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GLAUCOMA AND DIVING

Glaucoma is an eye disease in which the retinal ganglion cells of the optic nerve are destroyed, leading to progressive loss of vision. It is the most common cause of irreversible blindness worldwide. Cataracts are a more common cause of blindness but they can be corrected surgically. Glaucoma affects 0.5% of people less than age 50 and 2.0% of people over 50. This fascinating disease has implications for diving, as do some of the treatments.

There are several types of glaucoma but they can be roughly divided into two groups, 'closed angle' and 'open angle'. In closed angle glaucoma visual loss can develop very quickly but this problem is usually quite painful and therefore patients tend to seek medical attention before permanent visual loss occurs. This form of glaucoma accounts for less than 10% of cases in the USA (up to 50% in Asia) and in addition to pain, usually involves seeing halos around lights, nausea and vomiting, sudden decreased vision and a fixed, mid-dilated pupil. It is an ophthalmologic emergency.

Open angle glaucoma is usually painless and visual loss develops more slowly. Many patients will not realize that they have visual problems until significant, permanent visual loss has occurred. It accounts for 90% of cases of glaucoma in the USA and presumably Australia. Visual loss typically progresses from the edges towards the center with central vision preserved until very late in the disease process. Patients often have severe peripheral visual loss before they seek medical attention. The rest of this column will focus on primary open angle glaucoma (POAG).

The four major risk factors for POAG are increased ocular pressure, advanced age (3% at age 75), black race (4 to 6 times more common than in whites, more than 11% of blacks at age 80), and family history (2 to 4 times more common). Many East Asian groups have high rates and Inuit develop glaucoma 20-40 times more often than Caucasians. Unstable blood flow to the eye is emerging as a risk factor. Most cases of glaucoma (80-85% in the USA, Canada) are associated with pressures in the eye greater than 22 mmHg (normal is 8-22). Prolonged use of steroids (in the eye, inhaled and oral), severe diabetic retinopathy, central retinal vein occlusion, eye trauma, and uveitis (eye infection) increase the risk of developing glaucoma. The cause of POAG is not known.

Fluid in the eye (aqueous humor) is produced by the ciliary process, flows into the posterior chamber (the main portion of the eye), flows through the pupil (really just a hole in the iris) into the anterior chamber between the iris and the cornea. The fluid then drains through the trabecular meshwork via Schlemm's canal into the blood stream. A raised pressure is maintained in the eye to hold it's shape. In the acute episodes of closed angle glaucoma the iris is pushed forward, blocking the escape of fluid from the eye, resulting in a sudden rise in pressure and symptoms. In open angle glaucoma there is simply a reduced flow of fluid through the meshwork resulting in a slow rise in pressure and visual loss without other symptoms.

Screening for glaucoma is part of a standard eye examination performed by ophthalmologists and optometrists. They measure intraocular pressure and examine the optic nerve. Visual field testing is time consuming and only detects problems when more than 20% of the retinal ganglion cells are destroyed.

Treatment of glaucoma is primarily aimed at restoring normal eye pressures. Every mmHg reduction in intraocular pressure reduces the risk of visual field loss by approximately 9%. Pressures can usually be controlled with eye drops but sometimes surgery is required. Glaucoma can be an issue in divers for several reasons. The eye is a fluid filled structure with no gas spaces. Therefore, the pressure changes due to diving do not change the shape of the eye and have virtually no effect on the function of the eye. The absolute pressure is 3,800 mmHg at 40 meters (130 ft). However, this pressure is applied to the eye as well as the surrounding tissues so the RELATIVE pressure in the eye is NOT changed with diving. The visual losses associated with glaucoma become an issue in diving when the person simply can not see well enough to dive safely.

There are many different types of medications used to treat glaucoma, both drops and pills, and some of these medications do have concerns in diving. There are also several different types of surgery performed to treat glaucoma and some of these also have diving concerns.

Medications Used to Treat Glaucoma

Prostaglandin Analogs (bimatoprost, latanoprost, travoprost) increase the outflow of aqueous humor from the eye. These drugs can cause ocular irritation and redness, macular edema or iritis. If they have been used for several weeks without difficulty the person can return to diving.

Beta-Blocker eye drops (betaxolol, carteolol, levobunolol, metipranolol, timolol) decrease aqueous humor production by the ciliary body. They can have nasty side-effects like decreasing the heart rate, heart block, and worsening pre-existing congestive heart failure (CHF). Beta-blockers can cause bronchospasm in asthmatics and people with chronic obstructive pulmonary disease (COPD). Rarely they will cause airway obstruction in someone who does not have asthma. Most people taking these medications will not experience problems (they are commonly taken orally to treat high blood pressure in young people). It is reasonable to return to diving if a person has been using them for several weeks without problem.

Adrenergic Agonists (apraclonidine, brimonidine) reduce aqueous production and increase aqueous outflow. Problems with these drugs are usually limited to the eye (red eye, ocular irritation). They should be used with caution in someone

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with cerebral or coronary insufficiency, Raynauds, postural hypotension, hepatic or renal impairment. If no problems have developed after several weeks of use the person can usually return to diving.

Carbonic Anhydrase Inhibitors are used both as eye drops (brinzolamide, dorzolamind) and pills (acetazolamide, methaxolamide) to reduce the formation of aqueous humor. The pills can cause transient myopia, nausea, diarrhea, loss of appetite and taste, parasthesia, lassitude, renal stones and hematological problems. Numbness in the arms or legs is common on these medications and should make the person unfit diving (it would be impossible to tell if numbness after a dive was from the drug or DCS). People with depression should not dive and the drug should be discontinued. After several weeks of therapy, blood should be checked to ensure the drug is not causing problems with the electrolytes or acid-base balance. If the blood work is OK and the patient has no other adverse effects, they may return to diving. Fortunately, these pills are very seldom used and have largely been replaced by eye drops. The eye drops can cause local irritation and redness.

Cholinergic Agonists (carbachol, pilocarpine) increase the outflow of aqueous humor. These drugs can cause ciliary spasm leading to headaches, myopia, and dim vision. Long term they can cause cataracts and iris-lens adhesions. They are not very popular. After they have been used for a few weeks if vision is good and the headaches have resolved the person can return to diving.

Surgical Procedures Used to Treat Glaucoma

Canaloplasty involves inserting a catheter into Schlemm's canal and enlarging it to increase the outflow of aqueous humor from the eye. Once the incision has healed, it should be safe to return to diving.

Laser Trabeculoplasty is used to increase the outflow of aqueous humor. Argon laser trabeculoplasty can be performed only once while selective laser trabeculoplasty with the YAG laser can be repeated three or four times. Both procedures are temporary solutions. Laser Peripheral Iridotomy makes a hole in the iris, correcting any difference in the pressure on both sides of the iris and reducing abnormal bulging of the iris. It sometimes increases outflow of aqueous humor and can prevent acute blockage of the outflow. Diode Laser Cycloablation destroys the secretory ciliary epithelium, thereby reducing production of aqueous humor. It should be safe to return to diving almost immediately after these laser procedures.

Trabeculectomy is the most common surgery for glaucoma and involves surgically removing part of the trabecular meshwork to increase aqueous humor outflow. Glaucoma Drainage Implants of several types can be inserted into the eye to increase the outflow of aqueous humor. Laser Assisted Non-Penetrating Deep Sclerectomy is a newer procedure to increase outflow. For all of these procedures, diving should be safe after the eye has healed.

Glaucoma is a common eye problem, a frequent cause of reduced vision and blindness, and it requires lifetime monitoring and treatment. Treatment typically involves eye drops or surgery. Every person age 40 to 60 should be screened every 3 to 5 years (every 1 to 2 years if they have risk factors) for glaucoma. After age 60 screening should be done every 1 to 2 years. Most divers can return to diving after they have taken the drugs for several weeks to ensure they do not suffer side-effects from the medications or after they have recovered from the surgery (several weeks). ■

DAVID SAWATZKY, S.C., C.D., B.Med.Sc., M.D., M.Sc., is a diving medical specialist who was on contract at Defence Research and Development Toronto from 1998 to 2005. Previously he was the Canadian Forces Staff Officer in Hyperbaric Medicine at DCIEM (1986-1993) and later the Senior Medical Officer at Garrison Support Unit Toronto (1993-1998). He's written a monthly column on diving medicine in Canada's *Diver* Magazine since 1993, has been on the Board of Advisors for the International Association of Nitrox and Technical Divers (IANTD) since 2000, and is an active cave, trimix and closed circuit rebreather diver/instructor/instructor trainer. David's first love is cave diving exploration and he's been exploring and surveying underwater passages in Canada since 1985. David was responsible for the exploration and mapping of almost 11 kilometres of underwater passages in the Ottawa River Cave System. In 1995, he executed the first successful rescue of a missing trained cave diver. David received the Canadian Star of Courage for this rescue which took place in the chilly Canadian waters of Tobermory, Ontario. He still dives as much as possible, but admits his six year old son Lukas, five year old daughter Emeline and wife (Dr Debbie Pestell) are currently higher priorities than diving!