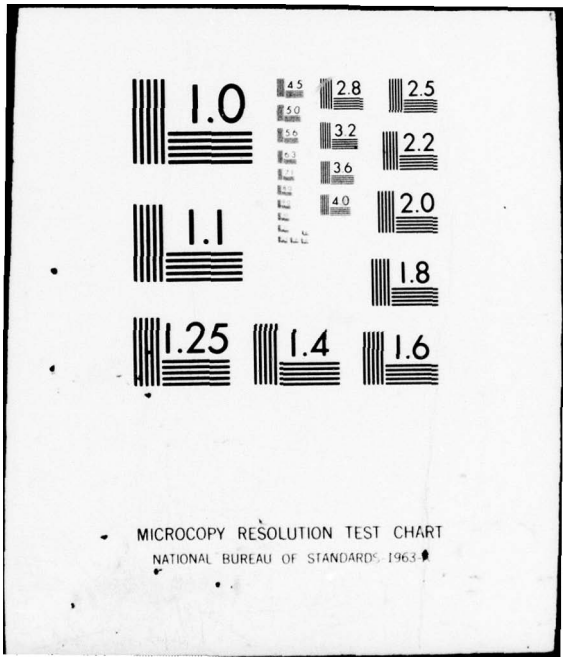
AD-A046 413 SCHOOL OF AEROSPACE MEDICINE BROOKS AFB TEX F/G 6/5
GLAUCOMA: A REVIEW FOR THE USAF FLIGHT SURGEON, (U)
SEP 77 R P RYAN, T J TREDICI
UNCLASSIFIED SAM-TR-77-17 NL

| OF |
AD
A046413

END
DATE
FILMED
12-77
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

REVIEW 3-77

12

AEROMEDICAL REVIEW

GLAUCOMA: A REVIEW FOR THE USAF FLIGHT SURGEON

September 1977

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This review was submitted by personnel of the Aerospace Medicine Branch, Education Division, and the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7755-16-03.

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This review has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This review has been reviewed and is approved for publication.

Thomas J Tredici for

ROBERT P. RYAN, Captain, USAF, MC
Project Scientist

Thomas J Tredici

THOMAS J. TREDICI, Colonel, USAF, MC
Supervisor

Robert G McIver

ROBERT G. MCIVER
Brigadier General, USAF, MC
Commander

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: Aeromedical Review 3-77	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): GLAUCOMA: A REVIEW FOR THE USAF FLIGHT SURGEON	5. TYPE OF REPORT & PERIOD COVERED: N/A
6. PERFORMING ORG. REPORT NUMBER: SAM-TR-77-17	
7. AUTHOR(s): Robert P. Ryan, Captain, USAF, MC, FC; Thomas J. Tredici, Colonel, USAF, MC, FS	8. CONTRACT OR GRANT NUMBER(s): SAM-Review-3-77
9. PERFORMING ORGANIZATION NAME AND ADDRESS: USAF School of Aerospace Medicine (EDK, NGOP); Aerospace Medical Division (AFSC); Brooks Air Force Base, Texas 78235	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62202F; 7755-16-03
11. CONTROLLING OFFICE NAME AND ADDRESS: USAF School of Aerospace Medicine (EDK, NGOP); Aerospace Medical Division (AFSC); Brooks Air Force Base, Texas 78235	12. REPORT DATE: Sept 1977; 13. NUMBER OF PAGES: 44
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 48 p.	15. SECURITY CLASS. (of this report): Unclassified; 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Glaucoma, tonometry, Schiotz, applanation, tonography, visual fields, ophthalmoscopy, perimetry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

With the maturation of the USAF flying force, glaucoma has become a more significant disease entity for the flyer. The Ophthalmology Branch at the USAF School of Aerospace Medicine has developed a program to identify and treat USAF flying personnel with this condition. A key element in this program is the flight surgeon. He screens all flying personnel for glaucoma by performing tonometry on all flyers over the age of 39. This volume reviews the disease condition itself, as well as ophthalmoscopy and perimetry, but primarily →

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

317000

20. ABSTRACT (Continued)

should serve as a manual on tonometry. In recent years even this relatively simple procedure has been altered and technically upgraded so that the non-ophthalmologist may be confused by the variety of instruments in use. It is the aim of this publication to clarify and simplify tonometry and glaucoma for the USAF Flight Surgeon.

GLAUCOMA: A REVIEW FOR THE USAF FLIGHT SURGEON

INTRODUCTION

Glaucoma is an eye disease characterized by an elevation of intraocular tension and cupping of the optic disc, and results in nerve bundle damage with reduction of the visual field. The initial process in glaucoma involves a change in the production or outflow of the aqueous humor, resulting in an increase in the intraocular pressure (IOP). It should be noted that IOP does not in itself establish a diagnosis of glaucoma; optic nerve damage with constriction of the visual field must be present to confirm the diagnosis. The presence of any of these findings on physical exam should be sufficient to warrant further evaluation.

Several classification schemes for glaucoma exist. The one presented here is used because it organizes the glaucomas essentially in order of decreasing frequency of occurrence in a flying population.

A. Primary Glaucoma

1. Open-angle glaucoma
2. Narrow-angle glaucoma

    a. Acute
    b. Subacute or chronic

B. Secondary Glaucoma

1. Due to trauma

    a. Massive hemorrhage into the anterior chamber
    b. Massive hemorrhage into the posterior chamber
    c. Corneal or limbal laceration with iris prolapse into wound
    d. Retrodisplacement of iris root following contusion

2. Associated with topical corticosteroids

3. Due to changes of the lens

    a. Dislocation
    b. Intumescence
    c. Phacotoxic or phacoanaphylactic
    d. Pseudoexfoliation of the lens capsule
    e. Spherophakia

4. Due to changes of the uveal tract

   a. Iridocyclitis
   b. Tumor
   c. Essential iris atrophy

5. Following surgical procedures

   a. Epithelial ingrowth into the anterior chamber
   b. Failure of prompt restoration of the anterior chamber following cataract extraction (flat chamber)

6. Other

C. Congenital Glaucoma

1. Primary congenital or infantile glaucoma
2. Glaucoma associated with congenital anomalies

ANATOMY OF THE NORMAL EYE

The eye is a bulb composed of three layers: the fibrous layer, composed of cornea and sclera; the vascular layer (uvea), composed of choroid, ciliary body, and iris; and the internal layer, the retina. (The anatomy of the normal eye is depicted in Figure 1.) The cornea and sclera give the eye its shape. The cornea, constituting the anterior one-sixth of the fibrous layer, is clear. It appears as a section of a smaller sphere attached to a larger sphere, the sclera. The sclera is the opaque white of the eye, and accounts for the posterior five-sixths of the fibrous layer. The junction of the cornea and sclera is known as the limbus. On the inner surface is the area where the aqueous humor filters through the trabecular meshwork from the anterior chamber into the canal of Schlemm. The choroid, accounting for the majority of the vascular layer, or uveal tract, lines the inner surface of the sclera. It furnishes much of the blood supply to the eye, including that to the outer one-half of the retina. The choroid extends forward to the ora serrata where it continues as the ciliary body.

The anterior area of the ciliary body is composed of ciliary muscle and ciliary processes. The ciliary processes are responsible for the secretion of most of the aqueous humor. The suspensory ligament of the lens arises between the processes. The ciliary muscle enables the lens to accommodate for near vision by allowing the lens to become more spherical as its circular ciliary muscle fibers contract, thus relaxing the zonular fibers. The iris originates from the ciliary body and acts as a diaphragm controlling the amount of light reaching the retina through the pupil. The iris partitions the space between the cornea and lens into the anterior and posterior chambers. (See Figure 2.)

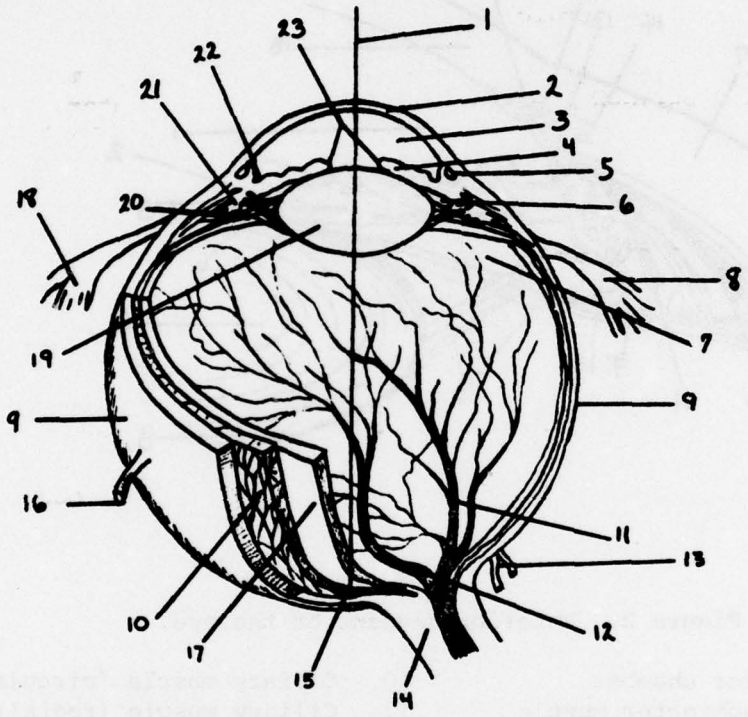


Figure 1. Anatomy of the normal eye.

1. Visual axis
2. Cornea
3. Anterior chamber
4. Iris
5. Schlemm's canal
6. Posterior chamber
7. Vitreous
8. Medial rectus muscle
9. Sclera
10. Choroid
11. Retinal vessels
12. Central retinal vessels
13. Ciliary artery and nerve
14. Optic nerve
15. Fovea centralis
16. Vortex vein
17. Retina
18. Lateral rectus muscle
19. Lens
20. Ciliary zonule
21. Ciliary muscle
22. Angle of anterior chamber
23. Pupil

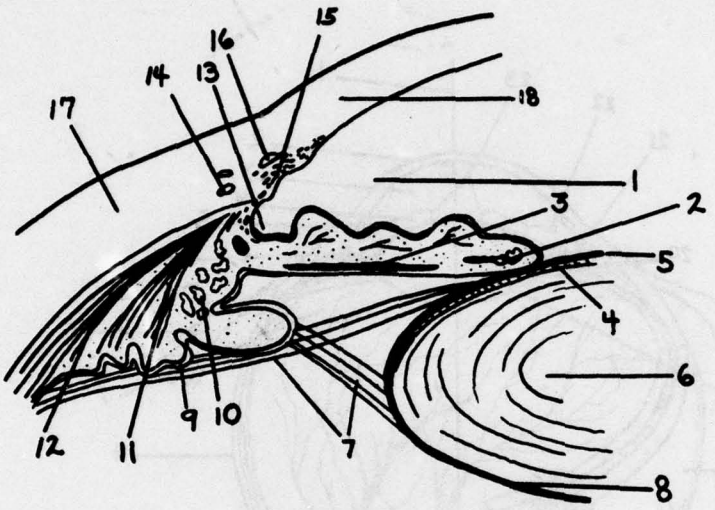


Figure 2. Anterior segment of the eye.

1. Anterior chamber
2. Iris sphincter muscle
3. Iris dilator muscle
4. Lens epithelium
5. Anterior lens capsule
6. Lens nucleus
7. Zonular fibers
8. Posterior lens capsule
9. Ciliary epithelium
10. Ciliary muscle (circular)
11. Ciliary muscle (radial)
12. Ciliary muscle (meridional)
13. Angle of anterior chamber
14. Aqueous vein
15. Trabecular meshwork
16. Canal of Schlemm
17. Sclera
18. Corneal stroma

The anterior surface of the iris lies just posterior to the corneoscleral junction where the trabecular meshwork is found; this is also known as the angle of the anterior chamber. The retina is the light-sensitive layer of the eye. It lines the inner surface of the choroid, extending forward to the ora serrata. Posteriorly, it becomes thicker and eventually continuous with the optic nerve. The nerve fibers of the retina converge on the optic disc in the pattern shown in Figure 3.

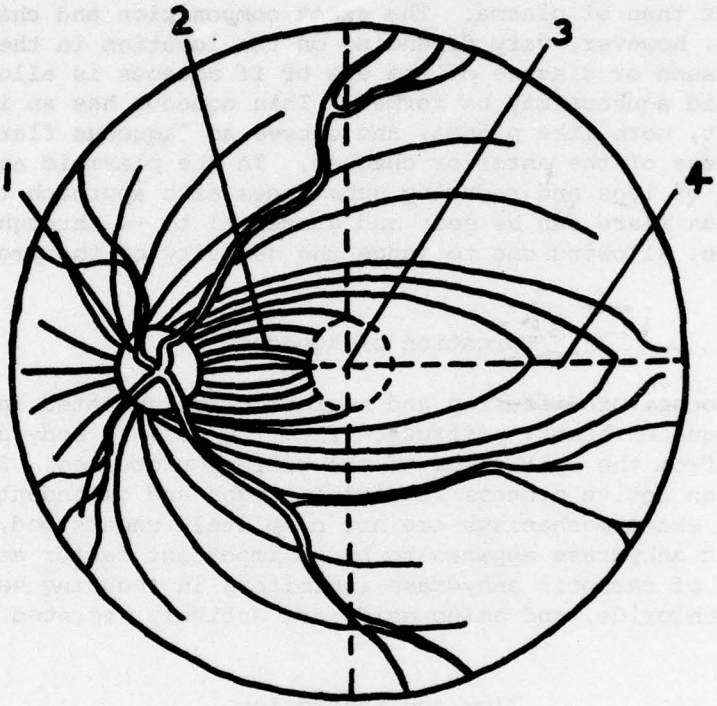


Figure 3. Nerve fiber pattern of retina: (1) optic nerve; (2) papillo-macular bundle; (3) fovea centralis; (4) horizontal raphe.

PHYSIOLOGY OF THE AQUEOUS HUMOR

Composition

The aqueous humor volume is approximately 125 ml. The aqueous, as one of its functions, provides nutrition to the cornea and lens; these structures are not supplied by blood vessels. It is also responsible for the oxygen and carbon dioxide transport for the lens and posterior surface of the cornea; the remainder of the gaseous exchange of the cornea occurs with the ambient air. The role of the aqueous in nutrition is reflected in its composition. Its protein content is 0.02% as opposed to 7% in serum. The albumin/globulin ratio is the same as in serum. The aqueous contains free amino acids, but little data are available on their concentrations. Reducing substances are present at about 50%-60% of their levels in blood. Concentrations of electrolytes differ slightly from those in serum; sodium, calcium, potassium,

magnesium, and bicarbonate levels are slightly lower than in serum; and chloride and hydrogen ion concentrations are slightly higher. The osmotic pressure of the aqueous (specific gravity about 1.025) is slightly higher than of plasma. The exact composition and characteristics of the aqueous, however, vary depending on the location in the eye. In response to trauma or disease of the eye or if aqueous is allowed to escape, plasmoid aqueous may be formed. This aqueous has an increased protein content, more like plasma, and causes an "aqueous flare," or slight cloudiness of the anterior chamber. In the plasmoid aqueous, the concentrations of ions and reducing substances also approach those of plasma. Aqueous flare can be seen and graded +1 to +4 through the slit-lamp microscope, allowing one to judge the severity of the process.

Formation of Aqueous

A dual process of diffusion and secretion is indicated in the formation of aqueous humor: diffusion from the ciliary body and iris, and secretion from the epithelium of the ciliary processes. Secretion of aqueous is an active process requiring oxygen and dependent on temperature. The exact mechanisms are not completely understood, but the enzyme carbonic anhydrase appears to be an important factor as evidenced by the success of carbonic anhydrase inhibitors in reducing secretion. Hydrogen ion, chloride, and amino acids are actively secreted.

Flow and Absorption

Aqueous normally flows from the posterior chamber through the pupil into the anterior chamber at a rate of 1.5-2.0 µl/min. The flow in the anterior chamber is then peripherally toward the angle formed by the sclerocorneal junction and the iris. Here the fluid filters through the multiple layers of perforated tissue in the trabecular meshwork. This meshwork accounts for about 75% of the outflow resistance. The majority of the resistance is in the deeper layers of the meshwork just adjacent to Schlemm's canal. The aqueous enters Schlemm's canal and then progresses into the aqueous veins and venous circulation. (See Figure 4.)

Factors Affecting Intraocular Pressure

Several factors are known to affect intraocular pressure. IOP varies as much as 5 mm with respiration, presumably as a result of changes in venous return to the heart, and 1-2 mm with arterial pulsation. Neural-emotional factors affect IOP, especially chronic emotional stress; also endocrine influences, e.g., corticosteroid-induced pressure increases are well recognized. Succinylcholine is another drug that raises pressure. Pilocarpine lowers IOP, as do most parasympathomimetics, by increasing facility of outflow; acetazolamide, epinephrine derivatives, and cardiac glycosides lower IOP by decreasing production. Exercise has

been shown to lower pressure for up to 2.5 hours after the exercise has ceased. The IOP also changes with a diurnal cycle, tending to be higher in the early morning and lower late in the day.

Figure 4. Flow of aqueous in anterior segment: (1) ciliary epithelium; (2) trabecular meshwork; (3) aqueous veins.

PATHOPHYSIOLOGY OF THE GLAUCOMAS

Open Angle

The most common type of glaucoma is open-angle, or chronic simple, glaucoma. It is bilateral and progresses slowly, without symptoms, until permanent damage to vision has occurred. In the overwhelming majority of cases, the pressure elevation is caused by obstruction to outflow in the deeper layers of the trabecular meshwork adjacent to Schlemm's canal. Rarely, in about 1% of cases, the pressure elevation is due to an increased production of aqueous. If not detected, the pressure rise may lead to cupping and atrophy of the optic disc, with resulting visual field loss. These effects may be due to either of two factors, or a combination of both: (1) the pressure acting directly on

the optic nerve head, or (2) a pressure-induced vascular insufficiency in the area of the optic disc. The resulting field loss follows certain characteristic patterns. The cupping and visual field defects will be discussed further under the evaluation section. Figure 5 shows the open and narrow angles of the anterior chamber.

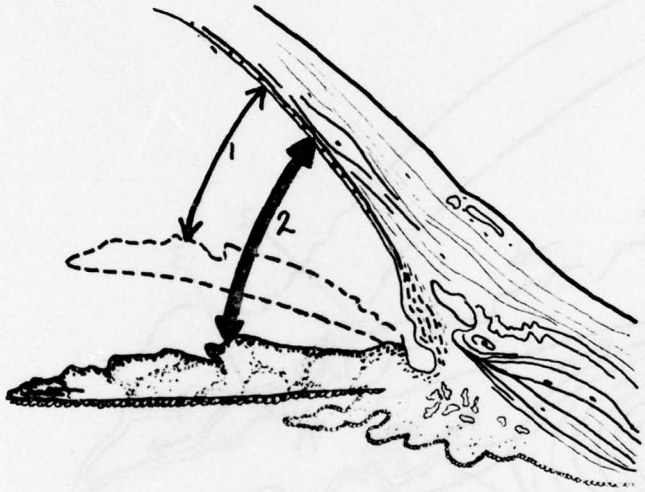


Figure 5. Anterior chamber angle: (1) narrow angle; (2) open angle.

Certain individuals are considered predisposed to open-angle glaucoma. Conditions which should arouse suspicion are:

1. Applanation reading of 21 mmHg or greater
2. Schiotz scale reading of 3 or less with the 5.5-g weight
3. Visual field changes
4. Prominent cupping of the optic disc
5. Family history of glaucoma
6. IOP elevation following use of topical corticosteroids
7. High myopia
8. Thyrotropic exophthalmos
9. Central retinal vein occlusion

10. Retinal detachment
11. Krukenbergs spindle and/or dense trabecular pigment band
12. Endothelial dystrophy of the cornea
13. Pseudoexfoliation of the lens capsule
14. Diabetes mellitus

Of all adult glaucomas, 60%-70% are of the open-angle type. Its prevalence in the general population over age 40 is approximately 2%. In the USAF flying population this figure is closer to 1%, probably because of the absence of high myopia in flying personnel and the fact that most of the other conditions cited above are disqualifying for flying.

Low-Pressure Glaucoma

Low-pressure glaucoma, or pseudoglaucoma, is somewhat of a misnomer; it is actually a group of variants of open-angle glaucoma in which the pressure is or has been elevated but appears normal when measured. Conditions included in this group are demonstrated as follows:

1. Individuals with open-angle glaucoma but low scleral rigidity. This results in false low or normal readings during Schiotz tonometry. True values may be obtained by applanation tonometry or by using a combination of weights on the Schiotz tonometer.

2. Individuals whose IOP is measured at a low point in their diurnal cycle, resulting in a false low or normal reading. IOP must be measured at different times during the day to obtain a true value.

3. Individuals who have had an increase in IOP at some time in the past, with residual damage, but have normal pressures later; there are also those who have damage to the optic nerve head due to vascular insufficiency or other causes.

Acute Angle-Closure Glaucoma

Angle-closure, or narrow-angle, glaucoma occurs when the root of the iris moves forward (Fig. 6) to block the angle of the anterior chamber. The resulting blockage of the aqueous outflow tract causes a rapid increase in the intraocular pressure (Fig. 7). The individual has a sudden blurring of vision in the affected eye with excruciating pain. This visual blurring is due to edema of the cornea caused by the increased pressure. Nausea, vomiting, and abdominal pain may occur due to vagal stimulation triggered by the increase in IOP. On physical exam, the eye appears acutely red about an hour after the attack begins. The pupil is fixed and semidilated and may be irregular. Other conditions causing an acutely inflamed eye include iritis and conjunctivitis; however, the pupil will be constricted in iritis, and the vision will be normal in

conjunctivitis. Angle-closure glaucoma occurs predominantly in people over age 55. Several factors may predispose an individual to angle-closure glaucoma:

1. A shallow anterior chamber--generally hereditary and therefore bilateral. An individual who has an attack in one eye is likely to have one in the other eye also.

2. Eyes with short axial length (axial hyperopia).

3. Physiologic iris bombé; a condition in which the iris lies in contact with the anterior surface of the lens in a sufficient area around the pupil to impede the flow of aqueous from the posterior chamber. The resulting pressure increase in the posterior chamber pushes the peripheral iris forward against the trabecular meshwork blocking aqueous outflow.

4. Enlarged lens--the size increases with age and becomes more rounded during accommodation, with the potential to push the iris forward against the trabecular meshwork.

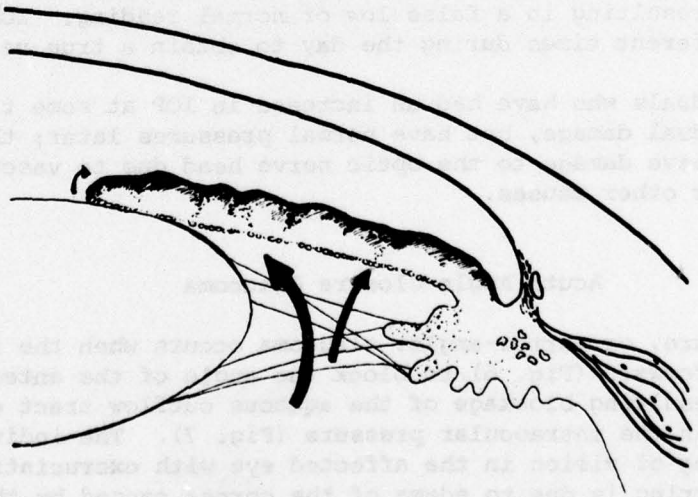


Figure 6. Iris block with pressure buildup in posterior chamber.

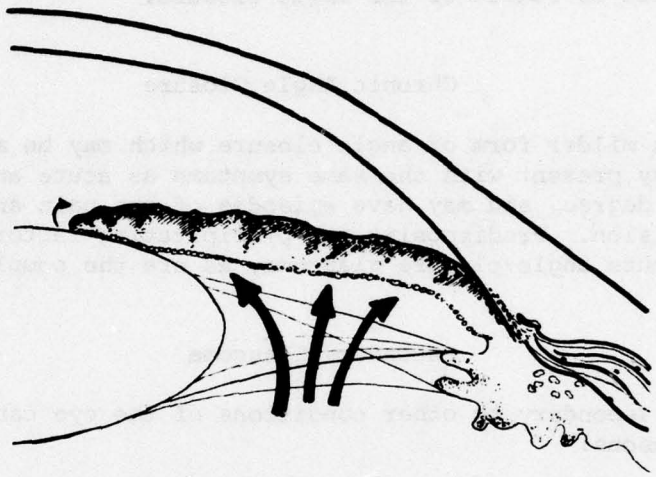


Figure 7. Blockage of the trabecular meshwork with rapid rise in intraocular pressure.

Other factors may actually precipitate the attack:

1. An increase in thickness of the iris with mydriasis--by exposure to darkness or by administration of mydriatic agents.

2. Congestion or edema of the iris, ciliary body, or choroid may increase the volume of the posterior chamber, resulting in displacement of the peripheral iris against the trabecular meshwork. A rapid increase in the production of aqueous could have the same effect.

If the acute attack is not treated within the first few hours, the inflammatory response may cause complications:

1. Peripheral anterior synechiae--adhesions formed between the iris and the trabecular meshwork. They begin to form several hours after the angle closure occurs.

2. Posterior synechiae--same process as above but between iris and lens.

3. Changes in the optic disc and visual fields as described under open-angle glaucoma.

4. A variety of other problems including cataract formation, atrophy of an area of the iris, and a decreased facility of aqueous outflow in spite of relief of the angle closure.

Chronic Angle Closure

This is a milder form of angle closure which may be asymptomatic. The patient may present with the same symptoms as acute angle closure, but milder in degree, and may have episodes of eye pain and brief blurring of vision. Predisposing and precipitating factors are the same as those in acute angle-closure glaucoma, as are the complications.

Secondary Glaucoma

Glaucoma secondary to other conditions of the eye can occur for a variety of reasons:

1. Changes of the lens--including traumatic dislocation, swelling of the lens due to cataractous change, and toxic or anaphylactic reaction of the uveal tract due to breakdown products of the lens released during cataract formation.

2. Conditions of the uveal tract--including uveitis; tumors, specifically melanomas; and atrophy of the iris.

3. Trauma to the eye--hemorrhage into the anterior chamber, prolapse of the iris into a corneal or limbal laceration, and damage to the trabecular meshwork associated with a contusion severe enough to deepen the angle and expose the ciliary body.

4. Post surgery--after cataract surgery.

Congenital Glaucoma

The poor visual acuity in most individuals with congenital glaucoma will probably preclude their presence in any flying population, be it military or civilian.

EVALUATION

A thorough examination of any individual over age 40 should include an evaluation for glaucoma. This is especially true for flying personnel because any decrement in visual fields may dictate removal from

flying status, in addition to the deleterious effects on the individual's well-being. The FAA is sufficiently concerned with glaucoma to require all air traffic controllers to undergo yearly tonometry.

Although screening for glaucoma usually begins with tonometry, the history is still important, especially once an elevated intraocular pressure is detected. Information on family history and concurrent medical conditions and therapy, in addition to any symptoms experienced, can help in determining the etiology of the pressure increase.

Many diagnostic techniques are available for determining the degree and etiology of an increase in IOP and for evaluating the other findings of glaucoma. The initial step should be to examine the external eye for any unusual findings, especially the presence of an acutely red eye. The cause of an acutely red eye in the absence of blurring of vision or an irregular fixed pupil is usually conjunctivitis. This is a contraindication to any type of tonometry in which the instrument must come in contact with the eye. Epidemic keratoconjunctivitis and other infections may be spread by this route.

Tonometry

Tonometry measures the intraocular pressure within the eye. Several different instruments exist for this purpose. While the mechanics of the instruments differ, the basic principle is to measure the IOP indirectly by determining the counterpressure necessary to deform an area of the cornea.

Schiotz Tonometry--The most common type of tonometer in use is the Schiotz (Fig. 8). It determines intraocular pressure by measuring the depth of an indentation made in the cornea by a plunger of known weight. The indentation, through a mechanical linkage, is measured on a scale from 0 to 20, each mark representing .05 mm of indentation. The instrument consists of a cylinder with an integral footplate enclosing a plunger, a handle which slides along the cylinder, a scale and frame attached to the cylinder, and a pointer pivoting on the frame and actuated by the plunger. Weights are added to the plunger above the cylinder as necessary. The most accurate measurements are obtained when the weight of the plunger (5.5, 7.5, 10 or 15 g) is adjusted to give a scale reading between 3 and 7. The scale reading and plunger weight are then used to determine the IOP in millimeters of mercury on a standardized chart (Fig. 9). The Schiotz tonometer has many advantages as a screening instrument for glaucoma. Its construction is relatively simple; it is familiar to many clinicians through extensive use; and it is portable, easy to use, and relatively inexpensive.

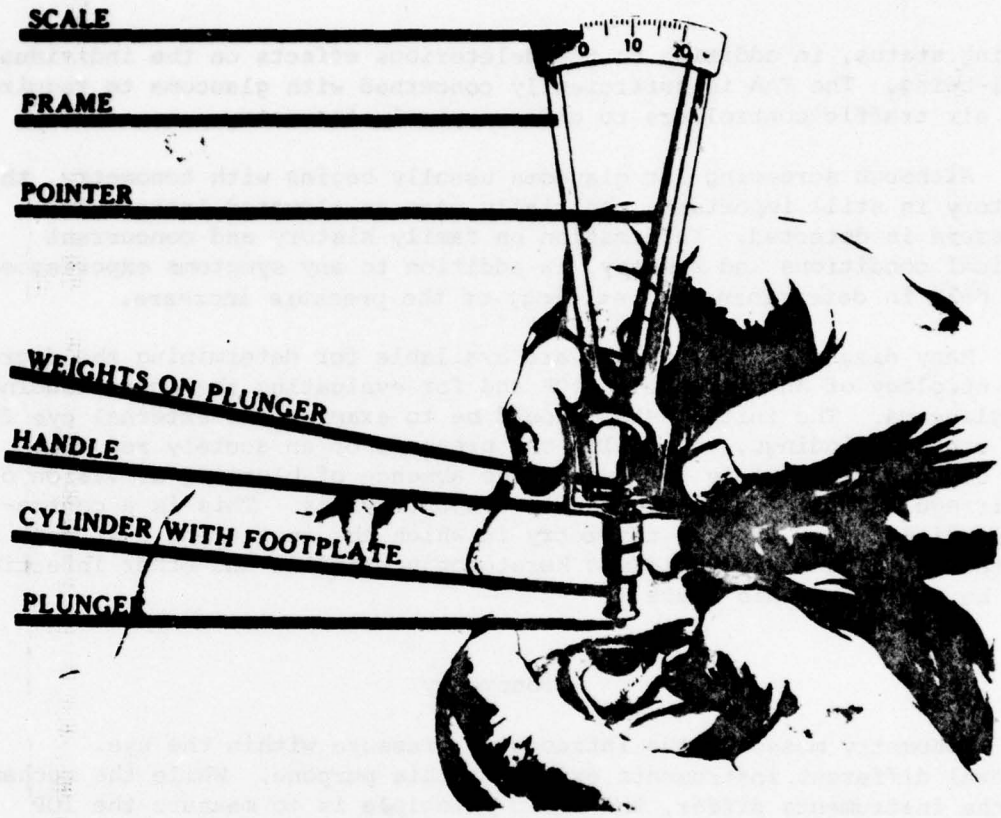


Figure 8. Schiotz tonometer.

Usage--The patient should be positioned supine on the examining table. The procedure--and if the patient shows interest, the reason for tonometry--should be explained to him. This should help put the patient at ease. He should be instructed to look up or down, and one or two drops of a short-acting topical anesthetic--0.5% Ophthetic, Ophthaine, Doroicaine, or tetracaine--are instilled in the eye. By looking up or down (Fig. 10), the patient will avoid seeing the drops fall into his eye, and the resulting anticipatory blink that would reduce the amount of anesthetic getting into his eye. A properly cleaned instrument should then be checked on the test block to assure calibration and free movement of the plunger. The examiner should instruct the patient to fix, with both eyes open, on some spot on the ceiling or, better yet, on his (the patient's) thumb held directly overhead. The patient can use his right hand to keep his right lower lid open by gently holding the lid with his fingers on the lower bony rim (Fig. 11a). This will enable the examiner, standing to the right of the patient, to place the fingers of his left hand on the upper lid, holding it open against the supraorbital ridge, while using the other hand to hold the tonometer. The instrument is then lowered to within 2 or 3 mm of the cornea of the

R	5.5 gm.	Load, gm. 7.5 gm.	10 gm.	15 gm.
Tonometer Reading		Pressure, mm. Hg		
0.0	41.5	59.1	81.7	127.5
0.5	37.8	54.2	75.1	117.9
1.0	34.5	49.8	69.3	109.3
1.5	31.6	45.8	64.0	101.4
2.0	29.0	42.1	59.1	94.3
2.5	26.6	38.8	54.7	88.0
3.0	24.4	35.8	50.6	81.8
3.5	22.4	33.0	46.9	76.2
4.0	20.6	30.4	43.4	71.0
4.5	18.9	28.0	40.2	66.2
5.0	17.3	25.8	37.2	61.8
5.5	15.9	23.8	34.4	57.6
6.0	14.6	21.9	31.8	53.6
6.5	13.4	20.1	29.4	49.9
7.0	12.2	18.5	27.2	46.5
7.5	11.2	17.0	25.1	43.2
8.0	10.2	15.6	23.1	40.2
8.5	9.4	14.3	21.3	38.1
9.0	8.5	13.1	19.6	34.6
9.5	7.8	12.0	18.0	32.0
10.0	7.1	10.9	16.5	29.6
10.5	6.5	10.0	15.1	27.4
11.0	5.9	9.0	13.8	25.3
11.5	5.3	8.3	12.6	23.3
12.0	4.9	7.5	11.5	21.4
12.5	4.4	6.8	10.5	19.7
13.0	4.0	6.2	9.5	18.1
13.5		5.6	8.6	16.5
14.0		5.0	7.8	15.1
14.5		4.5	7.1	13.7
15.0		4.0	6.4	12.6
15.5			5.8	11.4
16.0			5.2	10.4
16.5			4.7	9.4
17.0			4.2	8.5
17.5				7.7
18.0				6.9
18.5				6.2
19.0				5.6
19.5				4.9
20.0				4.5

Figure 9. 1955 CALIBRATION SCALE FOR SCHIOTZ TONOMETERS
(Approved by the Committee on Standardization of Tonometers of the American Academy of Ophthalmology and Otolaryngology.)

eye to be examined, as the patient continues to look at a fixation point with the other eye. After a pause of several seconds, the footplate is gently settled onto the cornea. As the footplate comes to a rest on the cornea, indicated by the cylinder sliding up within the handle, the examiner should note the reading on the scale. The procedure is then repeated for the left eye, substituting the opposite hand and eye as outlined above. An alternate method of holding the lids open is for the examiner, holding the tonometer in his right hand and standing to the patient's right, to use the forefinger and thumb of his left hand to hold the upper and lower lids, respectively, of the right eye open (Fig. 11b). The procedure for the left eye is for the examiner, still standing to the patient's right, to reach his left hand around the top of the patient's head and hold the upper and lower eyelids open with the thumb and forefinger, respectively (Fig. 11c). It is important that the patient maintain fixation, so the examiner should not place his head into the patient's line of sight with the fixating point. Slight fluctuations of the pointer reflect arterial pulsation within the eye. The scale reading and plunger weight are used to determine the IOP, and all values are recorded on the worksheet. Should the scale reading be less than 3 with the standard 5.5-g weight, then successive weights (7.5, 10, or 15 g) should be added to achieve a reading between 3 and 7 on the instrument (see Fig. 9).

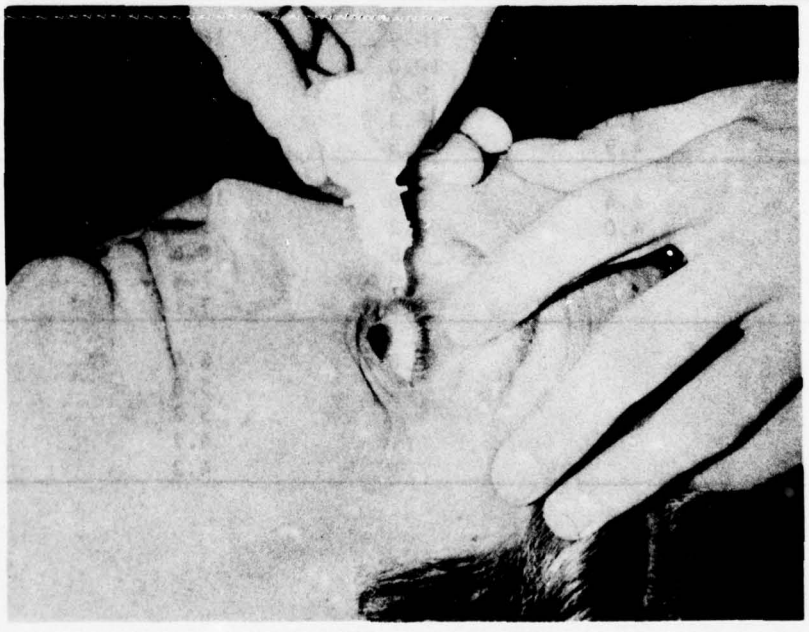
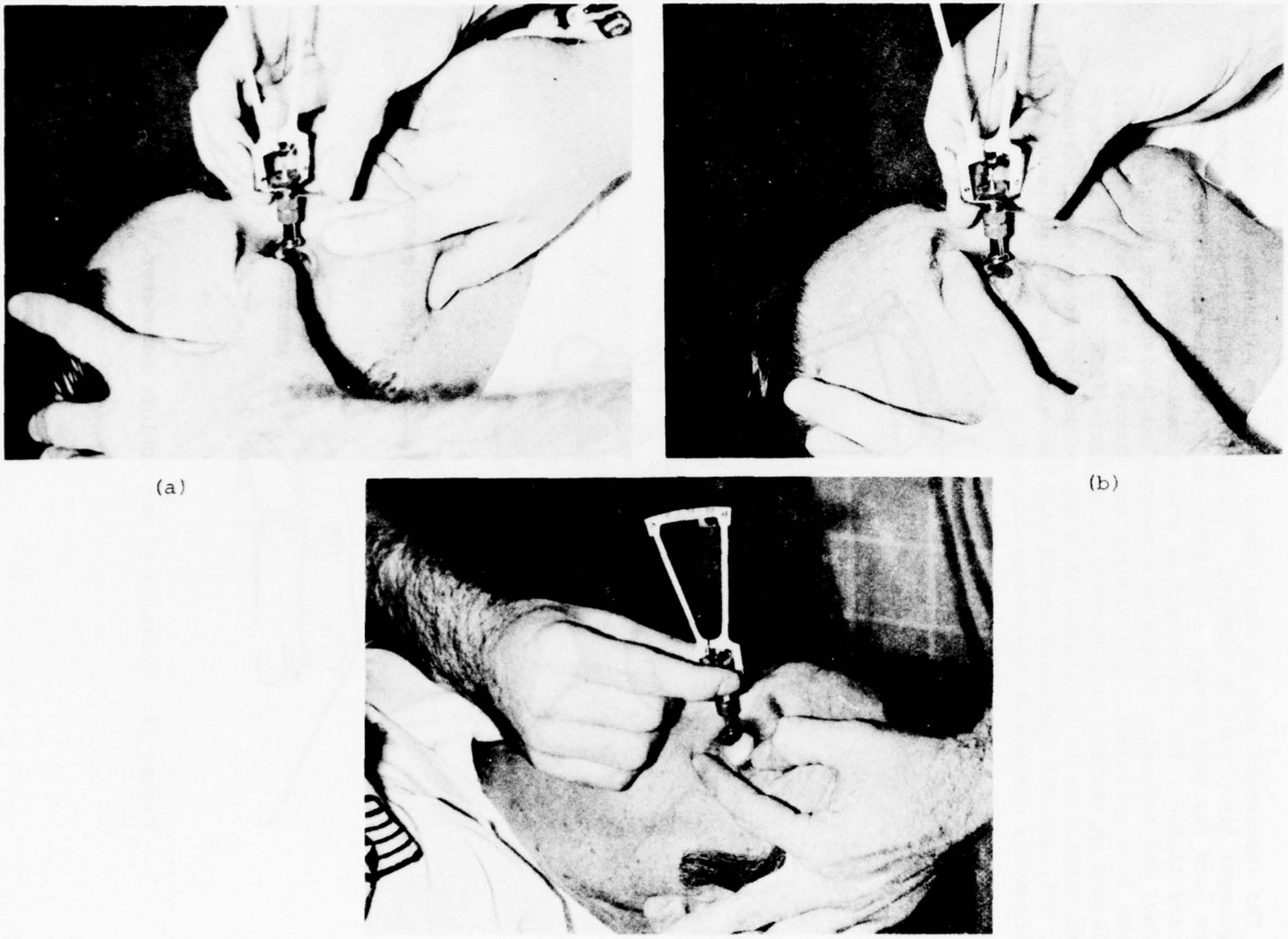


Figure 10. Instillation of anesthetic.



(a) (b)

(c)

Figure 11. Schiotz tonometry.

The instrument must be kept clean. Between patients, the footplate and plunger tip should be cleaned. Alcohol- or zepharin-soaked swabs may be used for this purpose, and then the footplate should be wiped with dry tissue. The instrument is stored in its case. At the end of the day, the tonometer should be disassembled (weight and plunger removed from cylinder). The plunger and channel in the cylinder should be cleaned thoroughly with alcohol or zepharin (Fig. 12). If an ultraviolet sterilizer is available, this may be used to store the instrument (Fig. 13), but the footplate should still be wiped between patients and the tonometer cleaned at the end of the day.

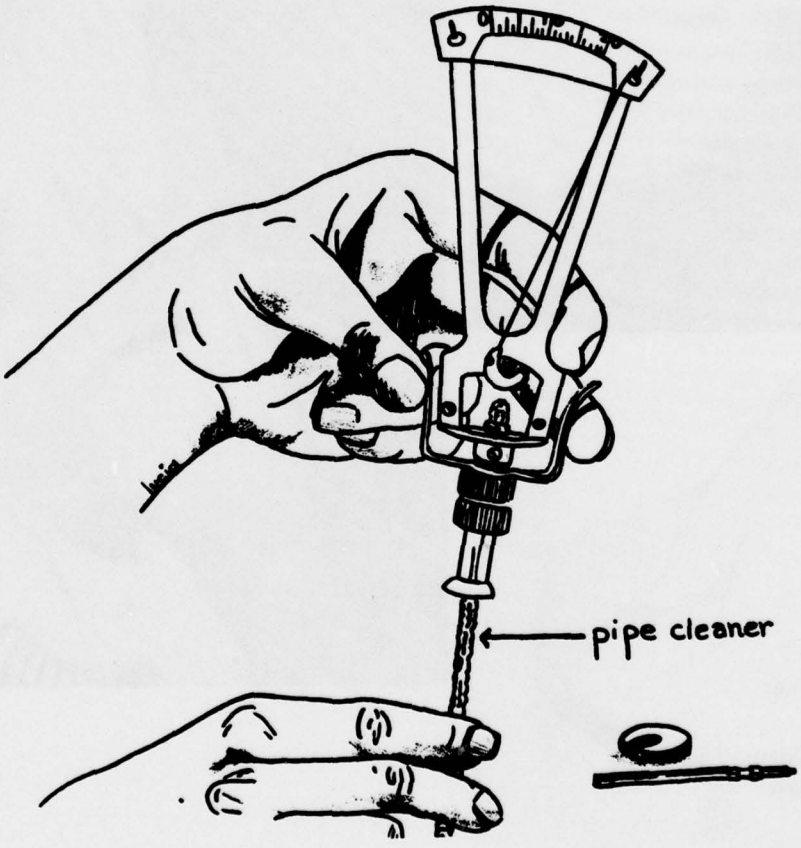


Figure 12. Cleaning of the Schiotz tonometer.

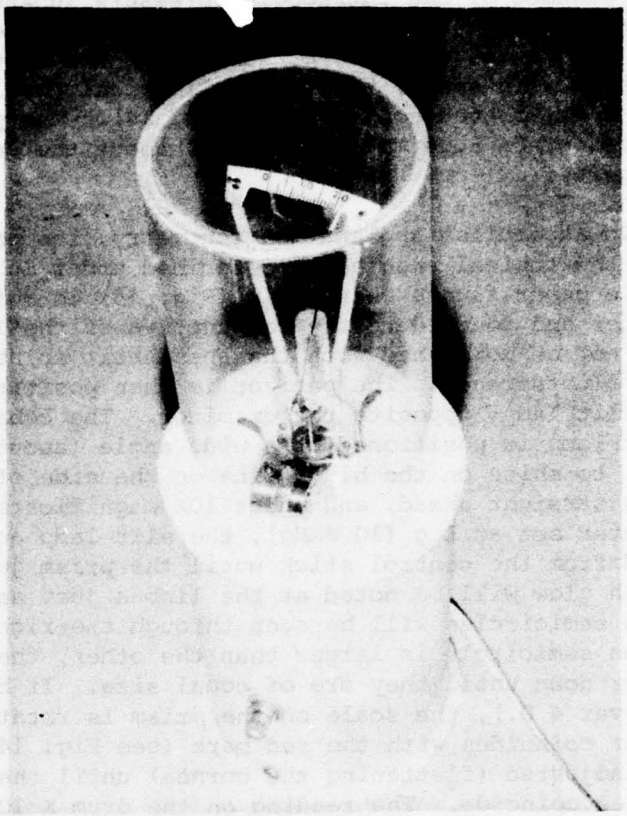


Figure 13. Schiotz tonometer in ultraviolet sterilizer.

Sources of Error--Several potential sources of error exist in Schiotz tonometry. The most important of these from an examiner's point of view (since he has control over these aspects) are improper technique and the use of a dirty or defective instrument. Other sources of error inherent in this method of measurement include the need to apply pressure to the eye (weight of the instrument) in measurement, variability in the scleral distensibility of individual eyes, and variability of individual corneal curvature. As a minor factor, protrusion of the cornea into the footplate hole in the low pointer-deflection range (i.e., below 3) when the instrument has an overly large footplate hole is also a source of error.

Applanation Tonometry

Most ophthalmologists use applanation tonometry to measure IOP. As the name suggests, applanation tonometry is the measurement of the force necessary to flatten a given area of the cornea. This force is

equal to the product of the intraocular pressure (unknown) and area (known); therefore, the IOP equals force-applied divided by area-applanated. The tonometer is an attachment to the slit lamp; and the mechanism itself is a small, tapered, cylindrical double prism attached by an arm to a calibrated coil spring (Fig. 14). The prism applanates an area of the cornea 3.06 mm in diameter, about the same size as the Schiotz plunger.

Usage--To accomplish applanation tonometry, the patient is first administered the topical anesthetic described under Schiotz tonometry. Then a sterile paper fluorescein strip (Fig. 15) is moistened with saline or water and touched to the conjunctiva of the lower lid. The strip should not be moistened with the anesthetic solution as this will diminish the fluorescence. The patient is then positioned in the head-rest of the slit lamp, opposite the examiner. The cobalt blue light from the slit lamp is positioned at a wide angle (about 60°) from the viewing axis, to shine on the black line on the side of the prism. The patient looks straight ahead, and under 10X magnification, with the drum of the tonometer set at 1 g (10 mmHg), the slit lamp and tonometer are moved forward from the control stick until the prism just contacts the eye. A bluish glow will be noted at the limbus just as the prism makes contact. Two semicircles will be seen through the right ocular on the prism. If one semicircle is larger than the other, the instrument is adjusted up or down until they are of equal size. If high astigmatism is present (over 4 D.), the scale on the prism is rotated so that the minus cylinder coincides with the red mark (see Fig. 14). The spring knob is then adjusted (flattening the cornea) until the inner edges of the semicircles coincide. The reading on the drum X 10 is equal to the IOP. Several views of the prism semicircles are seen in Figure 16.

Sources of Error--Although less susceptible to errors in the instrumentation than Schiotz tonometry, the average flight surgeon's office will not have a slit lamp and applanation tonometry routinely available. This may not be as unfortunate as it might seem since the primary source of error in applanation tonometry is poor technique and inexperience of the examiner. The distensibility (rigidity) of the eye is not a source of error in applanation tonometry since minimal fluid is displaced and minimal pressure increase is induced in the eye.

MacKay Marg Tonometry

Another type of tonometer in the Air Force inventory is the MacKay Marg tonometer (Fig. 17). This instrument consists of a box of electronics to which a hand-held transducer is attached. The transducer is the heart of the instrument. It consists of a 1.5-mm-diameter plunger which extends 5 μm beyond the surface of the footplate. The pressure exerted on the plunger during tonometry is transformed into an electrical signal by a crystal in the linear transducer. This causes a stylus to move on a piece of moving graph paper. The stylus movement is calibrated so that IOP can be read from the strip.

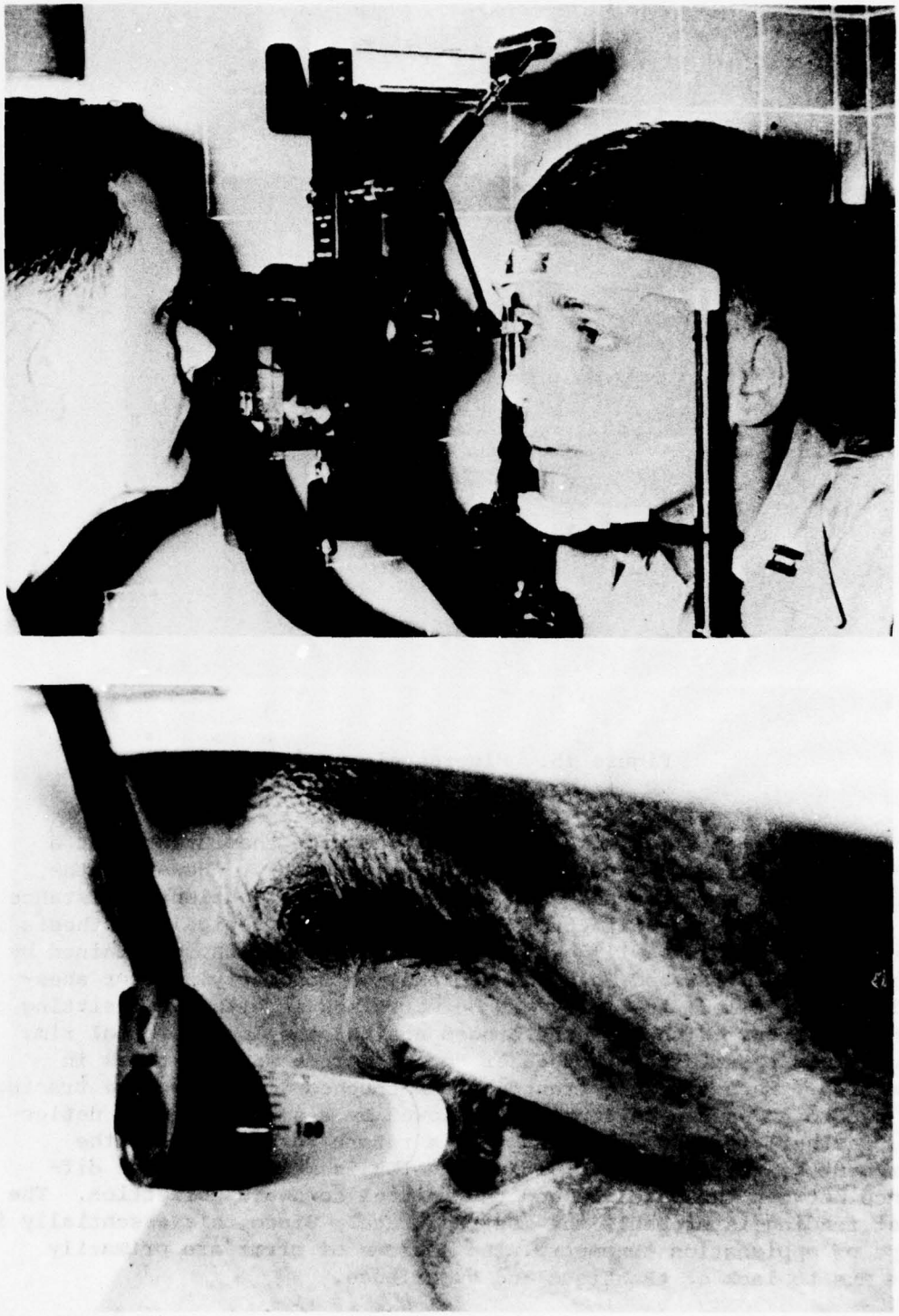


Figure 14. Applanation tonometry: (top) using the biomicroscope; (bottom) prism resting on the cornea.

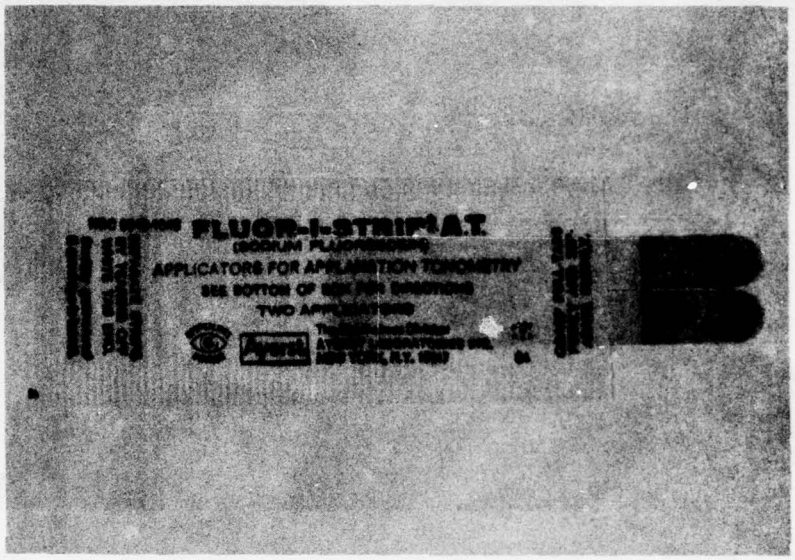


Figure 15. Fluorescein strips.

Originally this instrument was designed with the intent that a topical anesthetic would not be needed for tonometry. However, the MacKay Marg tonometer causes enough discomfort that patient resistance will make the readings difficult to interpret. If topical anesthesia is not used, the readings will generally be higher than those obtained by the previously described Goldmann applanation tonometry. After anesthetic is instilled, tonometry may be performed in either the sitting or supine position. With his hand braced against the lower orbital rim, the examiner touches the transducer to the cornea several times in succession. Each time the transducer is touched to the eye the tracing will record an upward deflection, followed by a small downward deflection, another rise and fall, and then a return to baseline as the instrument is retracted (Fig. 18). The IOP is measured as the difference between the baseline and the initial downward deflection. The lowest reading is probably the most accurate. Since this essentially is a type of applanation tonometry, the sources of error are primarily those due to lack of technique and experience.

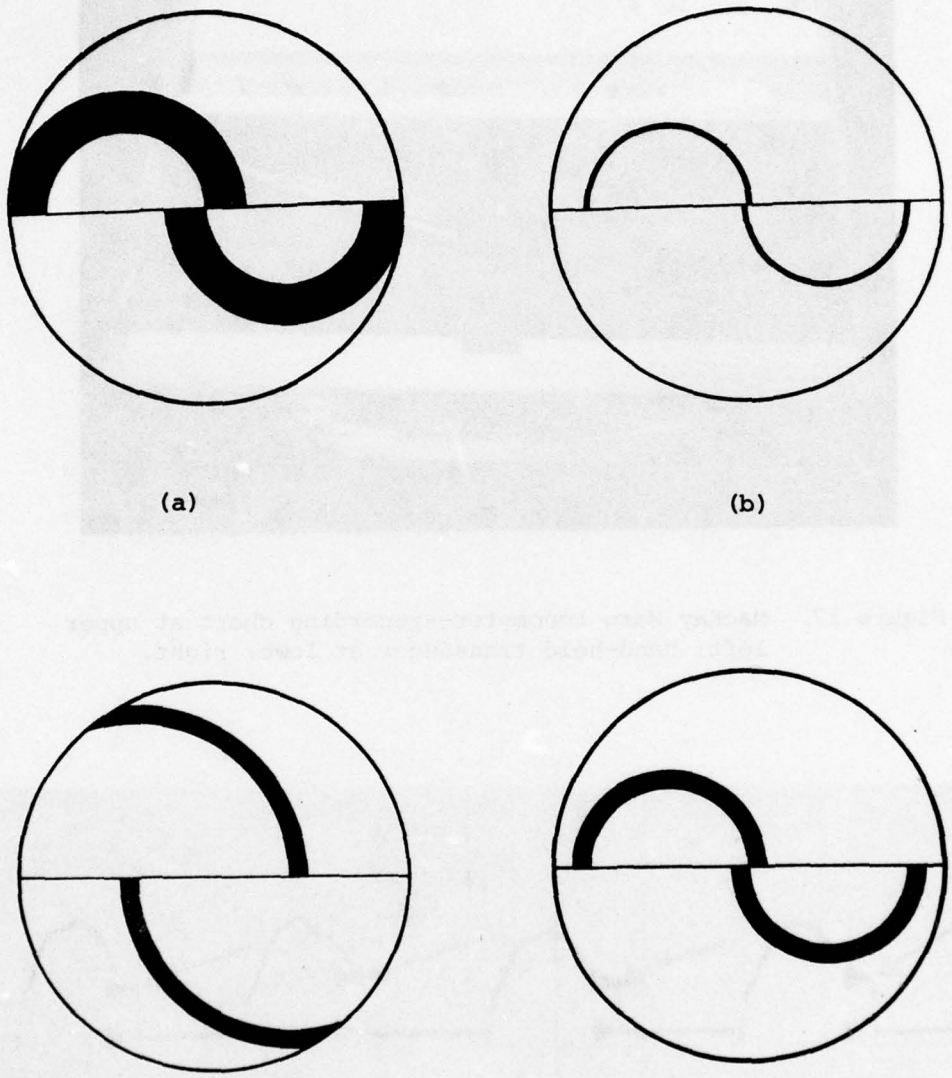


Figure 16. Applanation tonometry--views through the applanating prism: (a) excess tears; (b) tear-film dried excessively; (c) excessive pressure from the slit lamp; (d) correct final position.

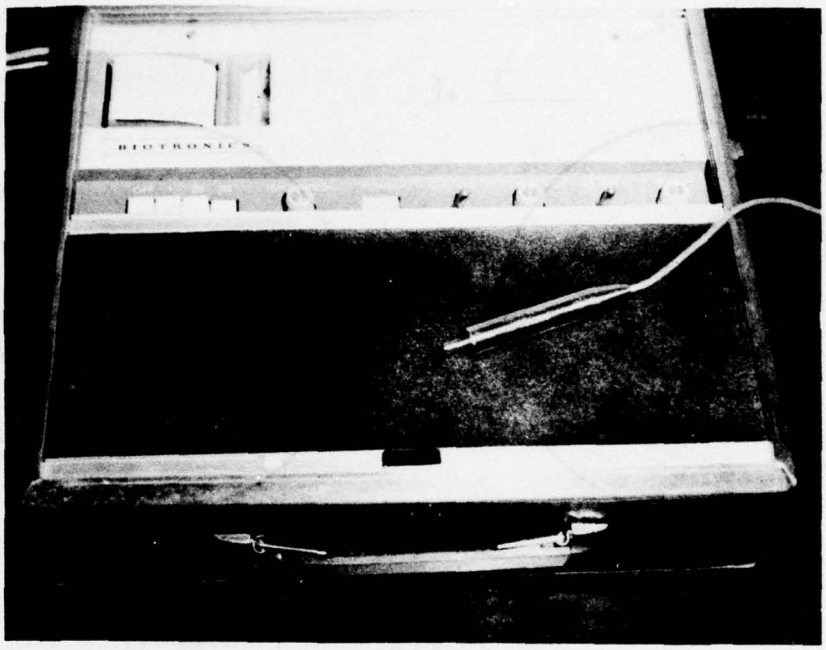


Figure 17. MacKay Marg tonometer--recording chart at upper left; hand-held transducer at lower right.

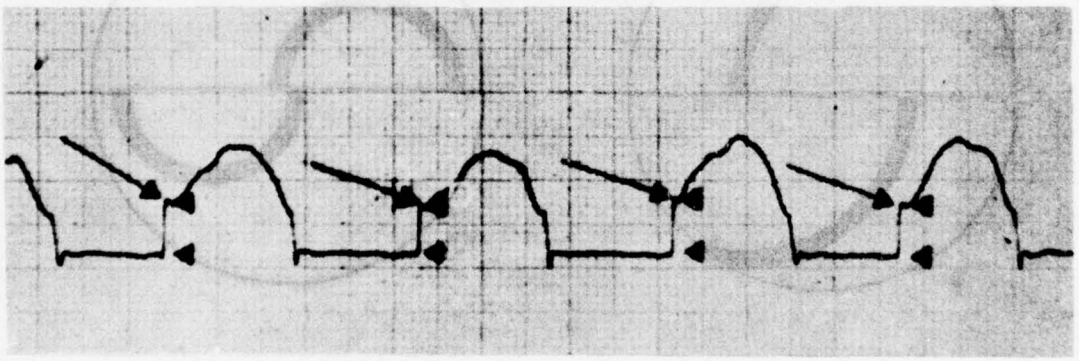


Figure 18. Intraocular pressure readings from MacKay Marg tonometer.

Noncontact Tonometry

The most recently developed tonometer which has found its way into wide clinical use is the American Optical noncontact tonometer (Fig 19). Since this instrument does not come in contact with the eye, no topical anesthetic is required; also, there is no potential for spread of infectious diseases (e.g., epidemic keratoconjunctivitis) and minimal or no threat of damage to corneal epithelium with multiple measurements. This device produces a small jet of air, normal to the cornea, that increases in velocity for a few milliseconds. As this stream of air hits the cornea, it exerts a pressure that at some point is sufficient to cause applanation. A light source placed obliquely to the axis of the airjet directs a beam at the cornea; at the instant of applanation, a sudden increase in the light is sensed by a photoelectric cell mounted obliquely on the other side of the airjet (Fig. 20). An alignment device and verification system is present to insure that the air stream is delivered normal to the cornea; otherwise, errors would result. The tonometer is arranged somewhat like a slit lamp, with a headrest for the patient and the instrument on a stand between the operator and patient. A small computer in the base of the instrument coordinates the alignment, airjet, and light-sensor readings to give a digital display of IOP in whole numbers.

Usage--The patient, with his head in the headrest, sits opposite the operator. Since the alignment device measures the distance from the machine to the center of curvature of the cornea, a control to compensate for the patient's refractive error is provided and adjusted accordingly. When the instrument is roughly aligned with the patient's eye, the patient is instructed to fix on a red-light dot target. The operator then moves the instrument fore, aft, sideways, up, or down as necessary to finely align the instrument. When this is accomplished, he also will see a red dot in his eyepiece and will press an event-start switch on the elevation control. A sequence then begins in which the machine assesses the alignment for 3 ms. If alignment is satisfactory, an air pulse is delivered, increasing linearly in force with time until applanation is detected by the light sensor. The IOP, computed from time of onset of the air pulse to applanation, is then displayed on the instrument.

Sources of Error--The primary sources of error with the noncontact tonometer are the failure of some patients to hold their lids wide open and problems with patients having cloudy or irregular corneas.

Tonography

One confirmatory test used after an elevated tonometry reading is tonography. This is performed with an electronic Schiotz-type tonometric apparatus that records IOP continuously on moving graph paper (Fig. 21). The principle of operation is that the weight of the plunger causes a progressive indentation of the cornea proportional to aqueous outflow.

To determine the facility of outflow, the instrument is warmed up for at least 30 minutes and calibrated. Applanation tonometry should have been previously performed to determine the appropriate weight on the plunger. Topical anesthetic is instilled in the eye while the patient is in the supine position and fixating on some target above. The tonometer is then gently lowered onto the cornea of one eye and held there for 4 minutes. The measurement is repeated on the other eye. The outflow facility (C) can then be estimated from the initial scale reading (Po), and the change over 4 minutes (ΔR), by the use of a set of charts (Fig. 22).

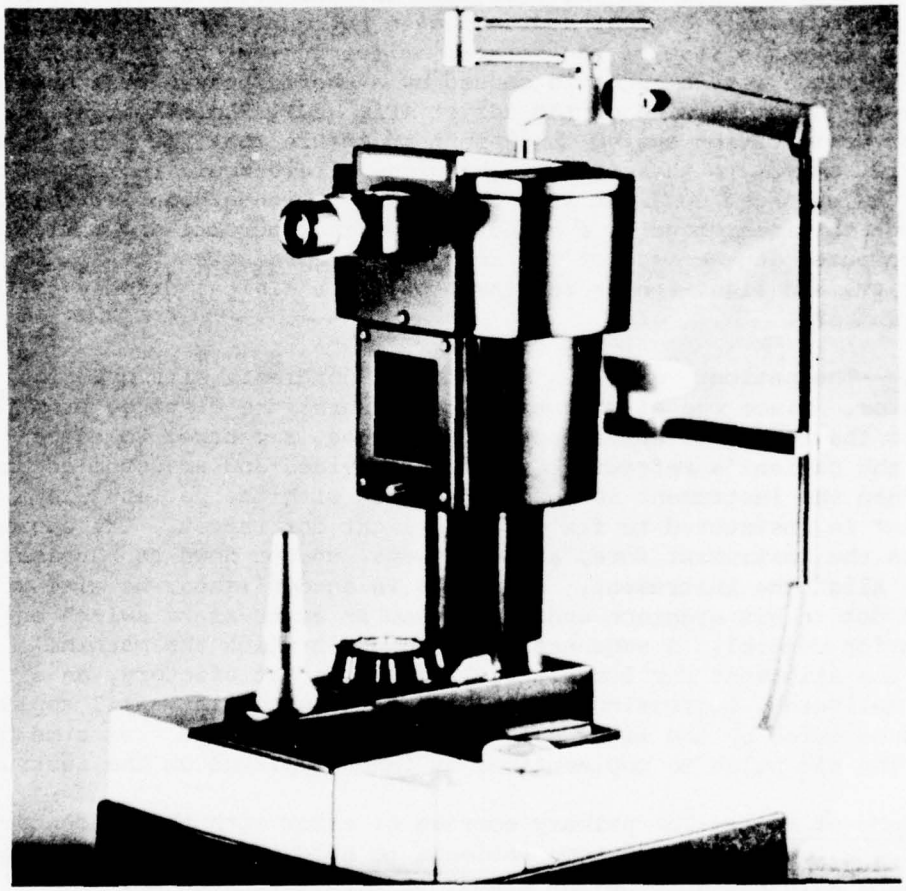


Figure 19. American Optical noncontact tonometer.

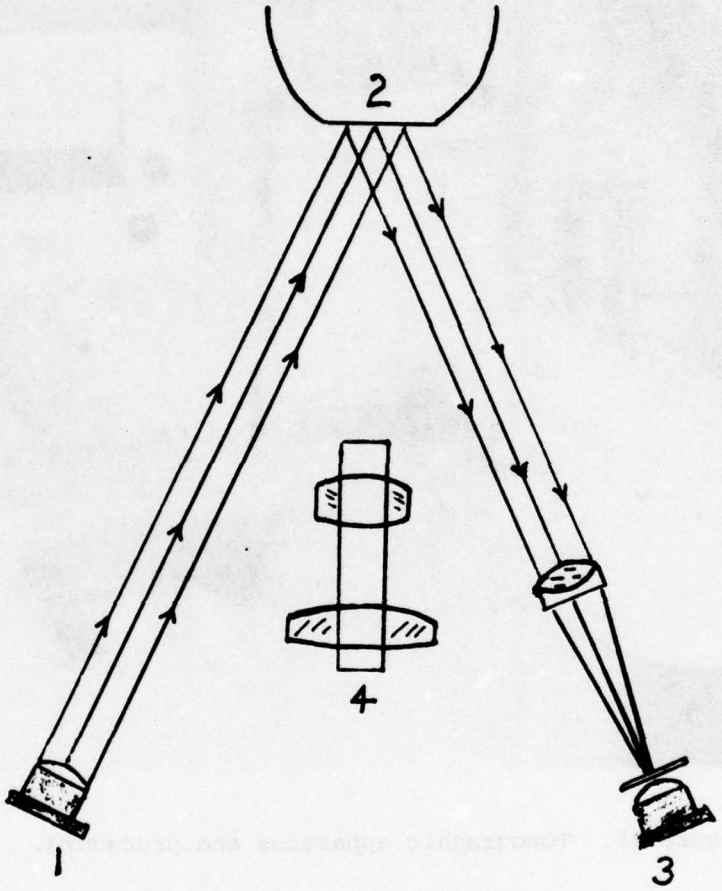


Figure 20. Principle of noncontact tonometer: (1) light source; (2) cornea (applanated); (3) light sensor; (4) airjet and aligning device.

In using these charts, several assumptions must be made which account for some of the sources of error. These assumptions are standardized values for ocular (scleral) rigidity, radius of curvature of the cornea, and increase in episcleral venous pressure with application of the tonometer. Constancy of aqueous secretion, eye blood volume, and outflow facility before, during, and after the procedure are also assumed. Other sources of error are in the instrumentation, patient response, and operator technique. Errors due to instrumentation may occur because of variations in line voltage, magnetic material close to the tonometer, or inadequate warmup of the instrument.

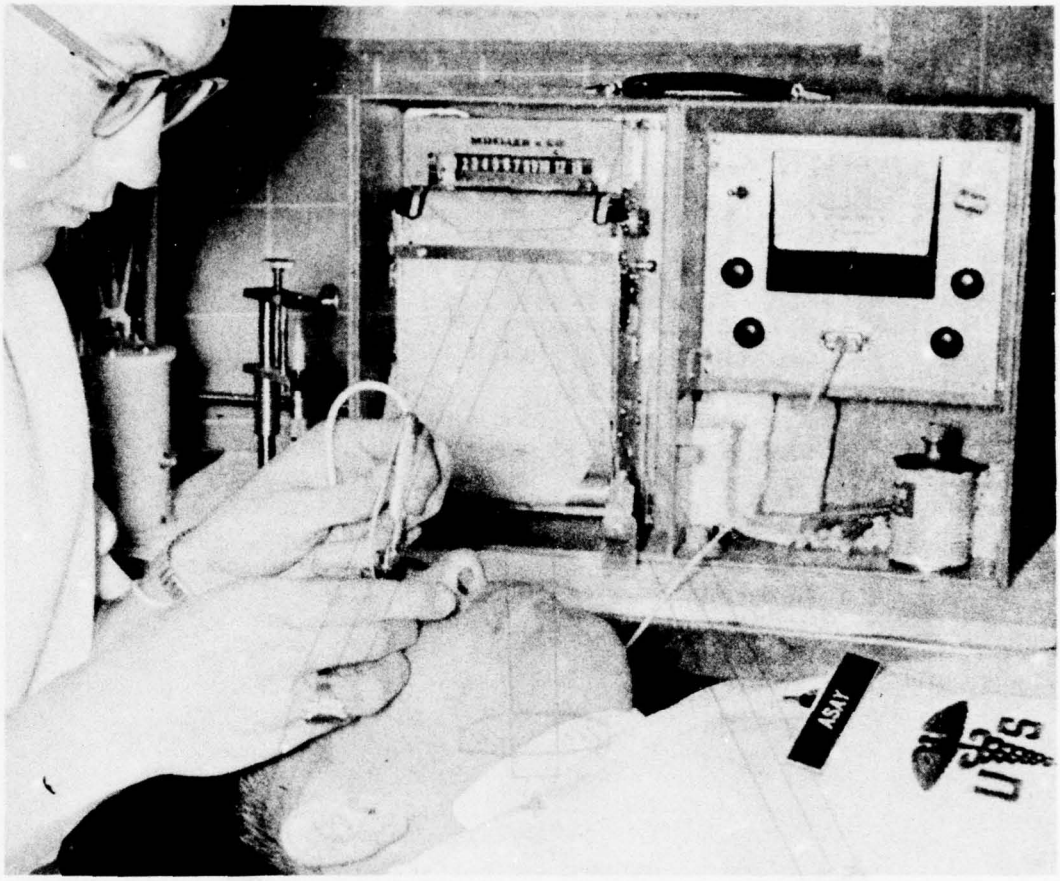


Figure 21. Tonographic apparatus and procedure.

Provocative Tests

If tonometry or tonography results are enough to arouse suspicion but not confirmatory for an elevated IOP, then certain provocative tests are available. Perhaps the best known of these is the water-drinking test, used primarily in suspected cases of open-angle glaucoma. After the patient fasts for at least 4 hours, initial tonometry or tonography is done. Then the patient is given a quart of water to drink over a 5-minute period, and either tonometry is performed at 30, 45, and 60 minutes or applanation tonometry and tonography are repeated at 40 minutes. A rise of more than 8 mm IOP indicates poor outflow.

Other provocative tests are designed to reveal a predisposition toward acute or subacute angle-closure glaucoma. With the darkroom test of Seidel, IOP is measured before and after the patient sits in a dark room for 1 hour without going to sleep; an 8-mm or greater pressure rise

is considered a positive test. The mydriatic test works on the same principle except the pupillary dilatation is induced by a weak mydriatic solution; e.g., phenylephrine. After the solution is instilled in each eye, IOP is measured every 10 minutes for 1 hour; again an 8-mm or greater pressure rise constitutes a positive test. For the prone-position test, the patient lies in the prone position for 30 minutes or more; a pressure increase of 8 mm or greater is a positive result. It should be noted, in each of these three tests, that a negative result does not rule out impending narrow-angle glaucoma, and a positive result must be confirmed by gonioscopy (discussed later).

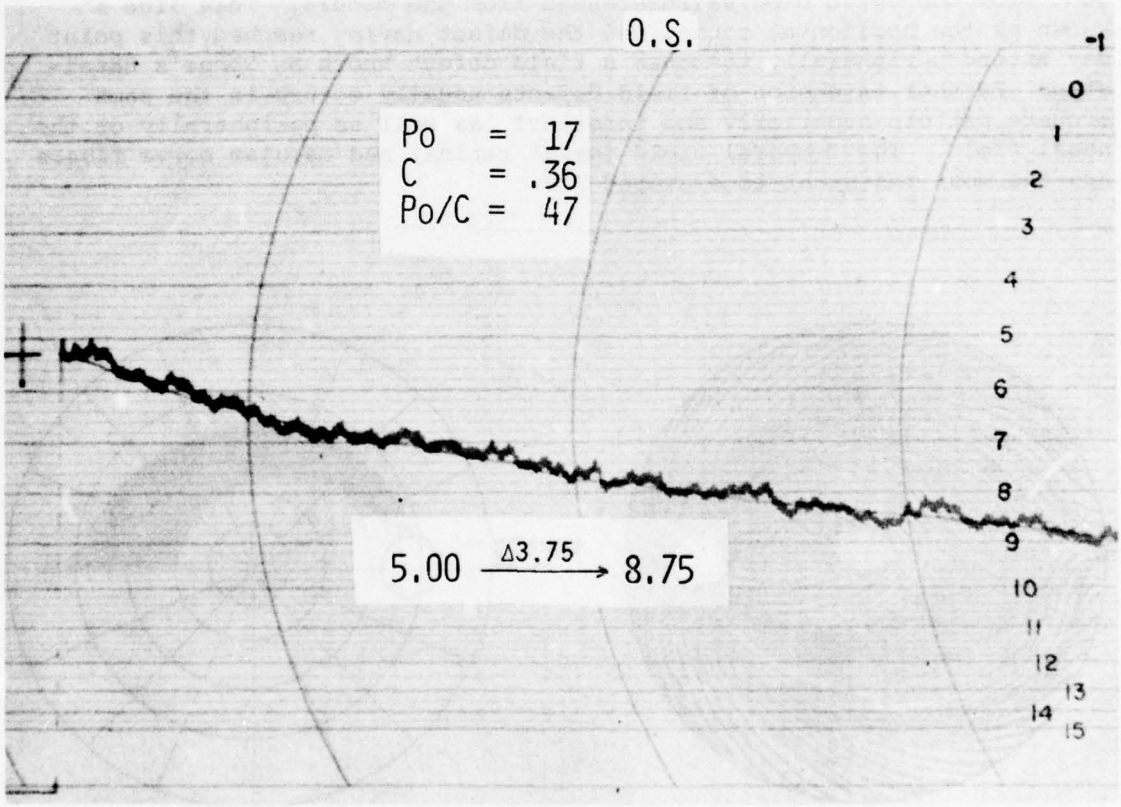


Figure 22. Normal tonogram: Po = opening pressure (mmHg); C = outflow facility; Po/C = glaucoma index.

Visual-Field Examination

The most important test for assessing the significance of an elevated IOP and following the course of glaucoma is evaluation of the visual fields. Glaucoma induces characteristic changes in the visual fields. The nature of these changes is explained by the pattern that nerve fibers follow in the retina (see Fig. 3). The earliest change which may be seen is termed "baring of the blind spot." This refers to an elongation of the blind spot along the superior-inferior axis. (An overall enlargement of the blind spot is a much less specific finding.) Next, defects expanding from the blind spot in an arcuate pattern may develop. Usually these affect the "Bjerrum's area" and hence are known as Bjerrum's scotomas (Fig. 23). The inferior fibers (superior field) are more susceptible to damage. The arcuate defect may extend to a line 180° from the optic disc as referenced from the macula. This line is known as the horizontal raphe, and the defect having reached this point may extend peripherally to cause a field defect known as Rönne's nasal step. Further extension of field defects usually occurs in the same arcuate pattern superiorly and inferiorly as well as peripherally on the nasal field. The temporal field (nasal retina) and macular nerve fibers are the most resistant to elevated IOP.

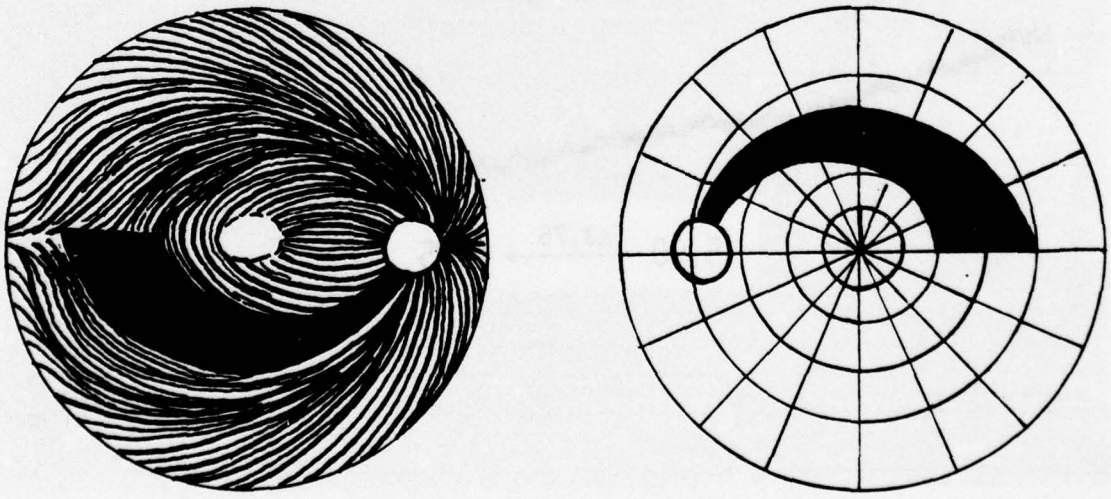


Figure 23. Bjerrum's scotoma: (left) arcuate course of retinal nerve fibers; (right) visual-field defect.

Several instruments and procedures are available to map the visual fields. The Goldmann perimeter is the most ideal device for this purpose (Fig. 24). This instrument consists of a metal bowl forming a half-sphere. The patient is seated at the center of this sphere, with eye 0.33 m from the fixation point. A target dot of light is moved along the metal sphere in different positions to map the fields on 12 meridians (Fig. 25).

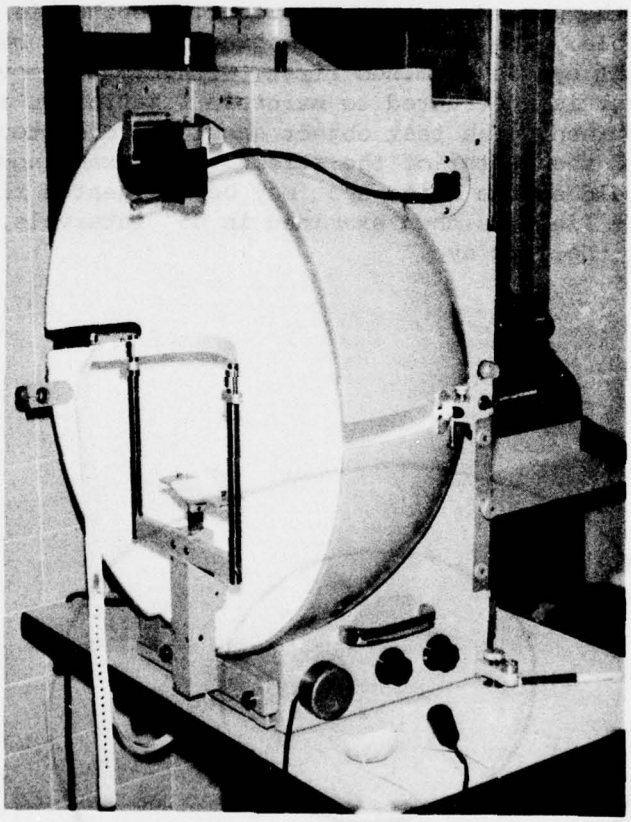


Figure 24. Goldmann perimeter.

The tangent screen is a more practical, less expensive means of determining visual fields. While peripheral fields cannot be adequately assessed, almost all glaucoma-induced defects will be detectable in the central 30° area plotted by the tangent screen. A tangent screen 0.4 to 1.5 m (48 to 60 in) square designed for a 1-m test distance is probably the most useful. The screen should be of black felt or other nonreflective material, and the test object as small as practical considering the patient's visual acuity. A 2- or 3-mm white test object on

a black rod is ideal for most patients (Fig. 26). Illumination should be uniform and of fairly low intensity (approximately 6 to 8 footcandles). When examining the central 25° to 30°, the patient should wear spectacles if he usually wears them to correct a refractive error. (Peripheral fields, however, are tested on instruments other than the tangent screen, and for this examination, the subject should not wear spectacles.) For examining the central 30° on the Goldmann perimeter, there is a holder for inserting proper trial lenses to compensate for age; therefore, the patient does not have to wear his own spectacles. Contact lenses may be worn for any of the examinations. As the examiner begins he should explain the procedure to the patient, keeping his explanation as simple as possible. The eye not being examined should be occluded; usually the right eye is examined first, with a patch covering the left eye. The patient is instructed to maintain fixation on a point at the center of the screen. The test object should be directed from the periphery toward the center of the screen. The exam should begin with the temporal field so the blind spot may be delineated first. The remainder of the field is then examined in 45° intervals. The procedure is repeated for the left eye.

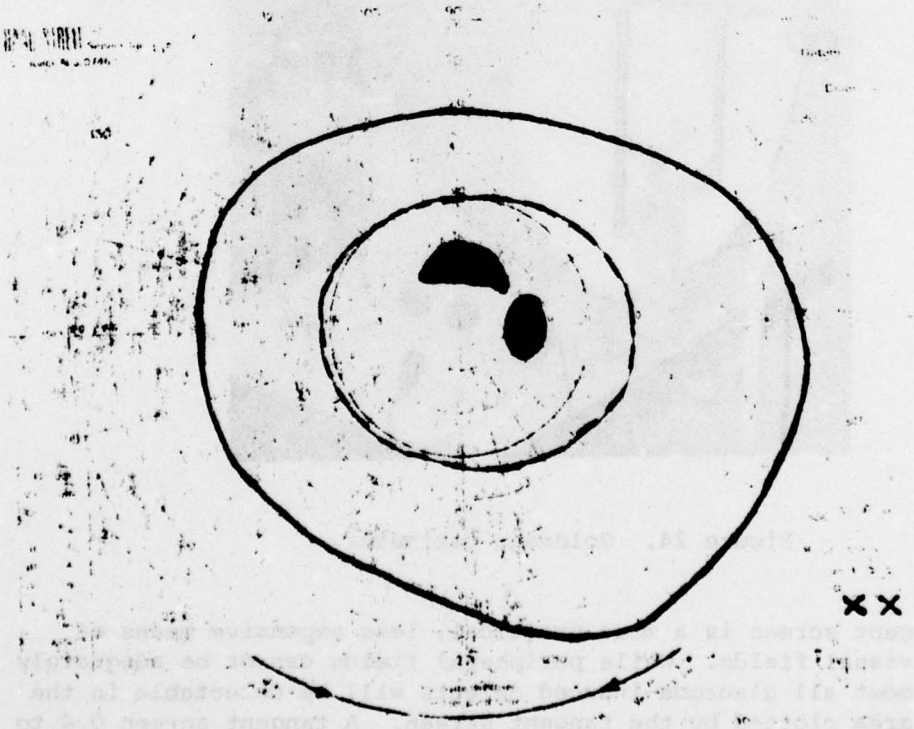


Figure 25. Visual fields recorded on a Goldmann visual-field chart.

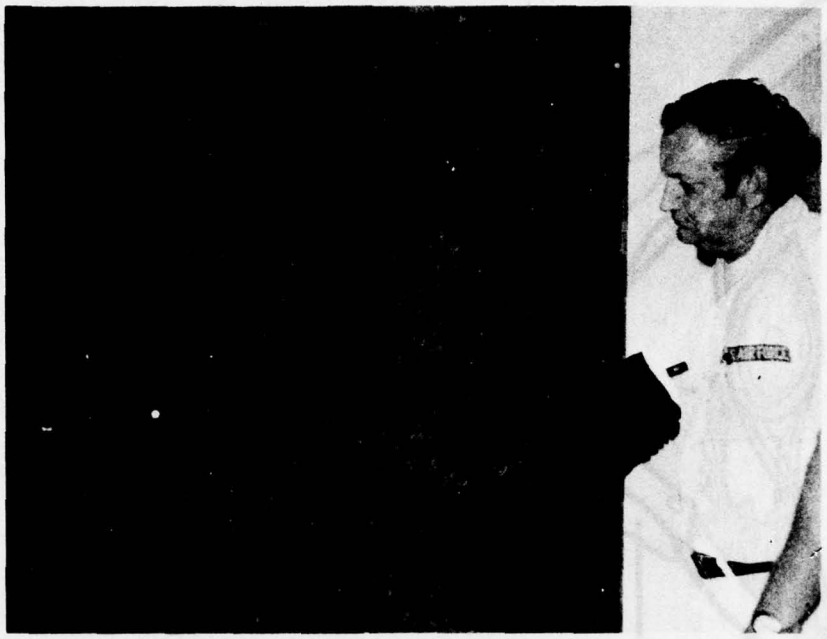


Figure 26. Visual-field plotting on the tangent screen.

Visual field can also be assessed crudely by confrontation. Constriction of peripheral fields and gross defects can be detected. This method essentially consists of the examiner's comparing the patient's fields with his own. Patient and examiner sit or stand facing each other; the patient occludes his left eye while the examiner closes his right eye; this is reversed to examine the opposite eye. The examiner extends his arm halfway between the patient and himself, to his maximum reach, and moves his fingers centrally (along each of the 12 meridians). He then compares the point where he sees his fingers with where the patient sees them. Of course, this method assumes the examiner has normal fields.

Gonioscopy

Another exam which should be performed upon determination of an elevated IOP is gonioscopy. The purpose of this procedure is to evaluate the angle of the anterior chamber to rule out narrow-angle glaucoma (see Fig. 5). The exam is performed with a special lens and a slit lamp. A special contact lens is necessary because the angle is impossible to view directly. Two types of lenses are in use. Indirect lenses (Goldmann, Allen-Thorpe, and Zeiss) enable the examiner to view the angle with tiny mirrors (Fig. 27), and the direct lens (Koeppe) refracts light from the angle (Fig. 28). Using these lenses, the

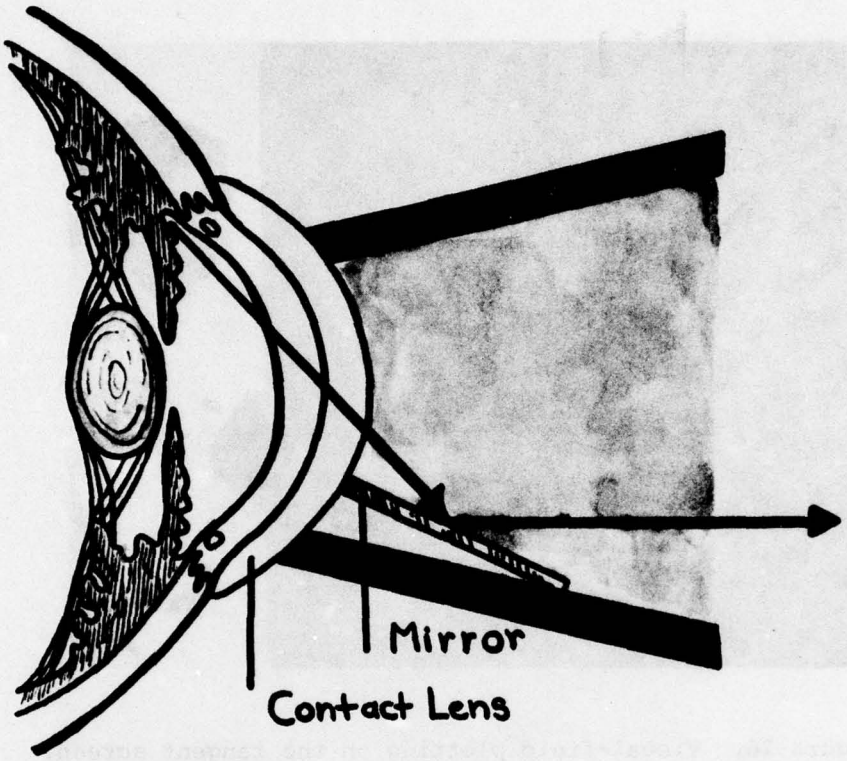


Figure 27. Indirect gonio prism, Goldmann lens.

examiner determines whether the trabecular meshwork (seen as a slightly dark band) is visible (Fig. 29). If only the sclera and iris are visible, then manifest or impending angle closure is present. Evaluation of the angle does require experience since knowledge of the variants of normal is necessary.

Ophthalmoscopy

Ophthalmoscopy must not be neglected in evaluating a patient with glaucoma. In the absence of an elevated IOP, cupping of the optic disc may indicate low-pressure glaucoma described above. An obvious large cup should alert the examiner to the possibility of glaucoma; also, a less severe degree of cupping that progresses from one year to the next is at least as significant if not more so. Generally speaking, the degree and azimuth of the excavation of the optic disc correlates well with the visual-field defects a patient may have. Figure 30 shows a normal cup; and Figure 31, the optic nerve in far-advanced glaucoma.

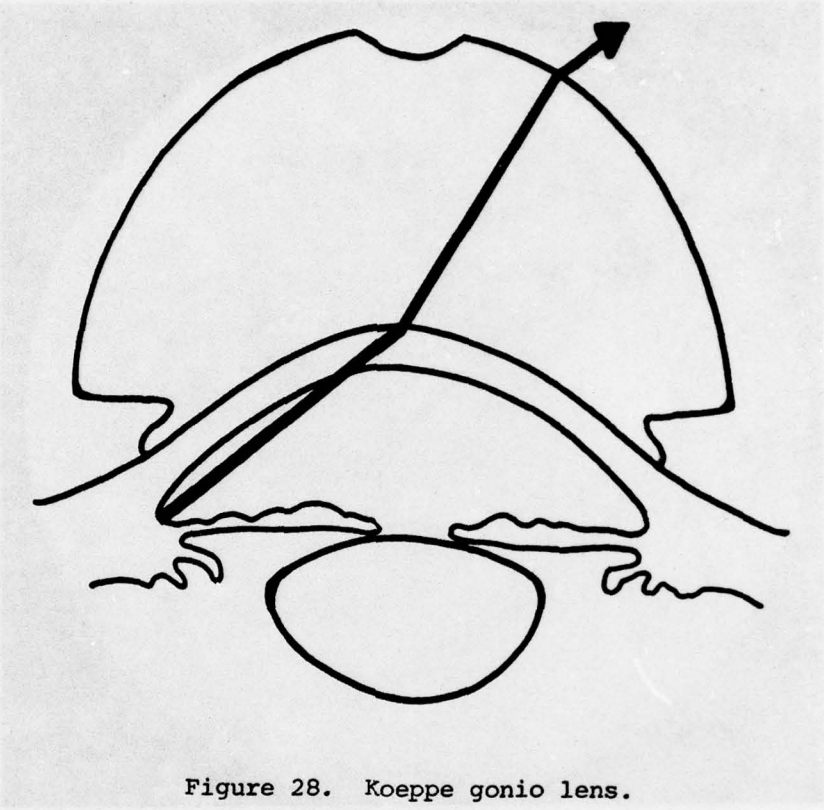


Figure 28. Koeppe gonio lens.

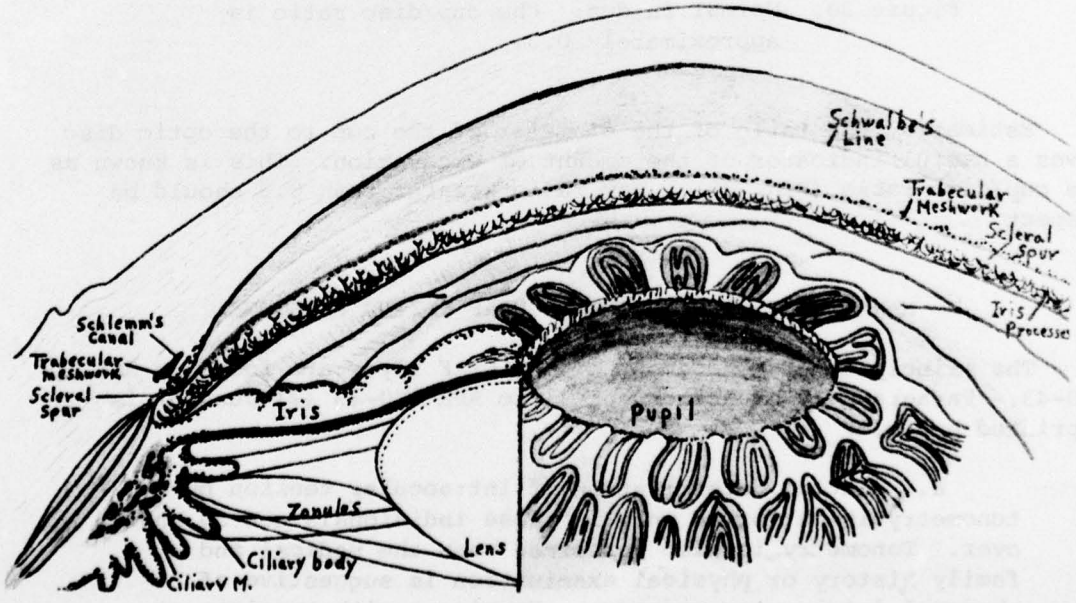


Figure 29. View of the angle through a gonio prism.

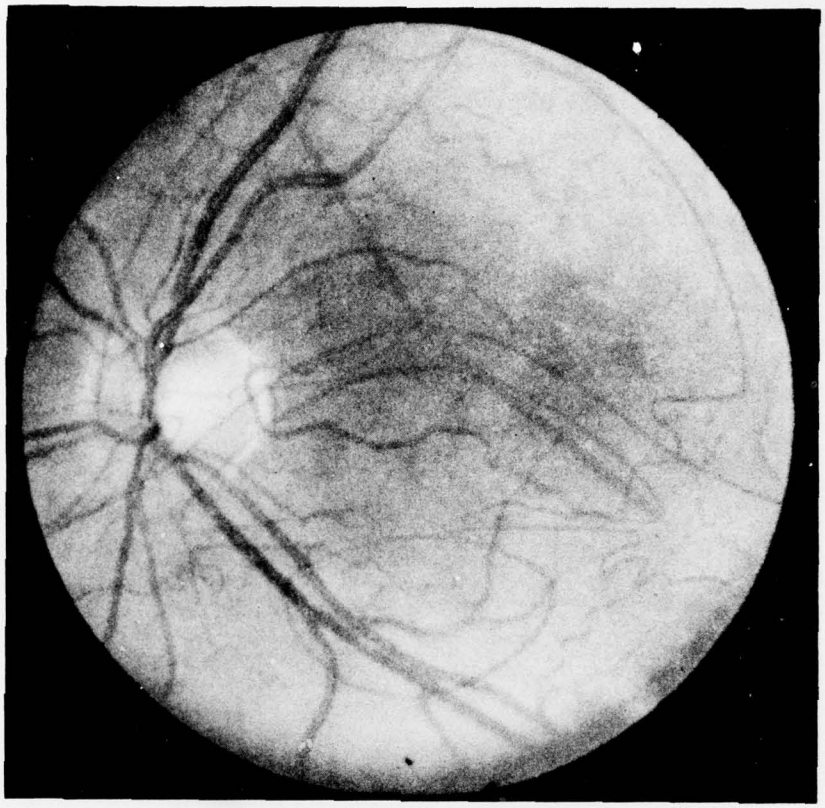


Figure 30. Normal fundus: the cup/disc ratio is approximately 0.3.

Estimating the ratio of the diameter of the cup to the optic disc gives a useful indicator of the amount of excavation. This is known as the cup/disc ratio (Fig. 32). Any ratio greater than 0.5 should be suspect.

MANAGEMENT OF GLAUCOMA IN USAF FLYING PERSONNEL

The principles of management of the USAF flyer are found in AFR 160-43. Paragraph 19 of attachment 11 to AFR 160-43 (21 Jun 76) is reprinted below.

> a. Routine determination of intraocular tension by tonometry is performed only in those individuals age 39 and over. Tonometry is also performed when the medical and family history or physical examination is suggestive of abnormal intraocular pressure. Examinees with tensions as follows must be referred to a qualified ophthalmologist for consultation:

(1) Two or more current determinations of 22 mmHg or higher.
(2) One or more determinations of 25 mmHg or higher.
(3) A difference of more than 4 mm between right and left eyes.

b. For personnel who are required to meet medical standards for flying, a "pre-glaucoma" group may be identified. This group will include those flying personnel whose intraocular pressure exceeds the limits in "a" above but who have no visual field defect or optic disc changes and whose pressure is below 30 mm. Members of this group may be granted a waiver for retention on flying duty by the major command surgeon provided they are followed at least at three-month intervals but at shorter intervals if deemed necessary. These followups can be performed by an ophthalmologist or the flight surgeon. A decrement in visual fields, changes in the optic disc, or elevation of the tonometer reading to, or above 30 mm, will require institution of therapy and immediate removal from flying duty.

c. When ophthalmological consultation results in a diagnosis of glaucoma, any type, or the need for medication (either topical or systemic) to control intraocular tension, the condition is disqualifying for all categories. For personnel who are required to meet medical standards for flying, after an effective therapeutic regime has been established, if the flight surgeon and ophthalmologist agree that there are apparent aeromedical reasons to justify continued suspension from flying duties, the flyer may be referred to Aerospace Medicine Consultation Service for evaluation. Upon favorable recommendation and with the approval of the major command surgeon some of these patients may be returned to flying status with waiver. It must be emphasized that therapy must be effective and completely free of adverse side effects. Followup is similar to that given individuals classified as "pre-glaucoma." Patients who require systemic medication will not be considered for return to flying status.

The most significant part of the USAF policy on glaucoma is the preglaucoma, or observation only, portion. Nearly two-thirds of all subjects with increased IOP have been classified as preglaucoma (ocular hypertension) and are not treated with any medications, but they are examined at frequent intervals (every 3 months) for glaucoma indicators other than an increased IOP. If other manifestations do occur such as field defects, disc changes, or IOP over 30 mmHg, then medical treatment is initiated.

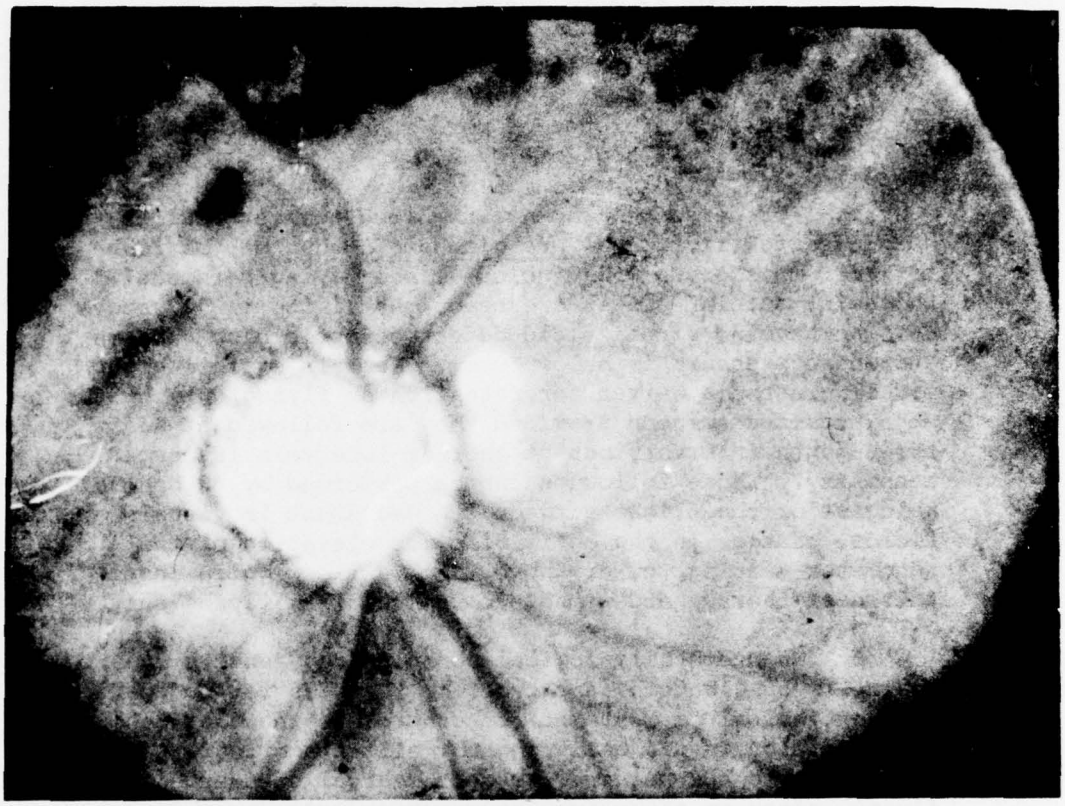


Figure 31. Severe cupping of the optic nerve in far advanced glaucoma: the cup/disc ratio is approximately 0.9.

The patient's intraocular pressure must be controlled by topical medication alone before waiver can be considered. This usually means that the IOP must be reduced to below 22 mmHg. Three types of topical medications are in use: epinephrine derivatives, parasympathomimetics, and cholinesterase inhibitors. Epinephrine derivatives act by decreasing aqueous secretion, possibly up to 30%; facility of outflow may also improve. Occasional side effects occur; e.g., allergic reactions to breakdown products, frontal headache, and conjunctival hyperemia and coloration by black melanin deposits. Parasympathomimetics and cholinesterase inhibitors increase outflow facility; the side effects of these agents are miosis, headache, eye pain, and myopia. The acetylcholinesterase-inhibiting agents may also induce systemic effects including nausea, diarrhea, and abdominal pain.

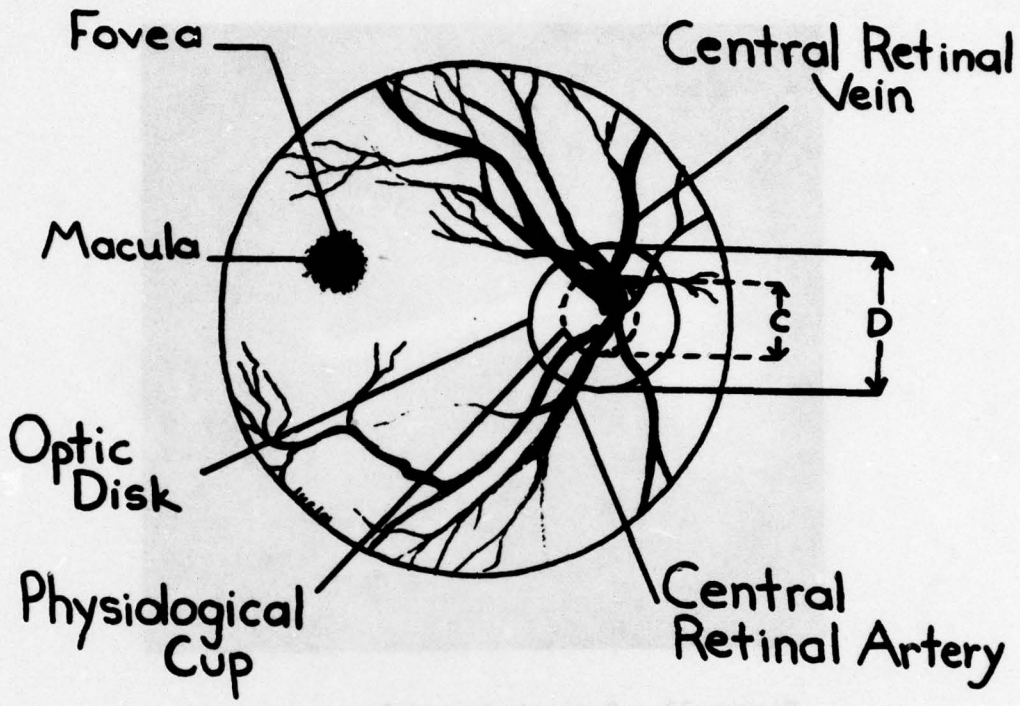


Figure 32. Fundus of the eye illustrating the cup/disc (C/D) ratio.

Although pilocarpine is generally considered the drug of choice in open-angle glaucoma, the associated side effects usually prevent its use initially in the flyer. Therefore, the first course of therapy should be with epinephrine. If this proves successful in controlling the IOP and if there are no side effects, waiver is likely. If the IOP cannot be adequately controlled with epinephrine, treatment with pilocarpine drops should be instituted. This will probably be effective in controlling IOP; however, the side effects of pilocarpine will usually preclude return to flying status. Individuals undergoing treatment with pilocarpine drops, especially those in younger age groups, may experience a significant degree of myopia within a few minutes each time the drops are instilled, with vision gradually returning to its original state over several hours.

A possible solution to the problem of pilocarpine-induced myopia lies in the Ocusert system. This device, presently being evaluated, consists of two thin membranes separated by a ring peripherally and a core of pilocarpine. The wafer, about the same thickness as a contact lens, is placed in the upper or lower conjunctival cul-de-sac (Fig. 33). Upon insertion, the Ocusert releases pilocarpine at a high but decreasing

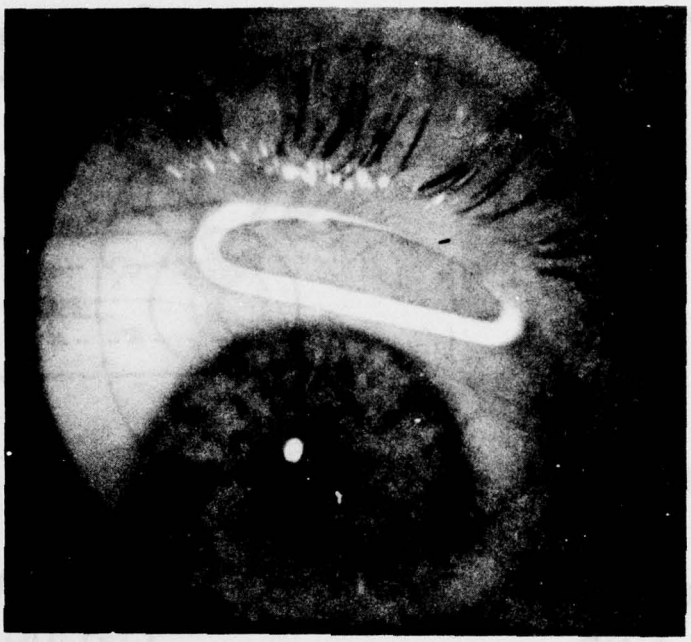


Figure 33. Ocusert drug-delivery system.

rate for approximately 12 hours. This constant release maintains the patient's refractive error in a sufficiently steady range for him to be fitted for glasses ground to this correction. The Ocusert lasts seven days.

Another effect of pilocarpine is miosis (pupillary constriction), resulting in a slight constriction of visual fields and reduction in dark adaptation. From a practical standpoint these may not necessarily have a great deal of bearing on flying; the contraction of visual fields is measurable, but no greater than 10° in any case. The significance of the reduction of dark adaptation has not been well defined.

Should pilocarpine drops adequately control IOP and no significant side effects occur, a waiver could conceivably be granted by the USAF Surgeon General's Office for return to flying status after an Aeromedical Consultation Service evaluation; however, very few individuals will be able to meet these requirements. If a systemic medication such as acetazolamide (a carbonic anhydrase inhibitor) is required, a waiver will not be granted; side effects of this agent include paresthesias, nausea, and kidney stones. If IOP cannot be controlled by medical treatment, surgical procedures are available to improve outflow of aqueous and to lower IOP. After a period of nonflying status, a waiver might possibly be granted to return to flying.

A number of statistics are available regarding the glaucomatous USAF flyer. Of 211 identified preglaucomatous flyers, 43 were followed for 5 years. At the end of that time, 25 were still classified preglaucomatous; 12 had advanced to glaucoma, 2 were reclassified normal, and 4 were disqualified from flying status (2 required miotics and 2 had field loss). Of 81 flyers initially diagnosed as glaucomatous without field loss, 17 were followed for 5 years; 11 retained this classification, 1 was relabeled preglaucomatous, and 5 were disqualified (2 required miotics and 3 had field loss). Although exact numbers are not available, several individuals on miotics or after surgery have been granted waivers by the USAF Surgeon General's Office and returned to flying status after evaluation at USAFSAM.

Angle-Closure Glaucoma

Should the flight surgeon diagnose a case of angle-closure glaucoma and not have an ophthalmologist immediately available, he should begin medical treatment as soon as possible. An osmotic agent and miotics are used to lower the IOP. The initial treatment should be with oral glycerin, 1 mg/kg body weight, mixed with lemon juice and pilocarpine 4%; 2 drops in the affected eye every 15 minutes. The glycerin will make the blood hypertonic and decrease the volume of aqueous by drawing it from the eye; the pilocarpine will constrict the pupil, thereby freeing the iris from the trabecular meshwork, and permit aqueous outflow to reestablish. If this treatment is not successful in lowering IOP, IV Mannitol, 20%, 1.5-3 g/kg body weight, or IV urea 1 g/kg, may be given. A potent analgesic may be necessary to control pain.

Surgical intervention is the definitive treatment and should be scheduled as soon as practical. Peripheral iridectomy is the most commonly performed procedure. Because of the high incidence of bilateral disease, the procedure is usually performed on the other eye also, within several days or weeks. The iridectomy creates a safety valve between the anterior and posterior chamber, equalizing the pressure on both sides of the iris and thus precluding any further angle closure. Successful and completely healed cases have been returned to flight status.

FAA REGULATIONS ON GLAUCOMA

When a flyer is removed from flying status per AFR 160-43, he may still be eligible to fly civilian aircraft. Many pilots will appreciate the efforts of the flight surgeon who can keep them flying in this capacity. Assistance can be found in the FAA Guide for Aviation Medical Examiners. Although no specific value is given for glaucoma in the AME Guide, it is listed as a disqualifying condition. The Guide specifies that a copy of FAA Form 8500-14, Ophthalmologic Evaluation for Glaucoma, should be given to a patient who has a history of glaucoma or an apparent

elevation of IOP. This form should be completed by an ophthalmologist and returned to the flight surgeon's office for attachment to the FAA Form 8500-8 (the FAA physical exam form). The issuance of the medical certificate is deferred, and the application, medical certificate, and results of the evaluation for glaucoma are sent to Oklahoma City for review (and possible issuance of the certificate). Statistics are not available regarding the number of individuals with glaucoma granted FAA medical certificates, but there are many flying while under treatment with epinephrine drops and several flying while using pilocarpine or acetazolamide.

U.S. ARMY AND U.S. NAVY POLICIES REGARDING GLAUCOMA

The U.S. Army and Navy both appear to have similar programs for the diagnosis and management of glaucoma in the flyer. Both services perform tonometry in flyers over age 35. If an elevated IOP is found, treatment is at the discretion of the ophthalmologist to whom the patient is referred; treatment usually begins with epinephrine and may progress to miotics if necessary. Army policy more closely follows Air Force guidelines than does Navy policy. Army pilots who require treatment are waivered by the proper authority at the Aeromedical Lab, Ft Rucker, Alabama, after review of their findings and treatment program.

ACKNOWLEDGMENT

The authors are indebted to Lucia Tredici for her dedication and skill in doing the illustrations and art work in this publication.

BIBLIOGRAPHY

Becker, B., and A. Kolker. Glaucoma--A classic treatise. In Vision and its disorders. NINDB Monograph No. 4, DHEW (out of print). (Reprinted in EENT Monthly beginning Sep 1975.)

Becker, B., and R. Shaffer. Diagnosis and therapy of the glaucomas. St. Louis: C. V. Mosby, 1961.

Clark, W. (ed.). Symposium on glaucoma. Transactions of the New Orleans Academy of Ophthalmology. St. Louis: C. V. Mosby, 1959.

Becker, B. Aqueous production and flow--biochemistry, p. 53.
Provocative tests and their effect on tonography, p. 135.
Diamox and other inhibitors of aqueous secretion, p. 172.
Miscellaneous topics concerning glaucoma, p. 227.

Grant, W. Aqueous production and flow--physiologic and pathologic aspects, p. 69.
Basic tonometry and tonography, p. 91.

Scheie, H. Gonioscopy, p. 81.
Surgical treatment of chronic simple wide-angle glaucoma, p. 184.

Cooper, K., P. Lempert, and J. Culver. Effect of exercise on intraocular tension and its relationship to open angle glaucoma. Aerosp Med 36:51 (1963).

Craythorne, N., H. Rottenstein, and R. Dripps. The effect of succinylcholine on IOP in adults, infants, and children during general anesthesia. Anaesthesia 21:59 (1960).

Drance, S. The significance of the diurnal tension variations in normal and glaucomatous eyes. Arch Ophthalmol 64:494 (1960).

Forbes, M., G. Pico, and R. Grolman. A noncontact applanation tonometer. Arch Ophthalmol 91:134 (1974).

Francois, J., C. Heintz-DeBree, and R. Tripathi. The cortisone test and the heredity of primary open angle glaucoma. Am J Ophthalmol 62:844 (1966).

Grolman, B. A new tonometer system. Am J Optom Physiol Opt 49(8):646 (1972).

Halberg, G., S. Kelly, and M. Morrone. Drug delivery systems for topical ophthalmic medication. Ann Ophthalmol 7(9):1199 (1975).

Hertzog, J. Glaucoma, a general review and its significance in the aviation environment. SAM ACAM Thesis 62-A, 1962.

Keeney, A. Ocular examination, basis and technique. St. Louis: C. V. Mosby, 1970.

Leblane, R., R. Stewart, and B. Becker. Corticosteroid provocative testing. Investig Ophthalmol 9:946 (1970).

Lempert, P., K. Cooper, J. Culver, and T. Tredici. The effect of exercise on intraocular pressure. Am J Ophthalmol 63:1673 (1967).

Lindstrom, E., T. Tredici, and B. Martin. Pilocarpine effects on normal visual performance. Aerosp Med 39:1236 (1968).

Mims, J., and T. Tredici. Ocular hypertension and chronic open angle glaucoma in USAF pilots and navigators. SAM-TR-74-48, Dec 1974.

O'Briant, C., T. Tredici, and J. Culver. Evaluation of topical 2 percent levo-epinephrine. Aerosp Med 38:1171 (1967).

Pollack, I. Diagnosis of the glaucomas. In Symposium on glaucoma, ch. 2. St. Louis: C. V. Mosby, 1967.

Tredici, T. Tonometry and glaucoma. USAFSAM Ophthalmology Branch Handout, HO OP-3, Brooks AFB, Tex. Jan 1975.

Udeoul, K., D. Pavan-Langston. Pilocarpine Ocusert system for sustained control of ocular hypertension. Arch Ophthalmol 93:587 (1975).

Vaughan, D., and T. Asbury. General ophthalmology, 7th ed. Los Altos, Calif.: Lange Medical Publications, 1974.