



Early Diagnosis, Treatment of Glaucoma Can Limit Vision Loss

Even the slight loss of peripheral vision that often occurs in the early stages of glaucoma presents risks to pilots' careers and to aviation safety. Eye care specialists have a variety of diagnostic tools to detect the disease, which often can be controlled with the regular use of eye drops.

—
Stanley R. Mohler, M.D.

Hundreds of pilots risk denial of medical certification each year because of the development of glaucoma, a condition in which pressure inside the eye (intraocular pressure) increases and damages the optic nerve, causing a deterioration of vision — and, in some cases, blindness. Nevertheless, if glaucoma is detected early in its development, treatment can preserve vision and medical certification.^{1,2}

The eye has two liquid-filled compartments: the aqueous humor compartment in front of the lens and the vitreous humor compartment behind the lens (Figure 1, page 2). Aqueous humor is a watery substance, and vitreous humor is a gelatinous, proteinaceous substance. In the normal eye, both the aqueous humor and the vitreous humor are clear. The normal intraocular pressure of both is between about 12 millimeters and 21 millimeters of mercury. (Nevertheless, some people develop glaucoma even though their intraocular pressure is within the normal range, and others may never develop the disease, even with intraocular pressure greater than the normal range.)

The pressure of the aqueous humor is maintained by the flow of the humor from the periphery of the iris (the round, colored part of the eye) in front of the lens, where the humor is secreted. The humor flows through an opening in the pupil (the black area in the center of the eye) to an area between the iris and the interior surface of the cornea (the transparent



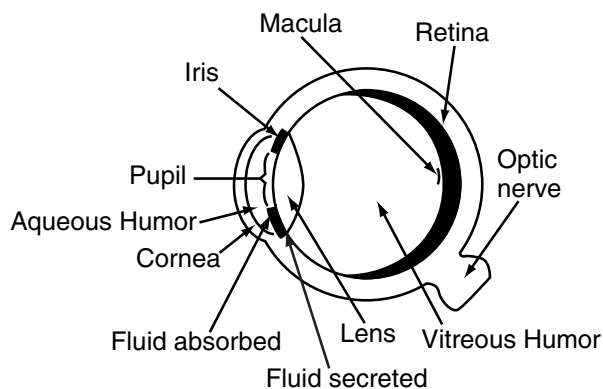
dome on the eye's surface), where the humor is absorbed. The humor contains nutritious elements and oxygen that benefit the iris, the lens and the cornea's inner surface.

If a problem occurs in reabsorbing the humor, the intraocular pressure increases. This pressure can affect elements of the optic nerve and can damage the nerve. In addition, the increase in pressure can impair the flow of venous blood from the retina back to the heart, causing the injury — and sometimes the death — of cells in the retina (the eye's light-sensitive innermost lining).

The United Nations World Health Organization (WHO) says that about 5.2 million people worldwide are blind because of glaucoma, one of the leading causes of blindness around the world. WHO estimates that about 105 million people have the disease.³

People of African heritage and Asian heritage typically are more likely than Caucasians to develop glaucoma,⁴ which also occurs most frequently among people older than age 45, those with a family history of glaucoma, those with elevated intraocular pressure, those with diabetes or myopia (nearsightedness, i.e., having better vision for near objects than for distant objects), or those who have used steroids or cortisone regularly for a long period of time.

Diagram of the Human Eye



In the eye of a person with normal vision, light enters the cornea and the pupil, which is surrounded by the iris. The iris controls the amount of light that enters the eye, allowing more light when the surroundings are dark and less light when surroundings are bright. The light passes through the lens, which focuses light on the retina, which in turn senses the presence of light. The retina translates the image into electrical impulses, which travel along the optic nerve to the brain. Together, the aqueous humor — which nourishes the iris, lens and inner surface of the cornea — and the vitreous humor help the eyeball retain its shape.

Source: Stanley R. Mohler, M.D.

Figure 1

Glaucoma can be acute, with symptoms that typically develop within a period of weeks, or chronic, with symptoms that develop over many months — possibly years. Without treatment, either condition results in a progressive loss of vision and ultimately in blindness.⁵

There are several types of glaucoma. The most common type is *open-angle glaucoma* (also called wide-angle glaucoma), which traditionally has been associated with chronic glaucoma. The term “open-angle” refers to the open — or “unclogged” — drainage of aqueous humor between the circular perimeter of the iris and the corneal interior wall. Although the humor drains, reabsorption is inadequate; as a result, a pressure balance is not maintained between the back of the iris, where the humor is secreted, and the front of the iris, where the humor is absorbed, and aqueous humor pressure begins to increase.

Absence of Symptoms Often Delays Detection

Open-angle glaucoma usually begins with no symptoms; if left untreated, however, open-angle glaucoma leads to a loss of peripheral vision, and may ultimately lead to blindness. In most cases, intraocular pressure exceeds 21 millimeters of mercury.

There are several types of open-angle glaucoma, including the following:⁶

- *Primary open-angle glaucoma* involves an increase in intraocular pressure so gradual that the cornea adjusts to the increase without swelling; as a result, the disease often is not detected until irreversible vision damage has occurred;
- *Normal-tension glaucoma* (or low-tension glaucoma) involves optic nerve damage and loss of visual field in an individual who has statistically normal intraocular pressure. Reducing intraocular pressure below normal often is required to prevent further loss of vision. This type of glaucoma is believed to be related to inadequate blood flow to the optic nerve;
- *Acute glaucoma* involves a sudden, painful increase in intraocular pressure that sometimes occurs in as little as a few hours and that may be accompanied by redness of the eye, swelling and clouding of the cornea, blurred vision and the appearance of halos around lights. The pain may cause nausea and vomiting.

Attacks of acute glaucoma often occur in movie theaters and other dark areas. When the pupil dilates in darkness, the result is maximum contact between the lens and the iris. Attacks also may occur at other times when the pupil dilates — with excitement or stress, or when an individual takes some types of medication, such as antidepressants, cold medications, antihistamines and some anti-nausea medications.

Some attacks of acute glaucoma are less severe than others and may end when the individual enters a lighted area or goes to sleep — conditions that cause the pupil to constrict and the contact between the lens and the iris to be reduced; and,

- *Pigmentary glaucoma* is a hereditary type of open-angle glaucoma that usually develops in men in their 20s and 30s who have myopia. In myopia, the iris is concave (curved inward like the inside of a hollow ball) and therefore more likely to rub against the lens. The rubbing causes the iris to shed some of its pigment into the aqueous humor and the trabecular meshwork (the area where aqueous humor drains from the eye); the pigment may clog the drain and may cause an increase in intraocular pressure.

In *closed-angle glaucoma* (also called narrow-angle glaucoma because of the narrow angle between the iris and the cornea's interior surface), aqueous humor cannot move easily through the reabsorption area in front of the iris; as a result, a rapid increase in the pressure of the aqueous humor occurs. Closed-angle glaucoma, which typically is acute, usually begins with pain in the eye, nausea, blurred vision and redness of the eye. This is a medical emergency that requires prompt medical care to prevent permanent blindness.

A closed angle denotes blockage of the drainage system at this point. Wide angle is an anatomic term describing an abnormally

wide angular distance between the iris and the corneal interior surface. Narrow angle is also an anatomic definition, denoting an acute angle between the iris and the corneal interior surface.

Other types of glaucoma include *exfoliation syndrome glaucoma*, in which contact between the lens and the iris results in the accumulation on the lens of a flaky white material — a combination of material rubbed off the lens and pigment rubbed off the iris. This material clogs the area where aqueous humor drains from the eye, resulting in an increase in intraocular pressure that can cause either open-angle glaucoma or closed-angle glaucoma. People with exfoliation syndrome are about six times more likely than those without the syndrome to develop glaucoma — sometimes only in one eye.⁷

Glaucoma also can be caused by a blow to the eye, an eye-penetrating injury or a chemical burn on the eye that damages the eye’s drainage system.

Glaucoma can be diagnosed by eye care professionals — ophthalmologists, who are physicians specializing in eye care, or optometrists, who are specialists in examining the eyes and prescribing corrective lenses — during routine examinations using one or more diagnostic tools, including the following:⁸

- Tonometry, which measures intraocular pressure using a variety of techniques and equipment. For example, in applanation tonometry, after anesthetizing eye drops are administered, a plastic prism is placed against the eye; in air tonometry, a puff of air is directed onto the cornea to measure the pressure;
- Visual field tests use a computerized instrument to map an individual’s visual field. The computer randomly flashes points of light at different places on a bowl-shaped screen, and the individual presses a button whenever he or she sees the lights, which vary in brightness. Visual field tests typically are conducted regularly — usually once or twice a year — after glaucoma is diagnosed to determine whether the field of vision has changed; and,
- Ophthalmoscopy is an examination of the inner eye, conducted to evaluate the condition of the optic nerve. Glaucoma damages nerve cells on the optic nerve, causing “cupping” (formation of a depressed area) on the head of the nerve. If the area of cupping begins to increase, glaucoma could be developing. The examination may be conducted using any of several pieces of equipment that allow an eye care specialist to view the optic nerve head.

Reducing Intraocular Pressure Is Primary Goal of Treatment

Glaucoma treatments are designed to attempt to lower the intraocular pressure to a range that the eye care specialist

considers necessary to prevent any significant further loss of vision. Treatment usually begins with medications that are available in eye drops or in tablets, which are grouped in the following categories, according to the way in which they function (Table 1):⁹

**Table 1
Medicines Used to Treat Glaucoma**

Category	Example
Miotics (Cholinergics)	Pilocarpine
Cholinesterase Inhibitors	Physostigmine
Beta Blockers	Timolol
Carbonic Anhydrase Inhibitors	Acetazolamide
Alpha Agonists	Alphagan
Osmotic Diuretics	Mannitol
Prostaglandin Prostamide Analogs	Latanoprost

Source: Stanley R. Mohler, M.D.

- Miotics (also called cholinergics or cholinergic agonists), which have been used since the early 1900s, reduce the size of the pupil and increase the outflow of aqueous humor, causing a reduction of intraocular pressure. Miotics typically are administered as eye drops three times or four times per day. Side effects may include headache, eye ache (usually temporary), blurred vision or darkening of vision;
- Cholinesterase inhibitors, administered as eye drops or by mouth, cause the pupils to constrict, thereby increasing the draining of aqueous humor from the eyes;
- Beta blockers reduce the production of aqueous humor and, hence, reduce intraocular pressure. They typically are administered as eye drops once or twice a day. Beta blockers should not be administered to people with asthma, and development of asthma is the primary side effect of beta blockers. Other side effects may include slow pulse, dizziness, tiredness, depression, impotence or absence of interest in sex;
- Carbonic anhydrase inhibitors (also called acetazolamides) inhibit the enzyme that promotes the formation of aqueous humor. They are administered as eye drops or as tablets. Side effects may include a bitter taste in the mouth;
- Alpha agonists reduce the production of humor in the eye and may increase the flow of humor out of the eye. They usually are administered as eye drops two times or three times a day. Side effects may include a dry mouth and a feeling of being unwell;
- Osmotic diuretics such as mannitol — usually administered intravenously before surgery for acute glaucoma — help

rid the body of excess fluids, thereby reducing the amount of fluid in the eyes — and reducing the intraocular pressure; and,

- Prostaglandin/prostamide analogs. These eye drops usually are administered once a day to increase the flow of humor out of the eye. Side effects may include redness of the conjunctiva (the lining of the eyelid and the covering of the white of the eye), a darkening of the eye — especially if the iris is green or hazel — and growth of thicker, darker eyelashes.

Tablets sometimes are prescribed in addition to eye drops. These tablets usually are administered two times to four times a day. They are carbonic anhydrase inhibitors, which have more side effects than the same medication in eye drop form, including frequent urination and a tingling sensation in the fingers and toes, both of which usually disappear after several days; kidney stones; aplastic anemia, in which the bone marrow no longer manufactures enough blood cells; rashes; depression; fatigue and lethargy; gastrointestinal problems; impotence; and weight loss. People who take carbonic anhydrase inhibitors should take them with meals to reduce side effects and should add potassium-rich bananas or apple juice to their diets to help offset the potassium loss caused by the medication.

In some cases, when the drainage area is clogged by cellular debris, laser surgery or traditional surgery may be performed to alleviate the problem. The most common form of laser surgery performed on open-angle glaucoma is known as trabeculoplasty; the 10-minute to 20-minute procedure loosens the drainage area so that the aqueous humor drains more rapidly. The success of this laser surgery varies, but The Glaucoma Foundation says that 80 percent of those who undergo the procedure are able to avoid or delay traditional surgery, and some are able after a few weeks to stop taking some of their glaucoma medications.¹⁰

The most frequently performed type of traditional surgery is a trabeculectomy, a 30-minute to 90-minute procedure performed under local anesthesia or a general anesthesia, in which a surgeon removes a section of the drainage area to help create a new channel for aqueous humor to drain more easily from the eye. The goal of this surgery is to reduce intraocular pressure sufficiently to prevent any further damage to the optic nerve. After surgery, most patients are able to stop taking glaucoma medications, but 10 percent to 15 percent require additional surgery. Although the surgery is considered relatively safe, about one-third of trabeculectomy patients develop cataracts (clouding of small regions of the eye's normally transparent lens) within five years of surgery.^{11,12}

Acute closed-angle glaucoma is treated with another type of laser surgery known as iridotomy or traditional surgery called iridectomy to create one or more small holes in the outer, upper edge of the iris to relieve a blockage of the drainage area. The

procedure usually is performed not only on the affected eye but also on the unaffected eye, which is susceptible to a similar acute attack.

Precautions Recommended in Drinking, Exercising

A number of precautions are recommended for people with glaucoma, including the following:¹³

- People with borderline intraocular pressure should avoid drinking a large amount of liquid in a short period of time — for example, more than about four cups (0.9 liter) in 15 minutes — because a temporary increase in intraocular pressure may result. Overall fluid intake need not be restricted;
- Exercise in which the head is lower than the heart — such as some yoga positions — may increase intraocular pressure. For example, scuba diving and parachuting may increase intraocular pressure, and an eye care specialist should be consulted before such activities;
- Swimming should be delayed for about 15 minutes after eye drops are administered to prevent the drops from being washed out of the eyes. After a trabeculectomy, swimming pools present a risk of eye infection; and,
- If glaucoma has restricted an individual's field of vision, safe driving may be compromised. Legal driving standards for people with glaucoma vary among countries.

ICAO Recommends Regular Screening for Glaucoma

The International Civil Aviation Organization (ICAO) recommends that some form of tonometry be included in aeromedical examinations for applicants older than 40.¹⁴

“Mass surveys for the detection of glaucoma in its early stages revealed a prevalence of unsuspected ocular hypertension in some 2 percent of the general population over 40 years of age,” the ICAO *Manual of Civil Aviation Medicine* says. “The occurrence in the case of aviation personnel has been shown to be about the same. ...

“A minor visual field defect does not disable the average patient, but its detection in aviation personnel is of importance, as the defect could not only adversely affect the careers of aviation personnel but also introduce a safety risk.”

The *Manual of Civil Aviation Medicine* also says that pilots and other aviation personnel who use eye drops or tablets to treat

glaucoma should retain their medical certificates if they meet all visual requirements and if their medication does not cause disqualifying side effects. Periodic eye examinations, including evaluation of intraocular pressure and visual field, also should be required, the manual says.

Regular, periodic screening by an eye care professional is the preferred method of discovering glaucoma in its early stages. With this approach, proper treatment can be accomplished and loss of vision — or medical certification — can be prevented.♦

Notes

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Mohler received the 1998 Flight Safety Foundation Cecil A. Brownlow Publication Award for journalism that enhances aviation safety awareness.

Further Reading From FSF Publications

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