcus and converts it into a tube,called Schlemm's canal.Trabecular meshwork inserts into the peripheral cornea and a ridge is created,known as Schwalbe's line.Schlemm's canal is connected by intrascleral channels to the episcleral veins.The trabecular meshwork, Schlemm'scanal ,and the intrascleral channels comprise the main route of aqueous humor outflow.



The ciliary body attaches to the scleral spur and create a potential space,thesupraciliary space, betweenciliary body and the Sclera.On cross section,theciliary body has the shape of a triangle,and the ciliary processes (the site of aqueous humor production) occupy the inner most and anterior most portion of this structure in the region called the pars

plicata. The pars plicata region is also composed of smooth muscle, which serves the important functions of accommodation and uveoscleral outflow.The ciliary processes consist of 70 to 80 radial ridges (majorciliary processes), between which are interdigitated an equal number of smaller ridges (minor or intermediate ciliary processes). The posterior portion of the ciliary body, called the parsplana has a flatter inner surface and joins the choroid at the oraserrata.

The iris inserts into the anterior side of the ciliary body,leaving a variable width of the latter structure visible between the root of the iris and sceleral spur, referred to as the cilary body band.The lens is suspended from the ciliary body by zonules and separates the vitreous. posteriorly from the aqueous humor anteriorly. The iris separates the aqueous humor compartment into a posterior and an anterior chamber,and the angle formed by the iris and the cornea is called the anterior chamber angle[27].

AQUEOUS HUMOR DYNAMICS

Aqueous humor is produced by the ciliary processes gets collected in the posterior chamber and flows through the pupil into the anterior chamber. Aqueous humor exit the eye by passing through the trabecular meshwork and into Schelmm's canal and draining into venous system via various routes[28].

AQUEOUS HUMOR FORMATION

Aqueous humor is a biological process that is subject to circadian rhythms. Aqueous humor is formed by the ciliary processes. The inner non pigmented epithelial cells is proposed to be the actual site of aqueous humor production.

The ciliary processes itself provides large surface area for secretion.Aqueous humor formation and secretion results from three processes.

a. Active secretion

b. Ultrafiltration

c. Simple diffusion

Active transport (secretion) - it is an energy dependent process. It takes place in double layeredciliary epithelium. Active transport accounts for the majority of aqueous production.

Ultrafiltration – In Ultrafiltration water, water-soluble substances are limited by size, Charge and flowthrough theoretical micropores in the cell membrane in response to an osmotic gradient or hydrostatic pressure.Ultrafiltration is influenced by intraocular pressure, blood pressure inthe ciliarycapillaries and plasma oncotic pressure.

Diffusion - In diffusion lipid-soluble substances are transported through the lipid portions of the cellmembrane. It is proportional to a concentration gradient across the membrane.

Rate of aqueous Humor Formation: 2.0 – 2.5 microlitres/min.

Turnover of aqueous: 1% per minute[28].

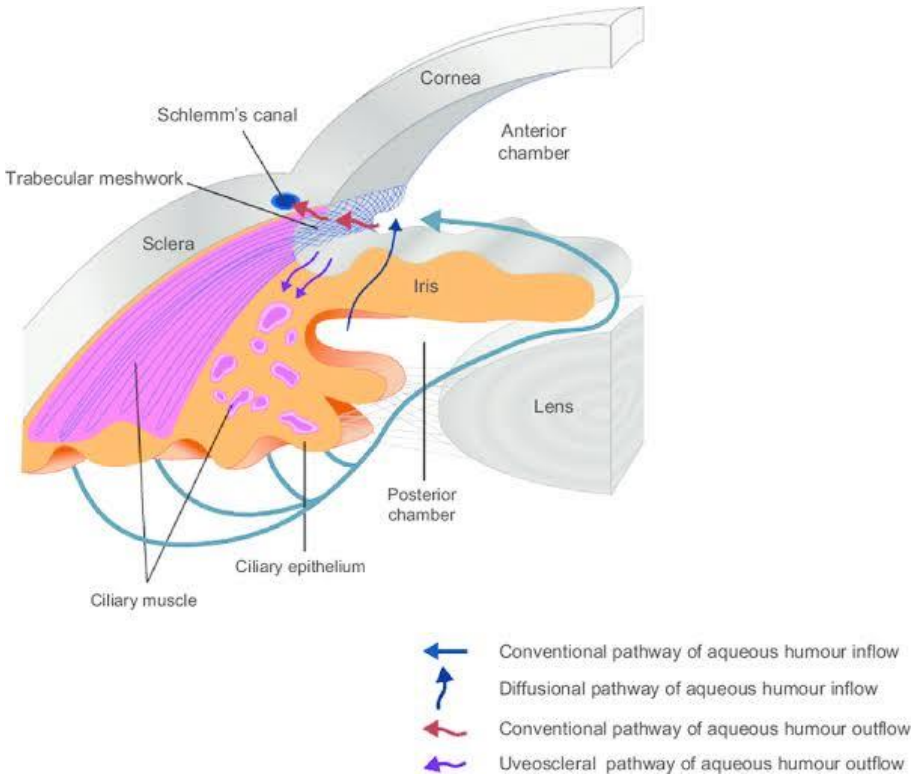
BIOLOGY OF AQUEOUS HUMOR OUTFLOW

Most of the aqueous humor leaves the eye at the anterior chamber angle through the system consisting of trabecular meshwork,Schlemm's canal, intrasceleral channels, and episceleral and

conjunctival veins. This pathway is referred to as the conventional or trabecular outflow.

In the unconventional or uveoscleraloutflow,aqueous humor exits by passing through the root of the iris, between the ciliary muscle bundles, then through the suprachoroidal-scleral tissues.

In general,the trabecular outflow in human eyes accounts for approximately 70% to 95% of the aqueous humor egress the eye. The other 5% to 30% of the aqueous humor leaves primarily by the uveoscleral outflow pathway,with a decline in the contribution of this pathway with age[27].



CLASSIFICATION OF GLAUCOMA:

I. Based upon age of presentation:

- Congenital
- Acquired

II. Based on mechanism of aqueous outflow:

- Open angle
- Angle closure

III. Based on presence or absence of associated factors contributing to pressure rise:

- Primary
- Secondary

FACTORS INFLUENCING INTRAOCULAR PRESSURE

LONG TERM:

GENETICS

Hereditary influences plays a polygenic,multifunctional mode[29-31.]

IOP is found to be higher in individuals with enlarged cup-disc ratio[32],and in relatives of open angle glaucoma[33,34].

AGE

IOP increases as the age advances.IOP distribution is Gaussian between 20 and 40 years of Age[33].Thereafter the curve begins to shift toward higher pressures with advancing age[33,35].

GENDER

IOP between 20 and 40 years of age is same,but with ageing mean IOP is greater in Women compared to men and coincides with menopause[33].

REFRACTIVE ERROR

A positive correlation between IOP and axial length of the globe[36] and increasing degrees of Myopia[32,34,37].Myopes have a higher incidence of chronic open angle glaucoma.

RACE

Blacks have been reported to have higher IOP compared to whites[38].Africans and Asians have higher pressures compared to Europeans and Americans[32].

SHORT TERM:

Short term factors are associated with fluctuations of IOP lasting from seconds to months.

DIURNAL VARIATION

The normal fluctuations of IOP ranges from 3mm Hg to 6mm Hg[39].An amplitude greater than 10mm Hg is pathologic. In glaucomatous eyes IOP fluctuation of over 30mm Hg has been noted[40].

IOP peak mostly in the mornings[41],beforenoon.Mechanism of diurnal variation is not exactly understood.However a relationship between adrenocortical steroids and IOP variation is suggested, because

the plasma cortisol has been observed to be elevated in morningsaround 3 to 4 hours before the IOP peak[42].

POSTURAL VARIATION

IOP increases from sitting to the supine position[43]. Postural variations are more common in glaucoma patients and persists even after successful trabeculectomy[43,44,45.]

EXERTIONAL INFLUENCES

Exertion can either lower or higher IOP,depending on the nature of activity. Prolonged exercise such as running or bicycling lowers the IOP[46-49]. Straining as in Valsalva maneuver[50] or certain Yogas, electroshock therapy[51],or playing a wind instrument[52]like flute can elevate the IOP. Probable mechanisms include increased episcleral venous pressure and increased orbicularis tone.

LID AND EYE MOVEMENT

Blinking, hard lid squeezing ,voluntary lid fissure widening all have shown to raise IOP[53]. Pressures have been found to be low in patients with Horner syndrome[54].Contraction of extraocular muscles also increase IOP.In normal individuals there is increase of pressures on up gaze,augmented in Graves infiltrative ophthalmopathy[55].

INTRAOCULAR CONDITIONS

Anterior uveitis often leads to slight reduction of IOP,due to decrease in aqueous Production[56]. Rhegmatogenous retinal detachment may be associated with reduced IOP[57].

SYSTEMIC CONDITIONS

There is positive correlation between systemic hypertension and IOP levels [58-62,34,38].Systemic hyperthermia causes an increase in IOP[63]. Obesity[58,60],haemoglobin level[59]and pulse rate[59] also have a positive correlation with IOP.

Diabetic patients have a higher IOP than the general population .Fall of IOP is noted in acute hypoglycaemia in insulin-dependent diabetes[60,63.]

IOP may also increase in response to adrenocorticotrophic hormone,glucocorticoids,and growth hormone and decrease in response to progesterone, estrogen,chorionic gonadotropin, andrelaxin[63,65]. Menstrual cycle has no effect[66],whereas in pregnancy IOP is significantly reduced[67,68],Topical vasopressin lowers IOP[69].

IOP is lower with hyperthyroidism, higher with hypothyroidism[95].Treatment of hypothyroidism improves the facility of outflow, bringing IOP back to normal.

ENVIRONMENTAL CONDITIONS

Exposure to cold air reduces IOP, becauseepiscleral pressure is decreased[70].Reduced gravity causes sudden, marked increase in IOP due to cephalad shifts in intravascular and extravascular body fluid[71].

GENERAL ANAESTHESIA

General anaesthesia is usually associated with reduction of IOP[72],exceptions are Trichloroethylene[73] and ketamine.Hypnotics[74] ,tranquiliers[75] and barbiturates also decrease IOP in some cases.Depolarising muscle relaxants like succinylcholine[76]and suxamethonium[77] cause a transient rise in IOP.Tracheal intubation also increases IOP[77,78].

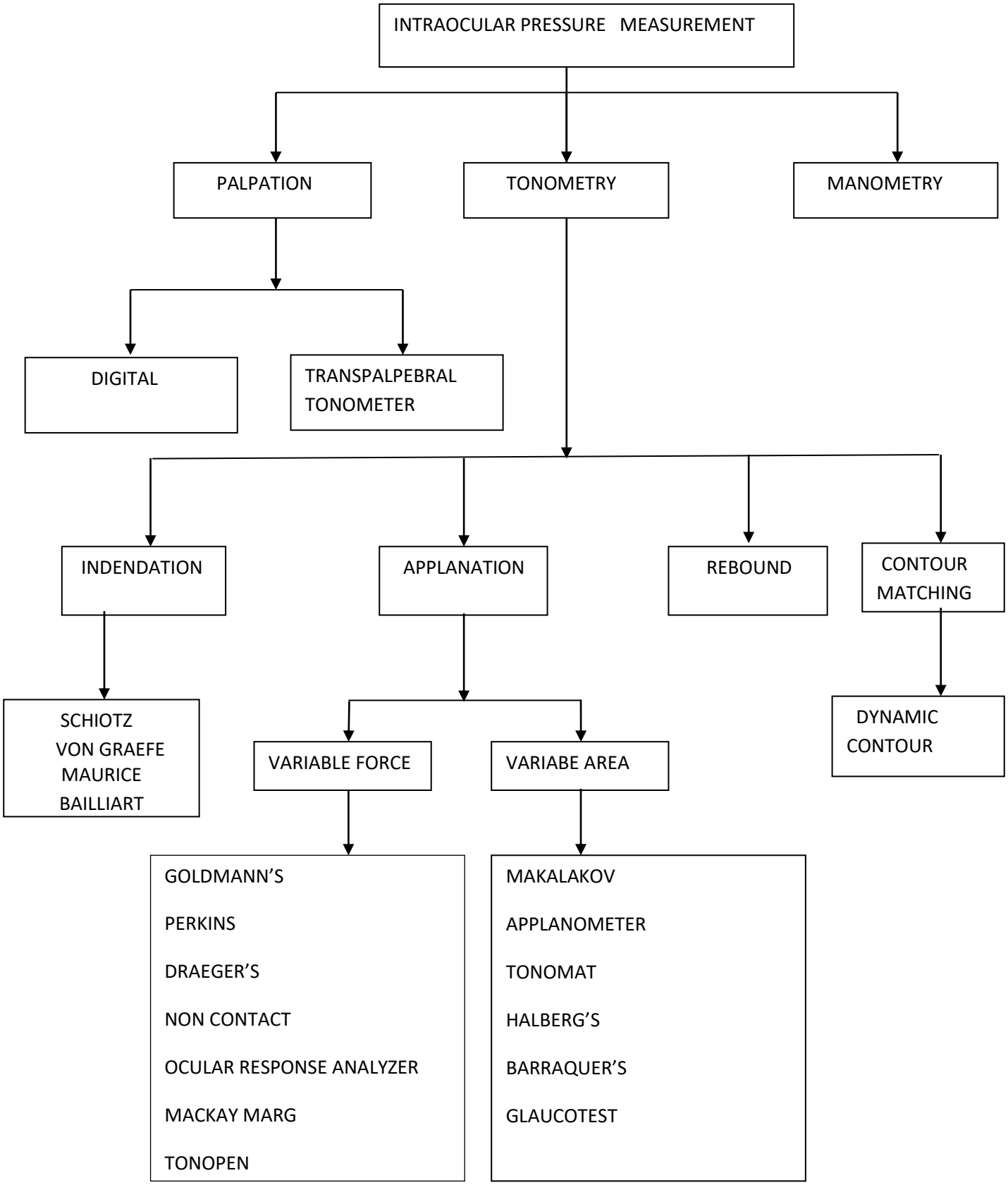
Elevated pCO2 causes an increase in IOP[79,80]or increased O2 is associated with an IOP Reduction[81].

FOODS AND DRUGS

Alcohol lowers IOP more so in glaucoma patients[82]. Caffeine may cause slight, transient increase in IOP[75,84].Tobacco smoking may cause a transient increase of IOP[85].A fat free diet reduce IOP[86].Heroin and marijuana lower the IOP, whereas LSD and corticosteroids increase IOP[87].

Systemic vasodilators[88], systemic anticholinergics[89,90], anticonvulsants[83] and H2 receptor Antagonist[91] have no influence on IOP either in normal or glaucomatous individuals with open anterior chamber angles. Sildenafil citrate does not produce any significant rise in IOP in chronic open-angle glaucoma[93].In women undergoing prostaglandin-induced abortion, there is no significant effect on IOP[94].

VARIOUS METHODS OF MEASUREMENT OF INTRAOCULAR PRESSURE



METHODS OF INTRAOCULAR PRESSURE MEASUREMENT

TRANSPALPEBRAL IOP MEASUREMENT

1. DIGITAL PALPATION:

Palpation is the oldest method of rough IOP evaluation. Johann Zacharias Platner was the first scientist to state that the glaucomatous eye was hard for the examination. The patient is asked to look in down gaze. The redundant skin of the upper eyelid is displaced, and the central meridian of the globe is balloted alternately with the tips of each index finger.

Tactile estimations of IOP is compared, and the examiner's sense of touch can be "calibrated" to a limited extent as in Bowman's grading system[110.]

Tn	=	normal tension
T+1, T+2, T+3	=	indicates degree of increased tension
T-1, T-2, T-3	=	indicates degree of low tension

Although palpation correlates poorly with Goldmannap planation readings, palpation may have a limited role in screening for marked elevations of IOP[98,99].

Merits

- Simplest, least expensive[98,100.]
- Instrumentation not required.
- Useful when external tonometry is not possible, for example, after penetrating keratoplasty or corneal scarring[100,101].
- Useful when other methods are unavailable or subject to gross error.
- Palpation may be the only feasible technique in patients who are unwilling or unable to undergo other methods of IOP measurement[99].

Demerits

- Least accurate method of IOP measurement.

Palpation is best avoided in eyes with significant trauma or in certain postoperative conditions[101,102,103.]

2. TRANSPALPEBRAL TONOMETERS

Transpalperbaltonometers, such as the TGDc-01 and IGD-02 devices. These portable instruments measure the IOP through the eyelid. The operation of both instruments is based on determining the

acceleration of freely falling rod after its interaction with the elastic eye surface.

Troost et al in his study demonstrated an increasing underestimation of Intraocular Pressure a when compared to Goldmannapplanation tonometer[104].

The **Proview eye-pressure monitor:** was developed as a phychophysical test for self tonometry at home. The pencil-shapedinstrument is pressed with its probe against the upper eyelid with increasing pressure until visual phenomenons are detected[105].These phosphenes should appear opposite to where the pressure was applied. The position of probeapplication can influence the measurement. Application of the probe tothesuperonasal part of upper lid gives the most repeatable and accurate results[106,107].

MERITS

- By not applanating or indentating the cornea, this kind of tonometry may circumvent inaccuracies related to corneal scarring, edema, astigmatism, and cornescleral rigidity.
- Variations of the central corneal thickness did not contributeto the difference.

DEMERITS

- Li et al compared IOP values using the proview eye pressure monitor with those measured with the Goldmannapplanation tonometer and with the TonoPen.
- TheIOP's obtained with the Proview eye pressure monitor were significantly lower.

B. MANOMETRY

Manometry is an invasive technique which measures the intraocular pressure insidethe eye accurately . It is the reference measurement against which all other tonometers are compared.

Manometry is used most commonly as a laboratory technique in performing continuous pressure measurements over time, evaluating the effect of physiologic and pharmacologic manipulations on pressure, and studying aqueous humor dynamics in post-mortem eyes[108]. Most widely used tonometers, such as Goldmann's applanation tonometry, Schiotz's indentation tonometry, pneumotonometry, and dynamic contour tonometry have been calibrated and validated on human cadaver eyes against a manometricreference pressure[109,110,111].

The ethical use of manometry in living human eyes is restricted to eyes undergoing enucleation or intraocular surgery[112].

C.TONOMETRY

Tonometers are the instruments for performing tonometry. Their purpose is to obtain an accurate measurement of the IOP with the least disturbance to the eye. So far, cornea is the only structure of the eye that is accessible to external tonometry. Each technique has its advantages and disadvantages, and none is ideal.

The ideal tonometer must record accurate, reproducible measurements , without affecting the pressure or harming the eye. In addition the tonometer should be portable, simple to calibrate, easy to maintain and standardize.

INDENTATION TONOMETRY[113]

The shape of deformation is truncated cone. There is no precise shape and these type of tonometers displace a relatively large intraocular volume in response to a standard weight applied to the cornea. Hence conversion tables are based on empirical data collected from in vitro and in vivo studies are used to measure IOP.

The prototype of indentation tonometry is Schiotz tonometer(1905). Because of its Simplicity, reliability, and relative accuracy, it is the only mechanical indentation tonometer in use today.

Other types of indentation tonometers include

- Von Graefe(1962)
- Donders(1863), Snellen(1868), Monnik(1868), Dor(1869)
- Layerat(1885), Smith(1887), Nicati(1900),Ro”mer(1918)
- McLean(1914), Many(1919), Bailliart(1923)
- Recording Tonometer by Maurice(1958)
- Electronic Tonometer by Mueller(1960)

SCHIOTZ TONOMETER[113]

The parts of the Schiotz tonometer are

- Footplate resting on cornea
- Plunger moving freely within a shaft in the footplate
- Indicator needle
- Scale

- Additional weights 7.5g, 10g, 15g. A 5.5g weight is permanently fixed to the plunger.

Basic concept of indentation tonometry: when Plunger indents the cornea

- Base line pressure Po is raised to Pt.Tonometer measures Pt, the change from Po to Pt is an expression of resistance an eye offers to the displacement of a volume of fluid(Vc). Po is estimated from conversion tables.

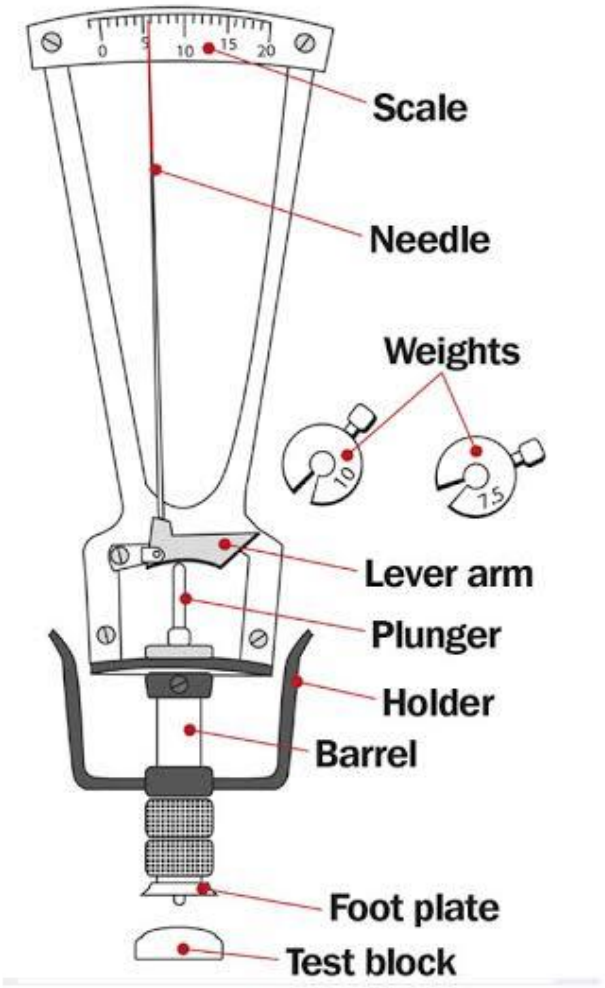
- Friedenwald[113] – developed an empirical formula for linear relationship

Between logarithm of pressure and volume change in a given eye. Constant used in the formula is –(K) coefficient of ocular rigidity

Conversion tables use

- K = 0.0245(1948 tables) or
- K = 0.0215(1955 tables)

1948 tables agree more closely with measurements by Goldmannapplaanation tonometry



Technique:

- With patient lying supine and fixing on overhead target
- Under the effect of topical anesthetic drops lid are separated by the examiner.
- Foot plate is placed perpendicular to cornea.
- Needle shows fine movements in response to ocular pulsations.

- If scale reading is less than 4, additional weight should be added to the plunger.
- A conversion table is used to derive the IOP in mm Hg from the scale reading and plunger weight.

Sources of Error

1. Ocular rigidity :conversion tables assume an average coefficient of ocular rigidity(K)

In eyes which deviate from K value show false values

High K-False high IOP

Low K-False low IOP

- High ocular rigidity seen in
  - High hyperopia
  - Long standing glaucoma
  - Vasoconstrictor therapy
- Low ocular rigidity seen in
  - High myopia
  - Elevated IOP

- Osteogenesis imperfect
- Miotic therapy
- Vasodilators
- Retinal detachment surgery
- Intravitreal gas

2. Blood volume alteration during indentation tonometry
3. Corneal influences: steeper and thicker corneas- more displacement of fluid – false high IOP
4. Moses effect: cornea moulds into the space between plunger and the hole- false elevation of IOP

Calibration: Placing the tonometer on a steel test block results in a scale reading of zero.

Other types of Indentation Instruments

Herrington's Tonometer

In this type the lever system is more complicated, rotates around a dial in an attempt to achieve greater accuracy by giving a magnification of 4 times that of conventional Schiotz instrument.

Grant's Tonometer

It is similar mechanically to Schiotz but substitutes an electrical for mechanical system of recording the position of the plunger

Maurice Indentation Tonometer

In this the force required for the plunger to indent into the eye is measured and recorded by a mechanic-electrical transducer valve

Aneuroid's principle

This depends on the working of a plunger,against a standardized spring

Ballistic Tonometry

The principle of this depends on photography,the oscillations in the recoil of a minute hammer,which is allowed to hit thecornea under standard conditions.

GoldmannApplanation Tonometer[115,116]**:**

In 1888, Fick devised a tonometer that used a fixed area of applanation. IOP was determined by measuring an adjustable force necessary to flatten the cornea. Significant skill was required to obtain valid and reproducible tonometer readings. Then Goldmann published his concept and developed the present day tonometer,

which became the standard against which all others tonometerswere compared until today.

Principle of Goldmann Applanation tonometer is based on the Imbert-Fick principle. It states that the pressure inside an ideal dry, thin-walled sphere is equal to the force necessary toflatten its surface divided by the area of the flattening:

$$P = F/A$$

where,

P - represents pressure,

F - represents force necessary to flatten

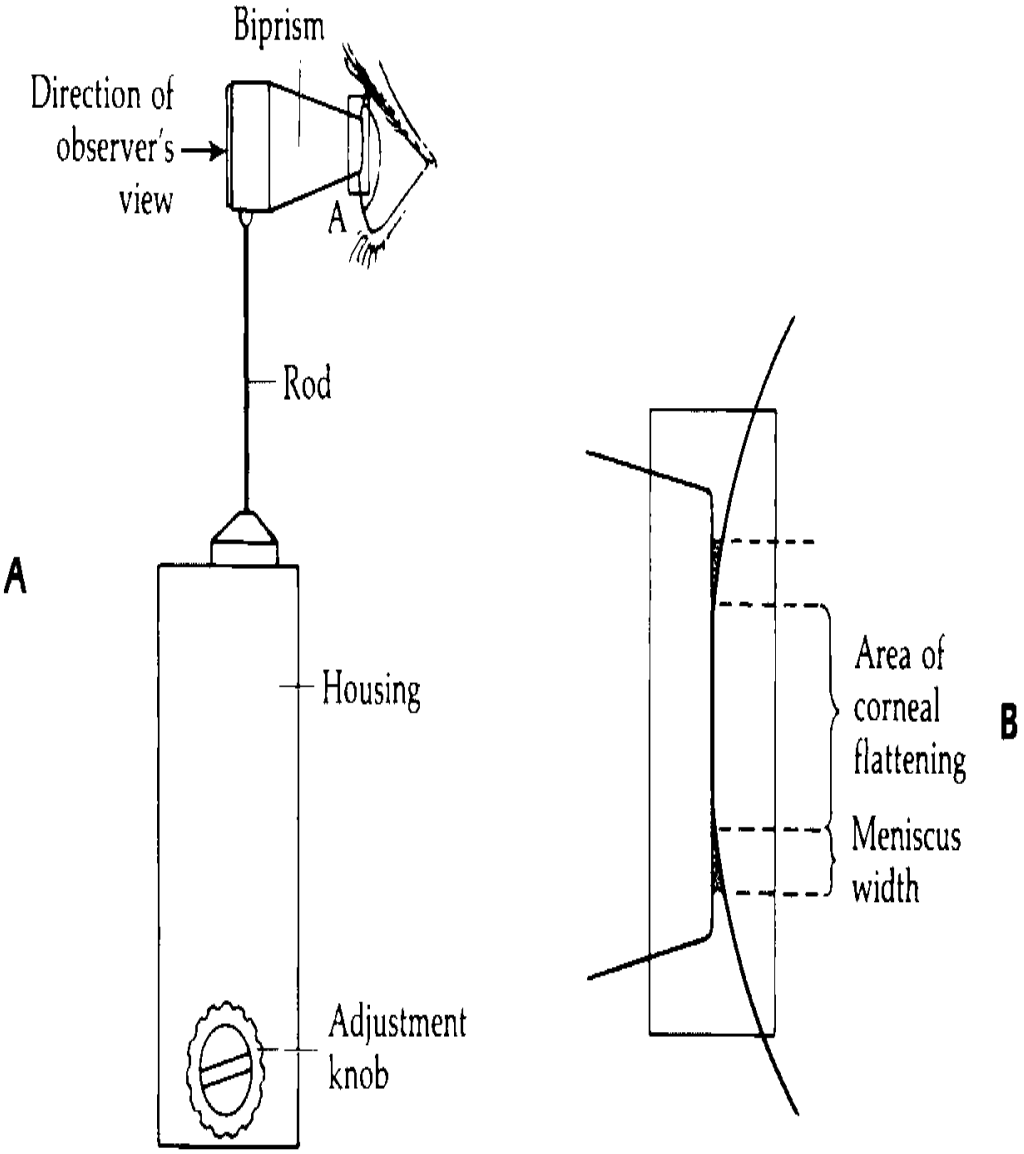
A - represents the area of flattening.

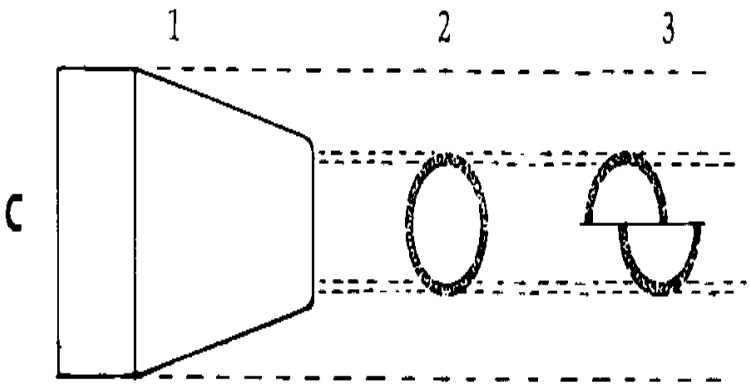
Hence in applanation tonometry, when the cornea is flattened, IOP is determined by measuring the applanating force and the area of flattening. In Goldmann applanation tonometer, the area of flattening of cornea is constant, which is of 3.06 mm in diameter. At this3.06 mm constant diameter, the resistance of the cornea to flattening is counterbalanced by the capillary attraction of the tear film meniscus to the tonometer head. The IOP (in mm Hg) equals the flattening force (in grams-force) when it is multiplied by 10.

A split-image prism allows the examiner to determine the flattened area with great accuracy and ease. Topical anesthetic and fluorescein dye are instilled in the tear film to outline the area of flattening. Fluorescein mires, which is visible through the split-image prism moves with the ocular pulse. The endpoint is reached when the inner edges of the semicirclesis made to touch each other at the midpoint of their excursion. By appropriately aligning the mires, the examiner gets the appropriate area of corneal applanation and obtain an accurate IOP values.

Instructions to patient:

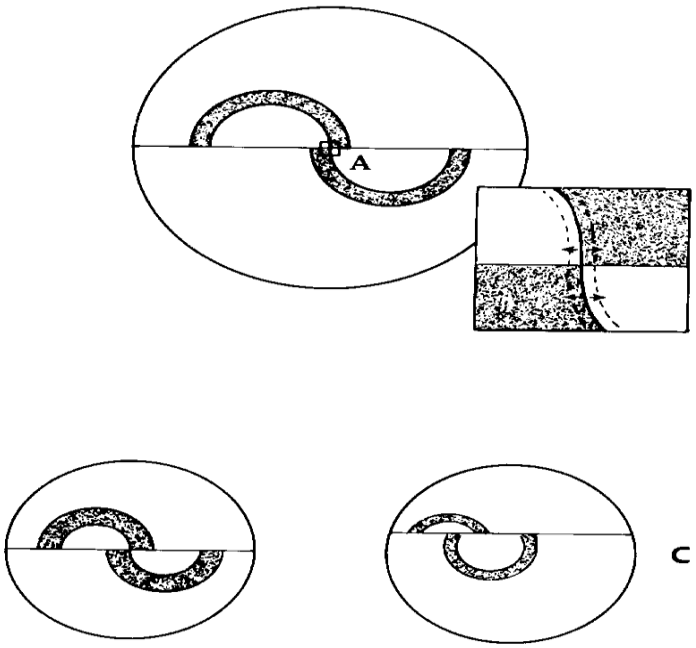
- Press head firmly against chin and forehead rest.
- Look straight ahead and fixate on a target (e.g. examiners opposite ear)
- Breathe normally, do not hold your breath
- Blink immediately prior to measurement to moisten cornea.


Biprism
Direction of observer's view
A
Rod
A
Housing
Adjustment knob
Area of corneal flattening
Meniscus width
B


1
2
3
C

Techniques of measurement:

- Position patient's head with forehead rest well above eyebrows, allowing raising of eyebrows.
- Anaesthetic (Proparacaine) & fluorescein (0.25%) ,separately, or as mixture (preserved) placed in inferior cul-de-sac.
- With maximal illumination of biprism the lamp is moved toward the eye until the tip of biprism contacts the apex of the cornea.
- Stop moving forward when limbus shines with light, best observed with naked eye. After contact, semicircles visible through left (or right) ocular, center in field of view.
- Adjust vertically until semicircles are equal in size.
- Tension dial adjusted so that inner edge of upper and lower semicircles are aligned.
- Multiply dial reading (grams of force) by 10 to obtain IOP (mmHg).



MIRES ON APPLANATION

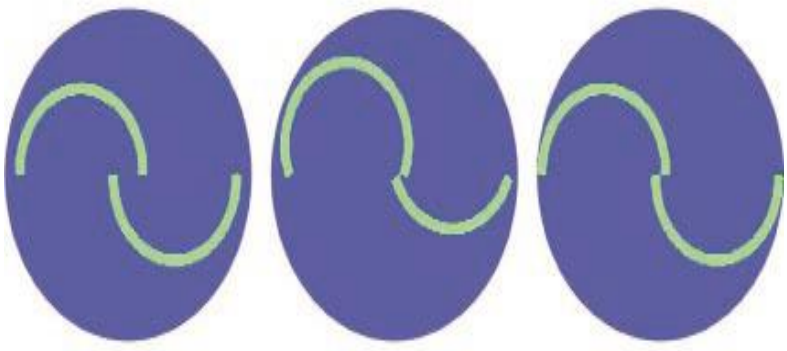
- Read at median over which arcs glide to control for excursions due to ocular pulsations.

- Blue central area represents applanated cornea, green semicircles are fluorescein-stained tears, inner border of ring is demarcation between flattened and non-flattened cornea. With outstaining of tears, bright reflection from air-cornea interface is seen; leads to underestimation of IOP.Mires should be approximately 10% of circle width.

Errors in Measurement:

- The fluorescein ring is too wide or too narrow

- **Too wide**: occurs if prism not dried after cleaning or lids touch prism. **Overestimates** IOP. Solution: dry prism
- **Too narrow**: inadequate fluorescein concentration may cause hypofluorescence. Underestimates IOP. Solution: patient blinks or additional fluorescein added.
- Thin corneas produces **underestimate IOP** Thick cornea due to increased collagen gives **overestimate IOP**, if due to edema **underestimate** IOP.
- Inadequate vertical alignment of semicircles leads to **overestimate** of IOP.
- Distortion due to irregular cornea influences accuracy, hence less useful with corneal scarring.



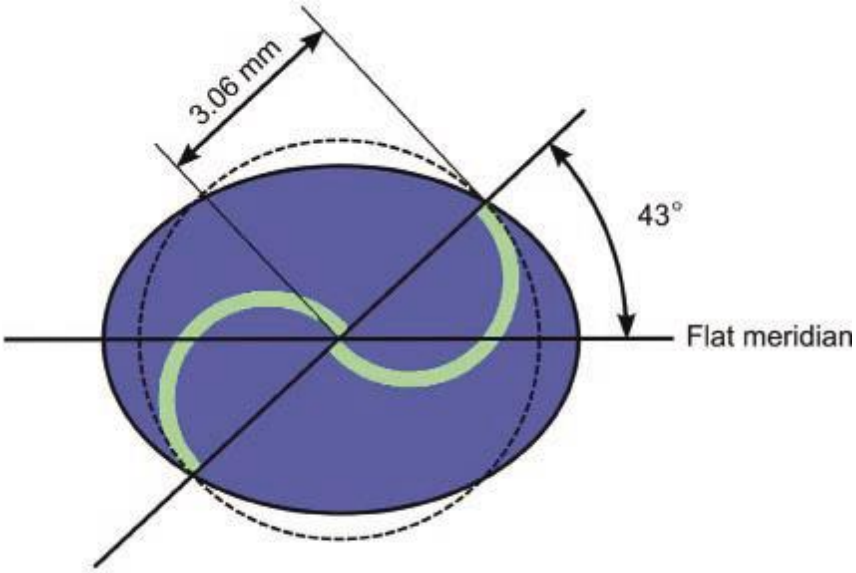
Semicircles seen by examiner during GAT.(a) Applanating force too high.(b)Incorrect vertical alignment.(c)Correct endpoint with the innermost aspects of the two semicircles touching.

Error due to corneal curvature:

- Increase of 1 mmHg of IOP for every 3D increase in corneal power.
- More fluid displaced under steep cornea- overestimating IOP.
- The steeper the cornea, the more cornea must be indented to produce standard area of contact.
- >3D astigmatism produces elliptical rather than circular area

Correction for astigmatism:

- With semicircles displaced horizontally, IOPisunderestimated by 1 mmHg for every 4D of With The Rule astigmatism, vice versa for Against The Rule astigmatism.
- To minimize, prisms should be rotated so that axis of least corneal curvature is opposite red line on prism holder (i.e. align negative cylinder axis).
- Can average reading with vertical and horizontal alignment of prism[117].



The applanated area is elliptical in the presence of corneal astigmatism. By orientating the tonometer head at an angle of 43° to the flattest corneal meridian the radius of the applanated meridian will produce an imaginary circle whose area almost equals the area of the elliptical tonometer-corneal contact

Sterilization[118]:

- Soaking the tonometer head for 5 minutes in 3%hydrogen peroxide 0.5% sodium hypochlorite, or 70% isopropyl alcohol (HIV, HSV, and adenovirus) meets the guidelines published by the Centers for Disease Control and Prevention (CDC) and the American Academy of Ophthalmology (AAO).
- Alternatively, disposable tonometer tips or silicone shield over the Goldmann tonometer tip can be used.

- Compared to uncovered GAT readings, a trend for overestimation of IOP using silicone shields and underestimation of IOP using disposable tips has been described.

Reliability:

- Goldmann applanation tonometry is the gold standard against which other modes of Intraocular pressure measurement is compared.
- Good accuracy in gas-filled eyes.
- Inter- and intra observer variability (>30% varied by 2-3 mmHg), due to subjective nature of optical endpoint.

Calibration: Wessels & Oh (1990):

- Tonometer calibration should be checked twice yearly in newer GAT.
- Older GAT >1 year old should be checked atleast monthly.
- Goldmann tonometers are supplied with a weight bar, which can be used to verify calibration at prisms prisms of 0,2 and 6 grams(0, 20,60 mm Hg respectively).
- The Applanation prisms should remain in place for these tests.

- The zero position should be verified by turning the pressure adjustment drum of the tonometer from 0 to -0.5 mm of Hg, at which time the arm holding the applanation prism should retract towards the examiner, striking the posterior stop to its motion.

- Moving the pressure adjustment drum to +0.5 mm of Hg should cause brisk forward movement so that the arm holding the prism strikes the forward stop.

- The weight bar is inserted into the bar of the holder. which is then inserted into the hole on the right side of the tonometer.

- The bar is positioned ,so that it extends towards the examiner, and the next to the furthest line on the bar is centered on the index mark on the bar holder.

- For eg with the bar in the above position, the tonometer head should move to the posterior limit of its motion, when the pressure is adjusted to 19.5mm of Hg and should move towards the anterior stop of its motion, when the pressure is adjusted to 20.5mm of Hg. This verifies proper calibration at 20mm of Hg.

Perkin's Tonometer[119, 120]**:**

The Perkins tonometeris a handheld applanation tonometer. It is similar to the Goldmann tonometer which uses a split-image prism. It requires instillation of fluorescein dye in the tear film.

Advantages:

- Portable
- It can be used either in supine or upright posture.
- Measuring the IOP in young children, elderly, and in obese patients, permitting measurements without having to position the patient at a slit-lamp.
- Measuring the IOP in anaesthetised and bedridden patients.

Perkin's Tonometer

Other types ofapplanation tonometry:

The applanation tonometry remains the gold standard method for measurement of IOP. There are numerous other methods which have been developed. Each tonometer has its advantages and disadvantages when compared with applanation tonometry.

Mackay-Marg-typetonometers:

MacKay and Marg tonometer is based on both indentation and applanation methods. The tonometer has a 3.06-mm diameter applanating surface. It is obtained by the footplate. A tiny plunger protruding by a microscopic amount from the center is attached to a strain gauge. The plunger gets resistance from the cornea as the tonometer is brought in contact with the eye. IOP producing a rising record of the force by the strain gauge. At the moment of applanation, the force is shared by the foot plate and the plunger. Hence there is a momentary, small decrease from the steadily increasing force. This phenomenon is used to determine the point of applanation. The small notch observed in the electrical waveform helps identify the force at applanation. Since the area of applanation is known, the Intraocular Pressure can be calculated[121].

- Portable electronic devices of the Mackay-Marg type tonometer is Tono-Pen. It contains a strain gauge to measure the pressure at the center of an annular ring which is placed on the cornea. Hence Tonopen is useful for measuring IOP in patients with corneal scars or edema.

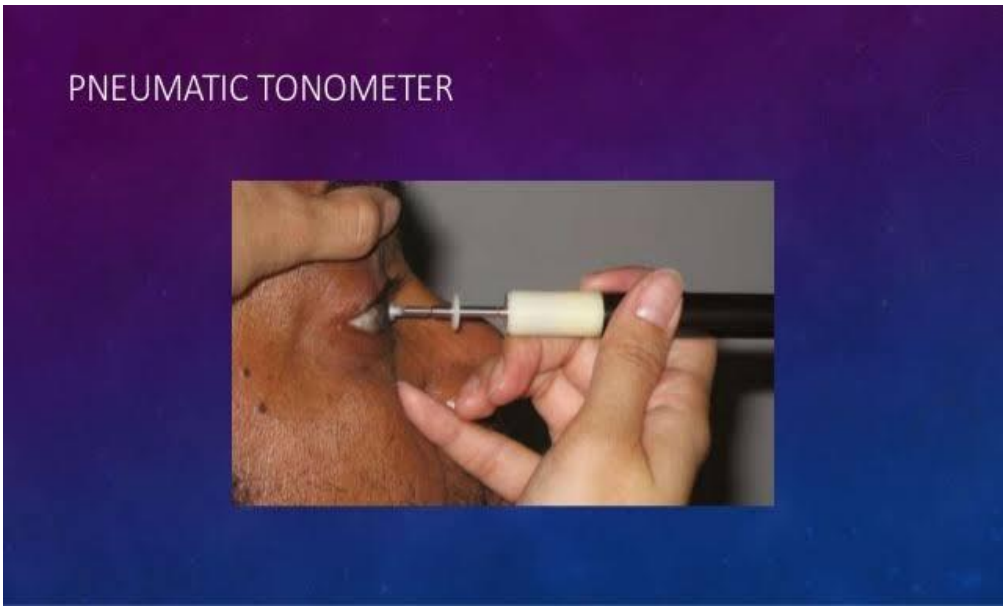
Tonopen

The pneumatic tonometer, or pneumatonometer:

Pneumatic Tonometer is an applanation tonometer which has same characteristics of the Mackay-Marg-type tonometer. It contains a cylindrical air-filled chamber and a probe tip covered with a flexible, and inert silicone elastomer (Silastic membrane) diaphragm.

There is a small gap between the diaphragm and the probe edge because of the constant flow of air through the chamber. When the probe tip touches and applanates the cornea, the air pressure increases until this gap is completely closed. That point of Intraocular Pressure is equivalent to the air pressure[122].

Pneumatic tonometer covers only a small area of the cornea. Hence it is useful in eyes with corneal scars or edema.



The dynamic contour tonometer:

Dynamic contact tonometer is a newer type of nonapplanation contact tonometer. The Principle is that when the surface of the cornea is aligned with the surface of the instrument tip, the pressure in the tear film between these two surfaces equals Intraocular pressure. It can be measured by a pressure transducer[123]. Multiple studies have shown that

IOP measurements measured with dynamic contour tonometry are more independent of corneal biomechanical properties and corneal thickness unlike tonometers.

PASCAL device.

Noncontact (air-puff) tonometers:

Noncontact tonometer estimates Intraocular Pressure by measuring the force of air required to indent the cornea to a fixed point. Hence this tonometer avoids contact with the eye[124,125].

Values obtained with noncontact tonometer vary widely, and hence IOP is often overestimated. Thus noncontact tonometers are often used in glaucoma-screening programs or by nonmedical health care providers.

The Ocular Response Analyzer: (ORA)

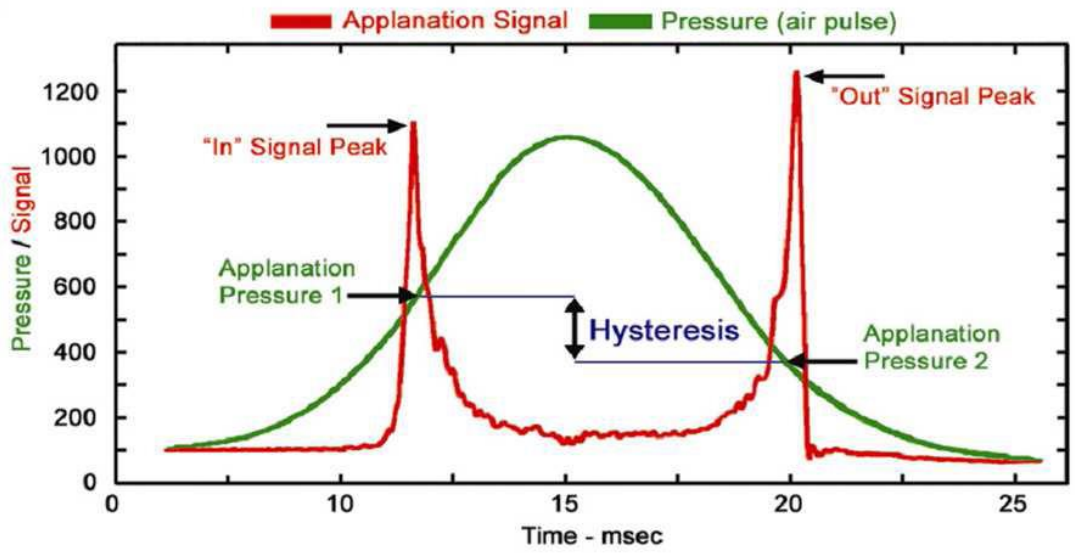
Ocular Response Analyser

Ocular Response Analyser is a non-contact tonometer that provides IOP values that are independent of corneal properties. In addition the ocular response analyser provides parameters that are indicative of the biomechanical properties of the cornea[126].

Ocular biomechanical properties indicators are calculated which includes corneal hysteresis and corneal resistance factor.

Corneal hysteresis is the difference in Intraocular Pressure measured during the initial corneal indentation and Intraocular Pressure measured during corneal rebound.

One of the risk factor for glaucoma is reduced corneal hysteresis.



Corneal hysteresis is defined as the difference between inward and outward applanation pressures. In this chart, a measurement of corneal hysteresis is illustrated on acurve, which compares corneal applanation signal and air pressure over time.

Rebound tonometry:

The rebound tonometer (RBT) is an assembly of two coils coaxial to a probe shaft that bounce a magnetized probe off the cornea and detect the deceleration of the probe caused by the eye. A moving magnet within a coil induces changes in the voltage at the two ends of the coil generating a magnetic field with a given voltage, which is detected by the tonometer sensor[127].

Rebound tonometers are portable.

Topical anesthesia is not required, making them particularly suitable for pediatric populations.

ICare Tonometer

TONOMETRY AND CENTRAL CORNEAL THICKNESS

Most common types of tonometers are affected by central corneal thickness (CCT). Even with Goldmann tonometer the measurements are most accurate when the Central Corneal Thickness is approximately 520 micrometre. Thick corneas resists deformation in most of the methods of tonometry. Hence this results in an overestimation of IOP. Thinner corneas may falsely give an low reading[128]. Intraocular Pressure measurement after refractive procedures in cornea may be underestimated because of changes in corneal thickness. However the relationship between Intraocular Pressure and Central Corneal Thickness is not linear. Thus any correction factors are only approximate to real values. In addition, the biomechanical properties of each individual corneas may vary from the other.

There is no validated correction factor on applanation tonometers for the effect of Central Corneal Thickness. Hence, any of the correction methods proposed in the major articles are arbitary. Thin Central Corneal Thickness is a risk factor for glaucoma. However whether the increased risk of glaucoma is due to underestimating the IOP in patients with thin central corneas or whether it is due thin central cornea itself has not been determined till date.

A study at the Moor fields Eye Hospital of four resident optometrists and three medical clinicians showed that of the 50 patients examined, agreement between optometrists and consultants in glaucoma clinical decision making was at least as good as that between medical clinicians and consultants. The study opined that optometrists can work safely as part of glaucoma team in outpatient clinics.

In this study Goldmann Applanation tonometer and Perkins tonometer which has the same principle were used to assess the reliability of ophthalmic assistants in measuring IOP compared to doctors

REVIEW OF LITERATURE

Applanation tonometry: A comparison of the Perkins handheld and Goldmann slit lamp-mounted methods(Clinical Ophthalmology,2014).

Arora R et al concluded that Perkins tonometer yields IOP measurements that are comparable with Goldmann Applanation Tonometer. Hence, Perkins can be used in routine clinical practice. Perkins tonometer has been recommended as a part of the implementation of national guidelines or preferred practice patterns for all types of glaucoma.

A comparative study of the tonometers : Goldmann Applanation, Perkins, Tono-pen XL and Reichert7CR (International Journal Of Ophthalmic Practice,vol.2,No.6,sep-2013*).*

E Eriksson et al concluded that all devices show reliable measurements of IOP in healthy eyes. Perkins, correlated intraocular pressure and Tono-pen XL show agreement with goldmann applanation tonometer, however are not interchangeable. Perkins showed the highest correlation to GAT.

Intraocular pressure measurement during the day and night for glaucoma patients and normal controls using Goldmann and Perkins applanation tonometry (Ophthalmologe 2006).

WoznaikK, et al concluded there were no statistically significant differences in IOP changes between the two groups during diurnal IOP measurements in an upright position. But in a supine position IOP was higher than in sitting position due to increased venous return. However this IOP difference was increased more in the glaucoma patients than in healthy controls. The reason may be due to faulty regulation of the fluid shift in glaucoma patients. This contributes to progression of glaucomatous damage.

Factors associated with fluctuations in repeated measurements of intraocular pressure using Goldmann applanation tonometer in Japanese patients with primary open-angle glaucoma (Clinical ophthalmology 2018).

Yaoeda K, et al concluded that IOP measured first either right eye or left eye was higher than the fellow eye in Japanese patients with POAG.

Intraocular Pressure Difference in Goldmann Applanation Tonometry versus Perkins Hand-held Applanation Tonometry in Over weight Patients (Ophthalmology, 1988).

Dos Santos et al analysed that in overweight patients the increase in intraocular pressure when using Goldmann Applanation Tonometry was caused by both anatomic and physiologic factors. In the study they proposed that simultaneous breath holding and thorax compression causes increase in venous pressure. This in turn may be a causative factor for transient elevations of IOP. Thus Perkins Tonometry in obese patients helps in avoiding false diagnosis of glaucoma caused by transient elevation in IOP.

Evaluation of accuracy in Goldmann and Perkins Applanation, ARVO Annual Abstract, May 2006.

It evaluated the reliability of intraocular pressure measurements with Goldmann applanation tonometry to Perkins applanation tonometry, along with central corneal thickness[CCT].It concluded Goldmann applanation tonometry resulted in lower IOP[0.29 mm of Hg] readings compared to Perkins Tonometry.

Comparison of Mackay-Marg, Goldmann, and Perkins Tonometers in Abnormal corneas, Arch Ophthalmology, 1975.

Intraocular Pressure was determined with manometry in owl monkey eyes having normal and edematous corneas. The intraocular pressure was measured with Perkins hand-held, Goldmann, and Mackay-Marg tonometers to compare its relative accuracy. In manometric levels of 20, 30,and 40 mm of Hg, a statistically significant difference in readings was found between normal and edematous corneas with use of both Perkins and Goldmann applanators. However no such difference was noted with the Mackay-Marg tonometer. The Mackay Marg tonometer showed more correlation with the true intraocular pressure in edematous corneas.

A comparison of Perkins and Goldmann applanation tonometry, Journal of American Optometric Association, 1986.

In this study compared intraocular pressure measurement with Perkins tonometer and the Goldmann tonometer. Intraocular Pressure readings between the two groups were highly correlated [+0.91] with each other.

Evaluation of the Perkins handheld applanation tonometer in the measurement of intraocular pressure in dogs and cats, Veterinary ophthalmology, 2009.

There was an good correlation between the IOP values measured from the direct manometry and the Perkins tonometry in dogs and cats.

Barrett, C.(2017) Optometric case finding for glaucoma in Ireland: an investigation of current practice patterns.

Chapter 3 and 4 report on a national survey. The results showed that optometrists were well equipped to carry out the glaucoma case finding triad.

Chapter 7 results highlights areas for clinical practice reforms which include measurement of Goldmann applanation tonometry, pacymetry and disc size measurement. Thus it will allow for better use of resources in secondary care. In primary care more detailed referral information facilitates more accurate triage in outpatient ophthalmology services.

Goldmann applanation tonometry versus non-contact tonometry: a comparative study. (International Journal of Research in Medical Sciences, Nov2016).

LipiChakrabarty concluded that intraocular pressure measurements of Goldmann Applanation Tonometry and Non Contact Tonometry are comparable. However Ophthalmologists should keep in mind the variation of IOP with Central Corneal Thickness.

The role of optometrists in India: An integral part of an eye health team. Indian Journal of Ophthalmology 2012.

De Souza N et al., stated in his review article that the training and practice of optometry in India has been not under control in the past decade. But in the last two years, progress has been towards the establishment of standardized, regulated profession which will provide proper eye health and vision care, provision of optical services to all those people needing vision correction. It includes The Indian Optometry Federation formation, adoption of the Common Minimum Optometry Curriculum, development and also adoption of the Delhi Declaration, commitment to a four-year degree program for all optometry students from the year 2020, and establishment of a peer reviewed Optometry Council of India to oversee education, educational institutions and also to register optometrists. This allow proper usage of resources for the elimination of the blindness and impaired vision due to uncorrected refractive error that affects 133 million Indians. Indian optometry is awaiting for approval from the Government of India to grant an independent healthcare professional status to all optometrists. This will aid in providing quality eye care services to all, regardless of their geographical location.

Roles and responsibilities in the secondary level eye care model, International Centre for Advancement of Rural Eye Care, L.V. Prasad Eye Institute, Hyderabad, Community Eye Health Journal, December 2005.

The ICARE model emphasises that all cadres of personnel both clinical and non-clinical are equally important. The tertiary eyecare centre at LVPEI manages leadership, training for ICARE model. This model proposes that each link in the chain of eye care delivery is important to achieve quality comprehensive eye care. It is not necessary to have all the individual eye care personnel. Nonclinical personnel possibly have 'cross-functioning'. However it is important that everyone individual health personnel knows their roles and responsibilities. Clinical and non-clinical staff in the ICARE model are mostly selected from the local communities. This supports sustainability of eye care services and generates local community employment also.

Models for Primary Eye Care Services in India, Indian Journal of Community Medicine, April 2015. Misra, et al stated that providing primary eye care services at the community level in rural and also in underserved urban areas through various proposed models is a promising strategy in creating both awareness and also reducing the burden of avoidable and treatable eye diseases. The integrated model of primary

eye care services with primary health centers and community health centers is cost effective method and is most suited for a developing country like india. The major advantage of this model is that the eye care personnel will work under the guidance of trained medical officers and the eye care services are integrated to the already existing health care infrastructure. One of the major aspects for the operational sustainability in the vision centers is to carry out regular monitoring of the entire set up by the ophthalmologists. Routine monitoring helps to ensure optimal performance of the eye care personnel as well improved output of the vision centers. It is recommended that a Management Information System (MIS) should be formed for providing reporting services at vision centers. They can develop indicators related to primary eye care, refraction services, and the number of refractions performed in a day, number of spectacles dispensed in a day etc. A monitoring visit by the ophthalmologist atleast once a month is essential in a vision center to ensure availability of appropriate skills and services.

The accuracy of accredited glaucoma optometrists in the diagnosis and treatment recommendation for glaucoma, British Journal of Ophthalmology, 2007.

Community optometrists who are trained in glaucoma provided satisfactory decisions in diagnosis and also for initiation of treatment in

glaucoma patients. With additional training in glaucoma, optometrists are at least as accurate as junior ophthalmologists. However some cases of glaucoma are missed too.

Agreement between specially trained and accredited optometrists and glaucoma specialist consultant ophthalmologists in the management of glaucoma patients, Eye 26(6), 853, 2012.

The study assessed the agreement between trained optometrists in managing glaucoma and consultant ophthalmologists in managing glaucoma patients. Agreement between both in intraocular pressure measurement was 84.5%. Hence optometrists can be safely involved in the co-management of glaucoma patients since the burden on the hospital eye service continues to increase.

Krishnakumar R, Anuradha N, JameelRizwanaHussaindeen M, Sailaja M.V.S. Role of Optometrist in Eye Hospitals, Sci J Med & Vis Res Foun.

This study stated that in the glaucoma clinic, optometrists can be engaged in the diagnostic procedures such as measuring Intraocular Pressure , doing gonioscopy using Goldmann 4-mirror gonioscopy and to perform any additional tests if needed in addition to doing routine procedures.

PART II

PART-2

AIMS AND OBJECTIVES :

To assess the agreement of intraocular pressure (IOP) measured with Goldmann applanation tonometer (GAT) by glaucoma consultant and Perkins Tonometer by Ophthalmic Assistant.

MATERIALS AND METHODS :

Study setting:

This is a cross sectional and observational study where adult patients visiting Glaucoma clinic, Aravind eye hospital, Madurai over a period of 6 months (December 2018 to May 2019)were studied.

Study design:

Prospective cross-sectional study.

Study population:

Patients in the age group of 20years to 70years coming for glaucoma screening and patients who were diagnosed to have glaucoma.

Sample size:

Convenient sampling of 500 patients were taken.

Inclusion Criteria:

All patients in the age group of 20 to 70 years.

Clear cornea.

Refractive error-Astigmatism<3D.

Exclusion Criteria:

Age <20years.

Any Corneal irregularities, corneal Edema, Bullous Keratopathy.

Refractive error-Astigmatism>3D.

Unco-operative patients.

Acute Eye conditions including ocular infections and systemic conditions such as HBV,HCV ,HIV.

Tool for data collection:

The Goldmann tonometer model used in our study is AT 900Mod.R (Haag-Streit, Switzerland) and for Perkins, Mk3 tonometer (Haag-Streit) model is used. The same Goldmann tonometer and Perkins Mk3 tonometer were used throughout the study for all IOP measurements. Calibration of each instrument is checked at the beginning of the session, according to the manufacturers' instructions. Thereafter

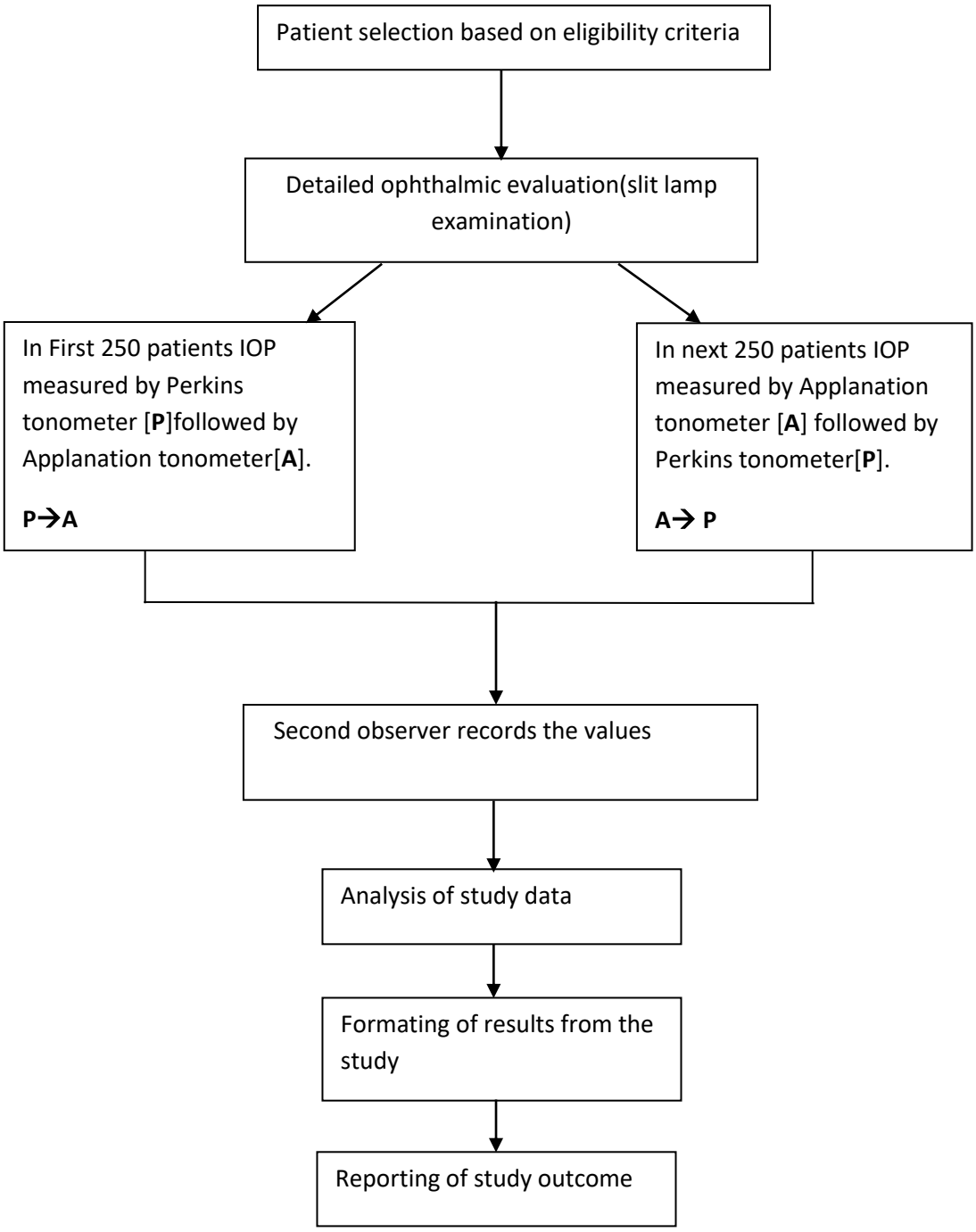
calibrated every month by the Instruments Department of Aravind Eye Hospital, Madurai. The record of the same is maintained and also sticked over it in case of Goldmann Applanation Tonometry. CCT is measured using Pacscan 300AP (Sonomed, NewYork, USA). One drop of 0.5% proparacaine is placed in each eye & the tip of moistened fluorescein strip is touched to the tear layer on the inner surface of each lower eyelid. The patient is asked to close the eyes, for uniform spread of fluorescein. All subjects were made to sit and instructed to view a distant target during the measurements with applanation instruments. GAT uses an applanation probe that is mounted on an arm on the slit lamp. A tonometer probe is inserted into the holder. Its zero axis marker was aligned with the reference mark. The slit lamp's illumination system was adjusted to approximately 60 degrees with a cobalt blue filter in front of the beam. Slit lamp magnification was set to 10x and the tonometer's drum scale set to 10 mm. The subject fixated on a distant target while the probe came in contact with the cornea. Two fluorescent semicircles will be visualized. The end point of measurement is when the inner edges of the two semicircles meet, which is adjusted by turning the knob of the tonometer. Scale reading was noted in mmHg. Then we multiply the value with 10 which is the final intraocular pressure.

As Perkins is a hand-held GAT with the illumination built into the instrument, there is no slit lamp required. A magnifying lens behind the probe allows the examiner to view the applanated corneal surface. Held in one hand and the wheel turned to 10 units on the scale, the probe is brought into contact with the patient's cornea. The reading of the measurement was made in the same way as for the GAT and noted in mmHg. CCT was measured using Ultrasound Pachymetry (Sonomed 300AP) after instilling a drop of 0.5% proparacaine hydrochloride ophthalmic solution. The correction for the central corneal thickness (CCT) is applied using the standard correction chart.

Data collection methodology:

After taking an informed consent, the IOP is first measured by Perkins Applanation Tonometer by an experienced paramedical staff. Thereafter, GAT was measured by an experienced ophthalmologist on a single slit lamp unit in the first 250 patients. Then for the rest of 250 patients Goldmann Applanation tonometer is done first followed by Perkins tonometer. The cyclical permutation was used to reduce the possible effect on the IOP of repeated measurements .CCT is taken by experienced paramedical staff.

METHODOLOGY



Three readings of IOP by each method was taken. Mean of the three readings was recorded under each section. Fifteen minute interval was given between two readings which are considered to be a safe interval. The observers were masked to the other readings. We took all precautions in recording the readings, explaining the procedure to the subject and discarding the first reading in each section. A single or two examiner performed all measurements with each type of tonometer to avoid interobserver variability. All readings were blinded for the examiner. Experienced paramedical person is one who have been measuring IOP by Perkins for atleast 6 months prior to the study and who have been assessed by Rubric Score sheet for measuring IOP by Perkins in atleast 10 patients and scored properly by a doctor. Experienced doctor includes working in Glaucoma department for not less than 1year.

Data analysis:

Statistical analysis was done calculating mean of all readings and noting age, gender, diagnosis and IOP distributions of the subjects. Correlation between Perkins Tonometry and Goldmann Applanation Tonometry was determined using Bland Altman graph. Inter-method agreement between tonometers was assessed using the method devised by Bland and Altman, which included calculation of the mean difference between measurements, the standard deviation and the 95% confidence interval of the differences.

RESULTS

The study compared 1000 eyes of 500 patients who attended Glaucoma clinic in the study period. The mean age of the patients were 56.98 and it ranges from 20-70 years. Around 12.2 % of patients was under 45 years, 41. 8% of patients between 45-60 years and 46% of the patients above 60 years.The study population comprised of 52.2% of males and 47.8% of females.

Age

The Mean (SD) age of patients is 56.98 (11.31) years and it ranges from 20 – 70 years

Age	n	%
<45	61	12.2
45 – 60	209	41.8
>60	230	46.0
Total	500	100

Gender

Gender	n	%
Male	261	52.2
Female	239	47.8
Total	500	100

The number of patients in each glaucoma subgroup

Diagnosis	n	%
POAG	355	35.5
PACG	131	13.1
PACS	125	12.5
Glaucoma suspect	77	7.7
Pxf / Pseudoexfoliation	58	5.8
Secondary glaucoma	36	3.6
OHT	26	2.6
Combined	10	1.0
Absolute glaucoma	4	0.4
Others	178	17.8
Total	1000	100

The number of patients in each glaucoma subgroup of Primary Open Angle Glaucoma, Primary Angle Closure Glaucoma, Primary Angle Closure Suspect, Primary Open Angle Glaucoma Suspect were 355,131,125,77 respectively. Around 36, 26, 10, 4, 178 patients were in Pxf glaucoma, Secondary Glaucoma, OHT, Combined mechanism Glaucoma, Absolute Glaucoma and others respectively.

The Intraocular Pressure under study ranged from 5 to 60 mm of Hg. The mean GAT IOP in right eye and left eye was 17.74 mm of Hg(+/-7.20), 17.21mm of Hg(+/-6.18) respectively. The mean Perkin's IOP in right eye and left eye was 15.91 mm of Hg (+/- 5.70),15.93mm of Hg(+/-4.98) respectively.

IOP RE

IOP RE	n	Mean (SD)	Min – Max
GAT (mmHg)	500	17.74 (7.20)	7 – 60
Perkins (mmHg)	500	15.91 (5.70)	8 – 54

IOP LE

IOP LE	n	Mean (SD)	Min – Max
GAT (mmHg)	500	17.21 (6.18)	7 – 53
Perkins (mmHg)	500	15.93 (4.98)	5 – 48

For analysis three groups were considered in the IOP ranges of less than 15 mm of Hg,15-22 mm of Hg and more than 22 mm of Hg. The mean difference in IOP between GAT and Perkins of 6.36 (highest) is noted in group more than 22 mm of Hg. Highest correlation is noted in the IOP range of 15-22 mm of Hg followed by IOP ranges of less than 15 mm of Hg.

IOP	Mode of measurement	
	GAT	Perkins
<15	380 (38.0%)	448 (44.8%)
15 – 22	477 (47.7%)	473 (47.3%)
>22	143 (14.3%)	79 (7.9%)

CCT

CCT	n	Mean (SD)	Min – Max
RE	500	541.99 (32.32)	420 – 645
LE	500	544.16 (31.80)	437 – 661

Central corneal thickness for RE ranges from 420 – 645. Mean Central corneal thickness for RE is 541.99. Central corneal thickness for LE ranges from 437 – 661.Mean Central corneal thickness for LE is 544.16.

IOP RE

IOP RE	n	Mean (SD)	Min – Max	P-value[a]
GAT (mmHg)	500	17.74 (7.20)	7 – 60	<0.001
Perkin's (mmHg)	500	15.91 (5.70)	8 – 54	

[a]independent t-test

In the above table the p-value <0.001 shows that statistically there is a difference in IOP measurements between the two machines. i.e. IOP measurement by GAT has higher value than Perkin's Tonometer with mean IOP of 17.74.

IOP LE

IOP LE	n	Mean (SD)	Min – Max	p-value[a]
GAT (mmHg)	500	17.21 (6.18)	7 – 53	0.0003
NCT (mmHg)	500	15.93 (4.98)	5 – 48	

[a]Independent t-test

In the above table the p-value 0.0003 shows that statistically there is a difference in IOP measurements between the two machines. i.e. IOP measurement by GAT has higher value than Perkin's Tonometer with mean IOP of 17.21.

Hence overall in both the eyes ophthalmic assistant underestimated the Intraocular Pressure than ophthalmologists.The difference in mean Intraocular Pressure between both the groups in RE is 1.83 and in LE is 1.28.

Mean IOP in Group A:

Group A. **P→A** **First 250 patients**	**Mean (SD)**	**Min – Max**
Perkins Tonometer	15.95 (6.09)	5 – 54
Goldmann Tonometer	17.24 (7.60)	7 – 60

In Group A, the mean Perkins reading is15.95 mmHg (SD: 6.09mmHg) and the mean Goldmann reading is 17.24mmHg (SD: 7.60mmHg).

Mean IOP in Group B:

Group B. **A→P** **Last 250 patients**	Mean (SD)	Min – Max
Applanation Tonometer	17.69 (5.76)	9 – 53
Perkins Tonometer	15.88 (4.55)	7 – 30

In Group B (where Applanation Tonometer is done first), the mean Goldmann reading was 17.69 mmHg (SD: 5.76mmHg), and the mean Perkins reading was 15.88 mmHg (SD: 4.55mmHg). The mean difference between readings in Goldmann Applanation Tonometry in both groups is 0.45 mmHg, and in Perkins Tonometry is0.07mmHg. Hence the order of measurement did not influence the intraocular pressure values.

Interclass correlation for IOP between two groups:

IOP – RE	**ICC**	**95% CI**	**P-value**
Individual	0.036	0.006 – 0.976	<0.001
Average	0.950	0.747 – 0.999	

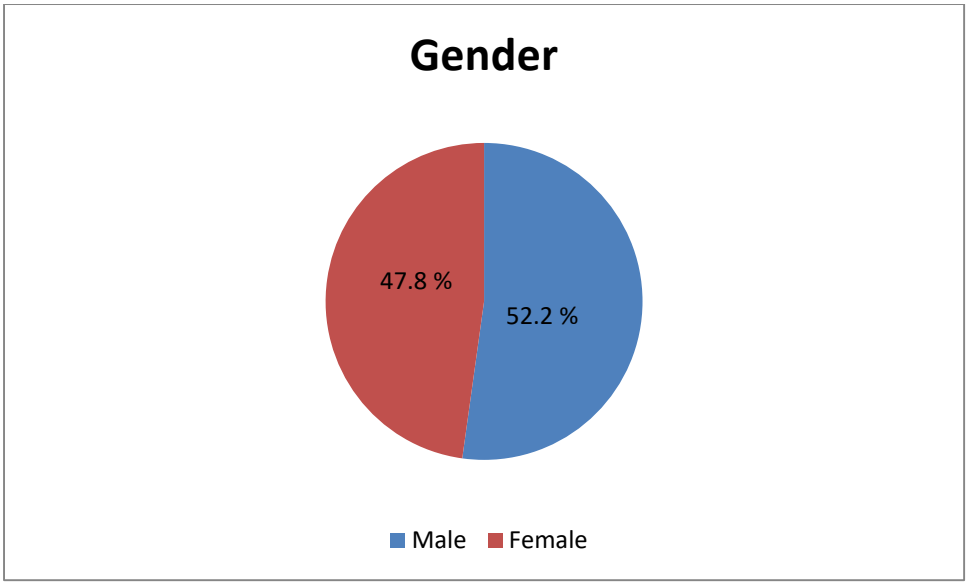
The IOP value measured by ophthalmologist with Goldman Applanation Tonometer and Perkins Tonometer by ophthalmic assistant are similar to each other. The P-value <0.001 shows that statistically there exists a very good positive correlation between the two groups. The interclass correlation value 0.950 says that the values given by both ophthalmologist and ophthalmic assistant are highly correlated to each other.

IOP – LE	ICC	95% CI	P-value
Individual	0.023	0.003 – 0.963	<0.001
Average	0.922	0.609 – 0.999	

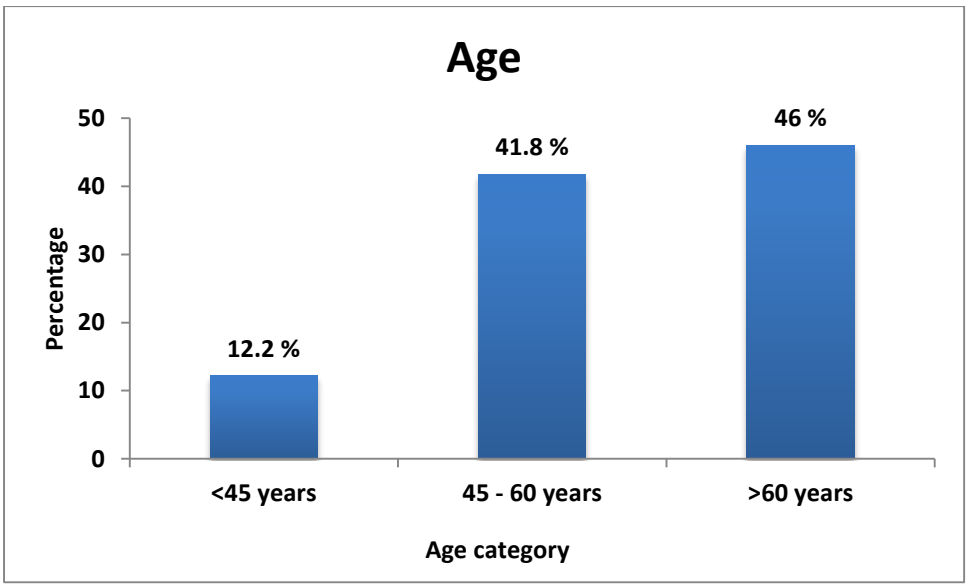
The IOP value measured by ophthalmologist with Goldman Applanation Tonometer and Perkins Tonometer by ophthalmic assistant are similar to each other .The P-value <0.001 shows that statistically there exists a very good positive correlation between the two groups. The interclass correlation value 0.922 says the values given by both ophthalmologist and ophthalmic assistant are highly correlated to each other.

GRAPHICAL REPRESENTATIONS

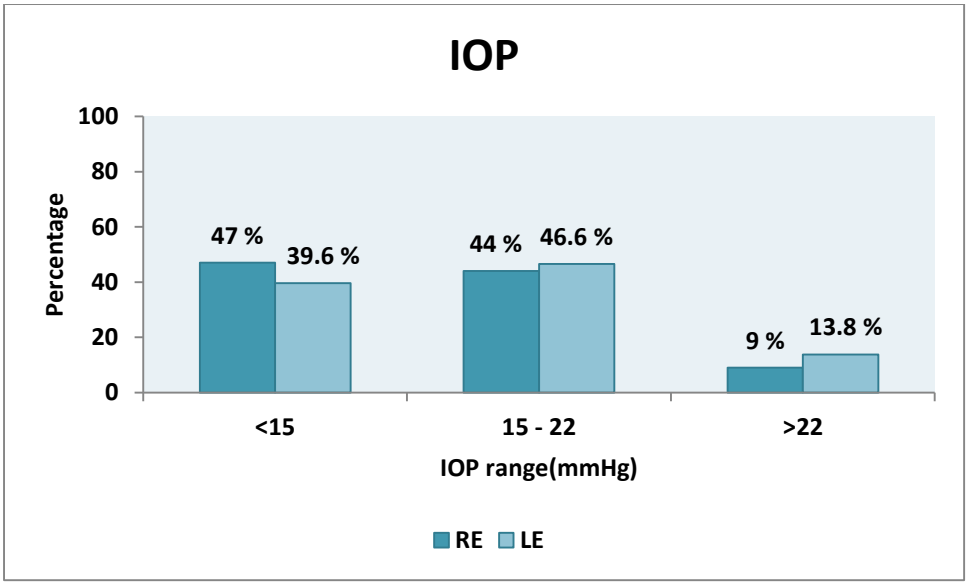
Gender distribution



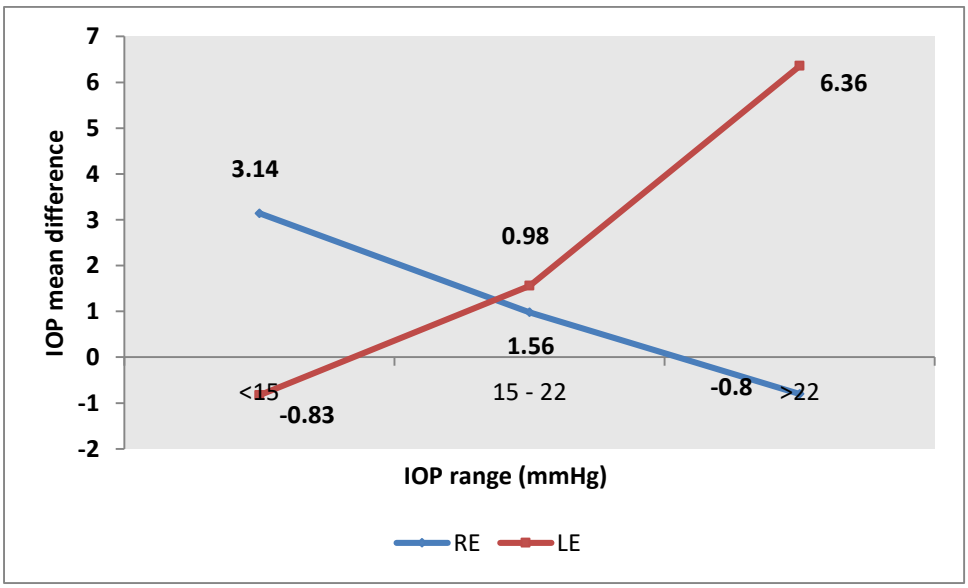
Age distribution



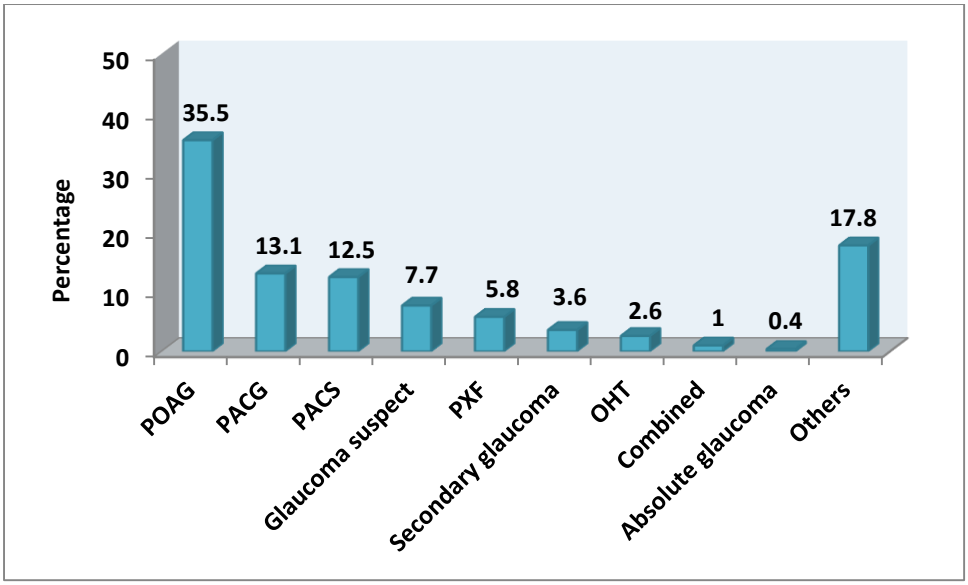
Percentage of IOP distribution in different ranges



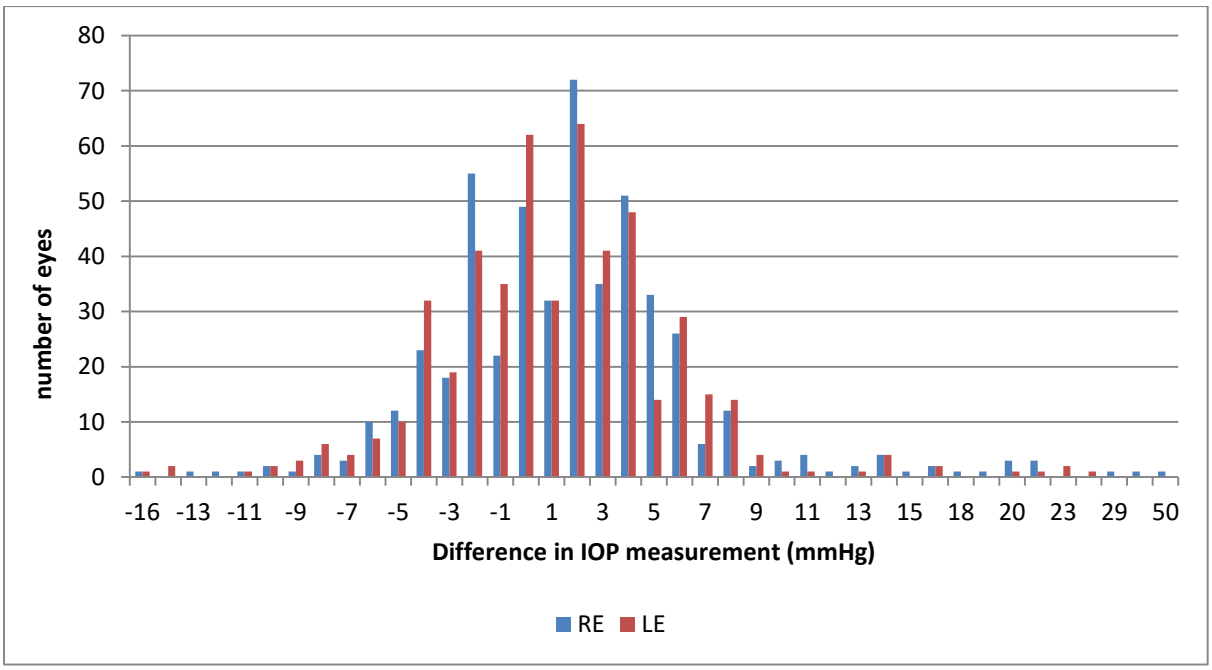
The Mean difference between GAT and Perkins in different IOP range



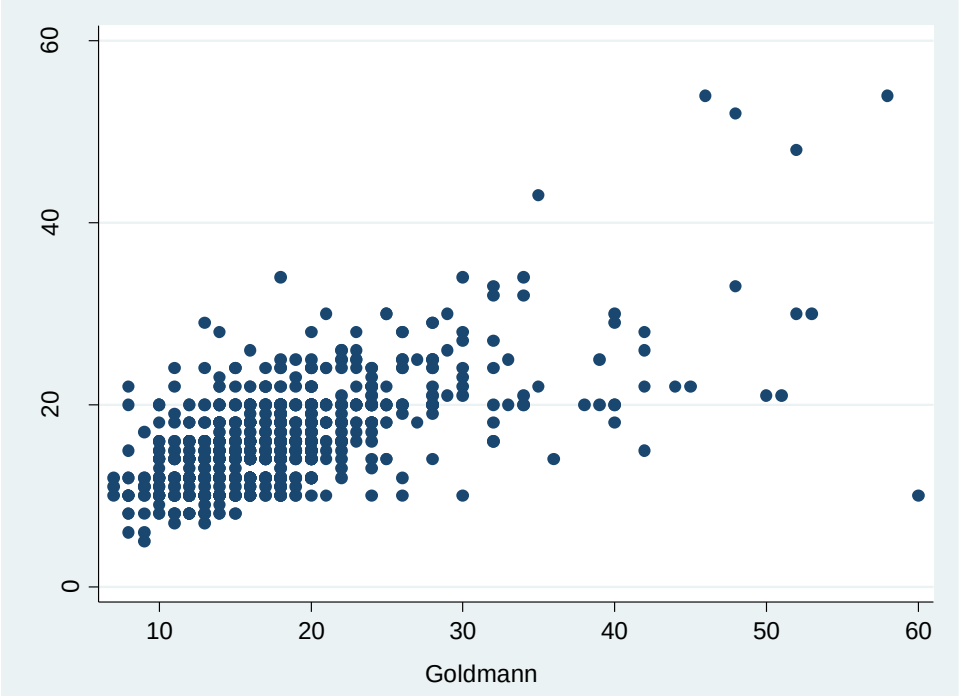
Patients in each glaucoma subgroup:



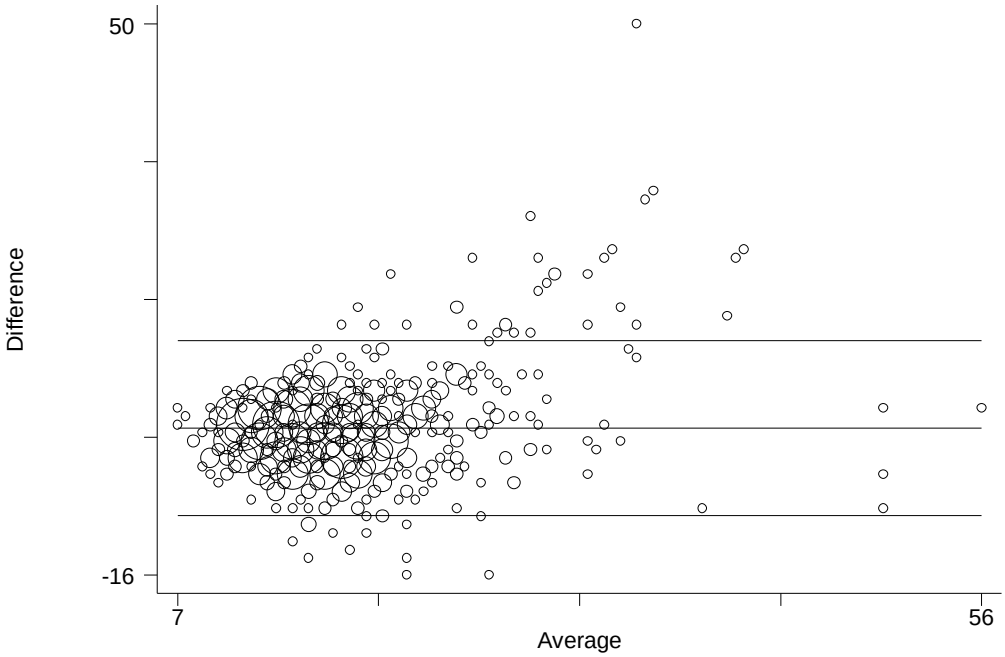
Eye wise difference



Scatter plot between GAT and Perkin's Tonometer



Bland Altman plot:



The Bland Altman graph shows that the mean difference of IOP between the two groups are 1.554(95% CI 1.228 to 1.880) and few differences are outside/closer to the limit lines. The actual limit of agreement is-8.94 to 12.05.

DISCUSSION

Precision in the measurement of IOP is an important prerequisite for management of glaucoma. The “landmark” glaucoma studies have showed that Intraocular Pressure plays an important role in clinical decision making and management of any type of Glaucoma. Goldmann Applantion Tonometer is the most commonly used tonometer in clinical practice because it has been proved to be accurate and precise in measuring IOP. It is easy to incorporate Goldmann Applanation Tonometry into routine slit lamp eye examination, and it shows low intra- and inter observer variability in various studies. Perkin’s Tonometer is a hand held Goldmann type tonometer which precludes the use of slitlamp. Hence Perkin’s Tonometer is used for measuring IOP under anaesthesia, patients who have difficulty in placing their face in slitlamp and in overweight patients in whom IOP may be fasely elevated in Goldmann tonometer due to breath holding and chest compression.

In a study conducted by Arora R et al Goldmann Applanation Tonometer and Perkins tonometer showed good agreement. The limits of agreement between both the instruments were calculated to be -0.64 to +1.08 mmHg (1.96 SD either side of the bias).

In a study by E Eriksson et al , Perkins tonometer showed the highest correlation to Goldmann Applanation Tonometer. The difference

in IOP readings between Perkins and GAT was not statistically significant ($p<0.05$).

Andrade et al demonstrated a strong correlation between the IOP values obtained by direct ocular manometry and Perkin's Applanation Tonometry in horses and cattle. Since both the instruments shares the same physical principles, similar basic instrument construction Perkin's Applanation tonometer should be comparable to Goldmann Tonometer. Multiple studies have showed that Goldmann and Perkin's Tonometer were comparable when done appropriately.

Hence in our study we assessed the reliability of Ophthalmic Assistant in measuring intraocular pressure (IOP) compared to Glaucoma consultant. We observed the mean difference in IOP readings between Perkin's tonometer done by Ophthalmic Assistant and Goldmann applanation by Glaucoma Consultant. Our study revealed that highest correlation is noted in the IOP range of 15-22 mm of Hg followed by IOP ranges of less than 15 mm of Hg. The mean difference in IOP is highest in the IOP group more than 22 mm of Hg.

Our study showed that the interclass correlation value in RE and LE were 0.950 and 0.922 respectively which shows that IOP measurement by ophthalmic assistant is highly correlated to Glaucoma

consultant.The Bland Altman graph shows that the mean difference of IOP between the two groups are 1.554(95% CI 1.228 to 1.880).

Hence we conclude that trained ophthalmic assistant can be used as an alternative for reliable measurement of IOP. This will allow for better use of resources.

CONCLUSION

We conclude that trained ophthalmic assistant can be used as an alternative for reliable measurement of IOP.Training of Midlevel Ophthalmic assistant in measuring intraocular pressure reduces the burden of Ophthalmologists to address the issues of avoidable vision impairment and blindness due to Glaucoma. It will allow for better use of resources in both secondary and tertiary centers. Also in primary vision centers for screening for Glaucoma and referral to higher centers. However proper training and frequent auditing system enhances the outcome. Routine monitoring helps to ensure optimal performance of the midlevel ophthalmic assistant. Hence the study concluded that within an appropriate environment, midlevel ophthalmic assistants can work safely as part of hospital glaucoma team in outpatient departments.

ANNEXURES

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ABBREVIATIONS

IOP	**-**	Intraocular Pressure
GAT	**-**	Goldmann Applanation Tonometer
PAT	**-**	Perkins Applanation Tonometer
POAG	–	Primary open angle glaucoma
PACG	–	Primary angle closure glaucoma
PAC	**-**	Primary angle closure
PACS	–	Primary angle closure suspect
PXF	–	Pseudoexfoliation

PROFORMA

COMPARISON OF IOP ESTIMATION USING PERKINS TONOMETER DONE BY OPHTHALMIC ASSISTANT AND GOLDMANN APPLANATION BY OPHTHALMOLOGIST

Glaucoma Clinic, Aravind Eye Hospital, Madurai

Name:_____ Age: _____ Sex: _____

Phone number: _____ UID No: _____

MR Number: _____ Study No.: _____

Applanation Tonometry		**Time of measurement**	**Perkins Tonometry**		**Time of measurement**	**Central corneal thickness**
Right Eye			**Right Eye**			
Left Eye			**Left Eye**			

Informed Consent form to participate in a Study

Study Title:

Comparison of intraocular pressure (IOP) estimation by Perkins tonometer done by Ophthalmic Assistant and Goldmann Applanation Tonometer done by Ophthalmologist

Protocol Number:

Subject's Name: _____Subject's Initials: _____

Subject ID No: _____ Date of Birth / Age: _____

		Please put initial in the box (Subject)
(i)	I confirm that I have understood the information about the study, procedures and treatments for the above study and have had the opportunity to ask questions and I received satisfactory answers to all of my questions. I have been given a copy of the informed consent form to take home	[ ]
(ii)	I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. However, this is may not be possible for certain surgical procedures	[ ]

(iii)	I understand that the Investigator of the study to access my health records for the research purpose. However, I understand that my identity will not be revealed in any information released to third parties or published.	[ ]
(iv)	I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s)	[ ]
(v)	I agree to take part in the above study.	[ ]

ARAVIND MEDICAL RESEARCH FOUNDATION
Institutional Ethics Committee
(REGISTRATION NO. ECR/182/INST/TN/2013 DATED 20.04.2013)

20th December 2018

To
Dr.Lakshmi Malar
MS Resident
Aravind Eye Hospital
Madurai

Dear Dr.Lakshmi Malar,

Thesis Title: **Comparison of Intraocular Pressure (IOP) estimation by Perkins Tonometer done by Ophthalmic Assistant and Goldmann Applanation Tonometer done by Ophthalmologist**

IEC Code: **IEC201800298**

Thank you for submitting your thesis and seeking the approval from the ethics committee. The documents provided by you for consideration which include the thesis protocol and informed consent forms were reviewed for the research methodology and scientific content. The Ethical committee did not find any correction and has recommended the thesis to go ahead in the present form.

Thanking you

Yours Sincerely,

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
ARAVIND MEDICAL RESEARCH FOUNDATION
No.1, Anna Nagar, Madurai-625 020

Dr.R.Sharmila
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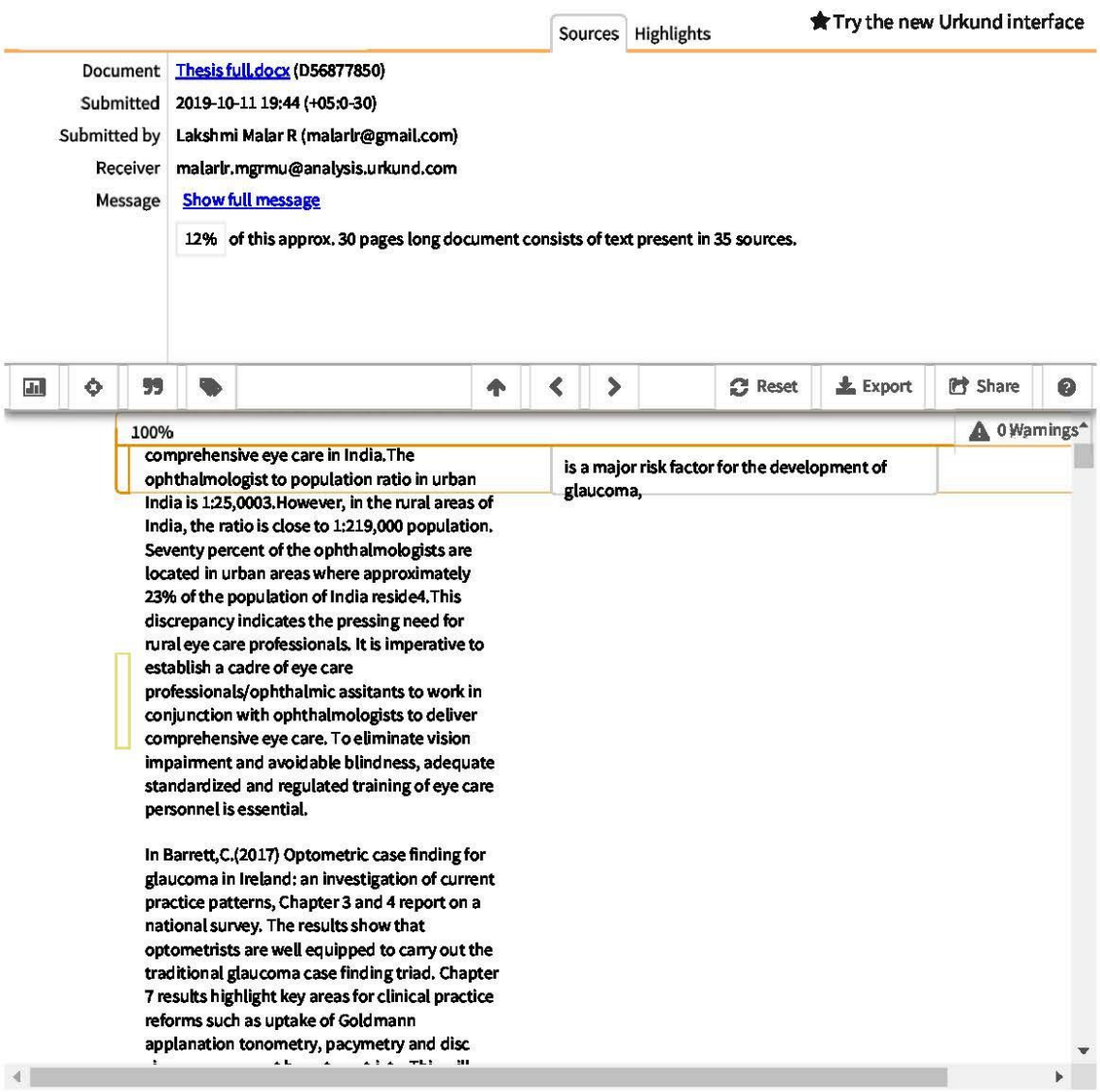
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In Barrett,C.(2017) Optometric case finding for glaucoma in Ireland: an investigation of current practice patterns, Chapter 3 and 4 report on a national survey. The results show that optometrists are well equipped to carry out the traditional glaucoma case finding triad. Chapter 7 results highlight key areas for clinical practice reforms such as uptake of Goldmann applanation tonometry, pacymetry and disc
is a major risk factor for the development of glaucoma,