CONTINUING MEDICAL EDUCATION

The Medical and Surgical Treatment of Glaucoma

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SUMMARY

Background: Ongoing demographic changes in Europe are heightening the importance of adequate treatment for glaucoma, a disorder that is markedly more common in the elderly.

Method: A selective search for relevant literature, including Cochrane Reviews and the guidelines of the European Glaucoma Society, regarding the topical and surgical treatment of glaucoma.

Results: It is recommended that the intraocular pressure (IOP) should be lowered by 20% to 50% from its baseline value, depending on the extent of already existing damage, the rate of progression, the baseline IOP, and the age of the patient. Topical monotherapy can lower the IOP by 15% to 30%. The success rate of filtration surgery has risen because of the intraoperative application of topical antimetabolites and currently ranges from 50% to 90%, depending on the study.

Conclusions: The goal of glaucoma treatment is to protect the patient from blindness and visual impairment while keeping the treatment-related decline in quality of life to a minimum. Any type of glaucoma treatment, be it medical or surgical, must further this aim in consideration of the situation of the individual patient.

Key words: glaucoma, intraocular pressure, medical treatment, glaucoma surgery

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The term "glaucoma" designates a pathophysiologically heterogeneous group of eye diseases whose common feature is that they result in a characteristic type of optic neuropathy if untreated. Glaucoma is one of the more common causes of blindness in industrialized countries.

According to the World Health Organization (WHO), 4.5 to 5 million people are blind around the world because of glaucoma (e1). In Germany alone, about 800 000 to 900 000 people suffer from glaucoma, and it is estimated that nearly the same number have undiagnosed glaucoma. Its prevalence rises with age, from ca. 2.4% in persons over 40 to more than 7% in persons over 75; there is no clear difference in prevalence between men and women (1, e2).

The learning aims of this article for the reader are

- to acquire knowledge of the diagnosis and treatment of glaucoma that is relevant to clinical practice, because this disease is becoming more common as a result of demographic shifts,
- to become acquainted with medical and surgical treatments that can lower the intraocular pressure, and to understand their indications.

The authors searched the PubMed database for "glaucoma" to identify important current review articles and large-scale clinical studies with high levels of evidence, then selected some of these to serve as the basis for this paper. The essential current guidelines for the treatment of glaucoma are those of the European Glaucoma Society and of the German Ophthalmological Society; both of these guidelines can be retrieved from the Internet (8, e5). Systematic reviews in the Cochrane database were also consulted.

In view of the large subject and the limited space available, a variety of further diagnostic aspects and therapeutic options could not be discussed in this article.

Prevalence

According to the World Health Organization (WHO), 4.5 to 5 million people are blind around the world because of glaucoma.

Figure 1: Glaucomatous papilla in a patient with myopia in an advanced stage, with a very large excavation (loss of neuroretinal tissue) and typical displacement of the vascular trunk in the nasal direction. A hemorrhage is visible at the edge of the papilla at 3 o'clock. The observed peripapillary lightening is mainly due to the pronounced myopia.

Disease entities

In Western Europe, open-angle glaucoma is much more common than narrow-angle glaucoma. Elevated intraocular pressure in open-angle glaucoma is usually due to pathologically elevated outflow resistance in the trabecular meshwork. This leads to high intraocular pressure, of which the patient is hardly ever aware and which usually leads, over the years, to glaucomatous optic neuropathy and to a progressive visual field defect. Elevated intraocular pressure (>21 mm Hg) is the main risk factor for glaucoma; other risk factors include markedly fluctuating intraocular pressure, myopia, a family history of glaucoma, a thin cornea, and other associated ocular pathologies, such as the pseudoexfoliation syndrome (1, 2). Epidemiological studies have shown that the risk of glaucoma rises by 12% with every 1 mm Hg rise in intraocular pressure (3).

In narrow-angle glaucoma, the peripheral chamber angle is typically narrow, in a relatively short, hyperopic, phakic eye. So-called pupillary block can drive the intraocular pressure to extremely high values (>50 mm Hg) and produce a classic painful "glaucoma attack," with conjunctival hyperemia, corneal clouding, and an irregularly deformed pupil.

Normal-pressure glaucoma (by definition, a progressive change of the optic nerve that is typical of glaucoma, but with intraocular pressure values no higher than 21 mm Hg, which is considered normal) should probably not be considered a single disease entity, but rather a part of the broad spectrum of open-angle glaucoma in which

many risk factors besides intraocular pressure are at work, including low blood pressure, vasospastic signs such as migraine, familial predisposition, low body-mass index, and a thin cornea (4–7, e3, e4).

Congenital glaucoma is rare (1 per 10 000 births) and is characterized by increased corneal radii, (often) cloudy cornea, tearing, and photophobia.

Secondary glaucoma is also rare. It is seen in rare hereditary syndromes, such as aniridia, and in traumatic secondary glaucoma, aphakic glaucoma, steroid-induced glaucoma, and neovascular glaucoma of various causes, including central vein thrombosis and diabetes mellitus.

Diagnostic aspects

The basic diagnostic evaluation of glaucoma comprises intraocular pressure measurement (tonometry) and morphological and functional studies of the eye.

The intraocular pressure is generally measured with applanation tonometry, which was introduced by Goldmann in 1954/55. In this technique, the cornea is topically anesthetized, its apex is "flattened" with a measuring head, and the applied force necessary to deform it is taken as an index from which the intraocular pressure can be derived. Depending on the apparatus used, applanation tonometry can be performed with the patient supine or sitting. The measured value depends not only on the examiner, but also on the biomechanical properties of the cornea, including its thickness. The newer tonometric techniques include rebound tonometry, which does not require anesthesia of the cornea, and dynamic contour tonometry, which is more cumbersome but less susceptible to inaccuracy resulting from the properties of the cornea. Goldmann applanation tonometry is still considered the standard technique.

The different types of glaucoma are characterized by a similar pathology of the optic nerve head, whose severity depends on the stage of the disease. The main pathological findings are

- neuroretinal rim loss,
- increased excavation of the papilla,
- nasal displacement of the vessels of the papilla (Figure 1),
- "bayoneting" (sharp bending) of the vessels, and
- hemorrhages at the periphery of the papilla.

Loss of the neuroretinal rim reflects a loss of retinal ganglion cells.

A visual field defect is usually not seen on perimetric examination until the morphologically evident tissue

Risk factors

- Elevated intraocular pressure (> 21 mm Hg)
- Marked fluctuations of intraocular pressure
- Myopia
- Family history of glaucoma
- Thin cornea
- Other associated pathology of the eye

Basic diagnostic evaluation

- Measurement of intraocular pressure (tonometry)
- Morphological and functional studies of the eye

damage at the neuroretinal rim is markedly advanced (>40%). When the papilla is damaged, but the visual field is found to be normal, the patient is said to have "preperimetric glaucoma," and follow-up examinations focus on the optic disk findings (e6).

Pharmacotherapy

Multiple large-scale randomized studies have shown, at a high level of evidence, that local treatment—either medical or surgical—lowers the intraocular pressure and protects the visual field to a statistically significant extent in primary chronic open-angle glaucoma, normal-pressure glaucoma, and ocular hypertension (1, 4–7, 9 10, e7). In contrast, the available evidence does not suffice to determine which medical treatment or surgical procedure should be used as the first choice, or under what circumstances a patient who has been treated medically should undergo surgery.

In the stepwise treatment algorithm recommended by the European Glaucoma Society (EGS), pharmacological reduction of the intraocular pressure is the first step, followed by laser surgery of the trabecular meshwork and (filtering) glaucoma surgery.

The EGS recommends that the therapeutic target for the intraocular pressure should be set as a function of the pre-existing degree of optic nerve damage, the patient's life expectancy, the rapidity of progression, and the baseline value of the intraocular pressure before treatment (8).

Generally speaking, a drastic reduction of the intraocular pressure by 30% to 50% is more likely to be needed in a later than in an earlier stage of the disease.

There are two approaches to the medical reduction of intraocular pressure:

- Reducing the production of aqueous humor production, with the use of:
 - beta-blockers (inhibition of the beta-mediated stimulation of $\text{Na}^+/\text{K}^+-\text{ATPase}$)
 - carbonic anhydrase inhibitors
 - sympathomimetic drugs (activation of the alpha-mediated inhibition of $\text{Na}^+/\text{K}^+-\text{ATPase}$)
- Increasing the outflow aqueous humor, with the use of:
 - cholinergic/parasympathomimetic drugs and prostaglandin derivatives (trabecular meshwork)
 - sympathomimetic drugs (uveoscleral outflow)
 - prostaglandin derivatives (uveoscleral outflow)

The advantages of improving aqueous humor outflow are the following:

- correction of the outflow deficit that is the primary cause of elevated intraocular pressure
- improved protection against fluctuations and dangerous spikes of the intraocular pressure
- maintenance of the physiological production of the aqueous humor and preservation of its normal functions (e.g., nutrition of the lens and cornea, removal of metabolic waste products).

According to the EGS guidelines, prostaglandin analogs, beta-blockers, alpha-2 agonists, and topical carbonic anhydrase inhibitors are the agents of first choice (8).

Topical prostaglandin analogs

Prostaglandin analogs (PGA) are among the more effective medications for reducing the intraocular pressure, with a lowering effect of as much as 33% (11). Their failure rate, defined as a less than 20% reduction, is 15% to 20% (e8).

Topical PGA have the following advantages over topical beta-blockers:

- application only once a day, usually in the evening (compliance)
- pressure reduction through improved outflow (uveoscleral and trabecular)
- prolonged pressure-lowering effect, lasting up to 48 hours
- a very short systemic half-life, and therefore a very low rate of systemic side effects.

Up to 50% of patients develop irreversible iridial hyperpigmentation (12), and patients should also be warned of the risk of increased eyelash growth. The risk of cystoid macular edema (water deposition in the middle of the retina, impairing central visual acuity) due to PGA treatment is of uncertain magnitude as far as can be determined from current data. If macular edema develops under PGA treatment, an attempt should be made to discontinue the treatment. In the authors' personal experience, however, the risk of macular edema is not so high that PGA would need to be discontinued before intraocular surgery. A recently published retrospective study supports our opinion (e9).

After application, PGA are split by corneal esterases to generate the active form of the drug. Latanoprost and travoprost have roughly equivalent pressure-lowering activity. Tafluprost has recently become available in a preservative-free formulation.

Bimatoprost belongs to the prostamide subclass; its pressure-lowering potential resembles that of latanoprost or travoprost.

Pharmacotherapy

Which medications and surgical procedures are the treatments of first choice, and under what circumstances a patient who has been under medical treatment should undergo surgery, are questions to which the literature does not yet provide any securely evidence-based answers.

Topical prostaglandin analogs

Prostaglandin analogs lower the intraocular pressure by as much as 33% and are thus among the more effective medications for this purpose. The failure rate is 15% to 20%.

Combined preparations (PGA and beta-blockers) are applied once in the morning, so that the topically applied beta-blocker can exert a more powerful effect on aqueous humor production, which is at its highest in the morning hours.

Topical beta-blockers

The average net pressure reduction from topical beta-blockers is 20% to 25% of the baseline value (11). Substances in this class that are currently in use include timolol, betaxolol, carteolol, levobunolol, and metipranolol.

Contraindications to the use of topical beta-blockers include sinus bradycardia, grade II/III atrioventricular block, congestive heart failure, bronchial asthma, and chronic obstructive pulmonary disease (COPD). As most of the pharmacologically active drug is resorbed through the nasal mucosa, the tear duct should be manually compressed after the eye drop is instilled in order to minimize systemic resorption.

Topical beta-blocker treatment often causes a problematic local worsening of sicca symptoms. The indication for topical beta-blockers in small children should be considered carefully, as it also should in pregnant women and nursing mothers in particular, because the active drug can accumulate in breast milk.

Topical alpha-agonists

Alpha-agonists lower the intraocular pressure both by reducing aqueous humor production and by increasing the uveoscleral outflow. Alpha-2 agonists are contraindicated in children up to age 8 because of their potential central sedating effect. This class of drugs includes clonidine, apraclonidine, and brimonidine.

Brimonidine can lower the intraocular pressure by as much as 27% (11). As it is alpha-2 selective, it has almost no mydriatic effect and no more than a mild vasoconstrictive effect. It does, however, have a high rate of local allergic reactions (over 25%).

Clonidine 0.125%, a more lipophilic agent, enters the central nervous system more easily and has a higher rate of systemic side effects. It also accumulates in breast milk and should therefore not be given to pregnant women or nursing mothers. It has the advantage of being available without preservatives. Apraclonidine 0.5%–1.0% and nonselective adrenergic drugs such as dipivefrin 0.1% are currently considered second-line medications because of their systemic and local side effects.

Topical parasymphomimetic (miotic) agents

Pilocarpine has been known since 1870 to lower the intraocular pressure; it is available in concentrations ranging from 0.5% to 6%. It lowers the intraocular pressure by about 20%. Miotic agents are now hardly ever given for indications other than narrow-angle glaucoma or the plateau-iris syndrome, in which they serve to keep the trabecular meshwork open. They are used to immobilize the iris in pigment-dispersion glaucoma and pseudoexfoliation glaucoma, thereby lowering the extent of pigment release and pseudoexfoliation, respectively, while also improving aqueous humor outflow through the trabecular meshwork. The induced miosis can, however, cause painful spasms of the ciliary body. Moreover, contraction of the ciliary muscle can induce up to –8 diopters of myopia. Miosis can also lead to marked visual impairment, particularly in dim light and in the presence of a cataract. Miotic agents are available in combined preparations, mostly together with beta-blockers.

Topical and systemic carbonic anhydrase inhibitors

Topical carbonic anhydrase inhibitors (CAI) for the treatment of glaucoma and ocular hypertension (OHT) include brinzolamide and dorzolamide, which produce a 20% to 25% net lowering of the intraocular pressure (11). Topical CAI lower aqueous humor production by inhibiting the enzyme carbonic anhydrase in the ciliary body epithelium. They are available in fixed combinations with beta-blockers, as well as in preservative-free formulations.

The carbonic anhydrase inhibitor acetazolamide can be given systemically either by mouth or intravenously, the latter only in cases of acutely elevated intraocular pressure. Acetazolamide in doses up to 1000 mg po qd is usually given when topical medications are not tolerated (or no longer tolerated), as a temporizing measure before glaucoma surgery. The dosage and duration of treatment are limited by the drug's side effects: electrolyte disturbances (potassium replacement), paresthesiae, confusion, fatigue, kidney stones, circulatory disturbances, nausea, diarrhea, and a bitter taste. Topical and systemic carbonic anhydrase inhibitors should not be given to patients who are allergic to sulfonamides.

Topical carbonic anhydrase inhibitors have no additional effect when given in combination with systemic carbonic inhibitors. Simultaneous topical and systemic administration is, therefore, not recommended.

Topical beta-blockers

The average net reduction of intraocular pressure with topical beta-blockers is 20% to 25% of the baseline value. Substances in this class that are currently in use include timolol, betaxolol, carteolol, levobunolol, and metipranolol.

Topical alpha-agonists

Alpha-agonists lower the intraocular pressure by slowing the production of aqueous humor and increasing uveoscleral outflow. Alpha-2 agonists are contraindicated in children up to the age of 8 years because of their potential central sedating side effects.

Hyperosmotic agents

The intravenous administration of a hyperosmotic drug (mannitol) is reserved for short-term emergency treatment, e.g., in an acute glaucoma attack with extremely high intraocular pressure.

Treatment other than by lowering the intraocular pressure

Many types of treatment for glaucoma that do not lower the intraocular pressure are currently under discussion, for potential use particularly in patients with normal-pressure glaucoma. The studies performed to date, however, have not yielded any high-level evidence supporting their use (e7). Proposed treatments in this class include the administration of low doses of calcium antagonists (nimodipine, nifedipine) to patients with vasospastic manifestations (e10), and of low doses of mineralocorticosteroids (fludrocortisone) to patients with marked arterial hypotension (e11). Neuroprotective agents, e.g., glutamate-receptor antagonists, have not yet been shown effective against glaucoma. Nor is there sufficient evidence to support the use of acupuncture for glaucoma (e12).

Surgical treatments for the lowering of intraocular pressure

Indications

If glaucomatous optic neuropathy or visual field defects (*Figure 2*) progress in a patient with chronic open-angle glaucoma despite the administration of two or three topical treatments, it is generally time to consider surgical intervention (e13). The same holds if local therapy is urgently needed but is not tolerated because of systemic or local side effects, or if the regular use of eye drops is an unrealistic prospect in view of the patient's social situation or comorbid conditions. For very old patients (aged 85 and above), the indications for surgery should be weighed carefully on an individual basis, as it can take years or even decades, depending on the intraocular pressure values, for any functional deficits to develop that will impair the patient's everyday activities.

Trabeculectomy with mitomycin C

Trabeculectomy with mitomycin C is the surgical treatment of first choice for medically intractable glaucoma. In a large-scale randomized trial, the intraocular pressure was significantly lower, after two to nine years of postoperative follow-up, than in the medically treated control group (15 vs. 17.2 mm Hg) (13). Depending on the trial

Figure 2: The course of a visual field defect (demonstrated with two different perimetric apparatuses) in a patient with chronic open-angle glaucoma and intermittent intraocular pressure spikes of up to 35 mm Hg. (a) The defect (black) is limited to one quadrant at first, but widens out (b) over time to give the typical appearance of a "glaucoma field defect."

Figure 3:

The filtering bleb after trabeculectomy with mitomycin C. The conjunctiva bulges markedly at the limbus. This procedure enables the aqueous humor to enter the subconjunctival space.

and the patient's individual situation, the procedure's success rate (variously defined) after one to five years lies between 50% and 90% (14–16). "Success" typically means that the visual field defect remains stable and the intraocular pressure does not rise above 20 mm Hg.

The goal of the procedure is to establish a permanent transscleral outflow of aqueous humor from the eye into the subconjunctival space. Thus, in the ideal case, a mild bulging of the filtering bleb is seen in the upper quadrant of the globe (*Figure 3*). Cataract acceleration is a side

Topical and systemic carbonic anhydrase inhibitors

Topical and systemic carbonic anhydrase inhibitors should not be given to patients who are allergic to sulfonamides.

Proposed treatments for glaucoma that do not lower the intraocular pressure

Neuroprotective agents, e.g., glutamate-receptor antagonists, have not yet been shown effective against glaucoma. Nor are there adequate data to support the use of acupuncture in glaucoma.

Figure 4:

Filtering bleb infection with secondary endophthalmitis due to migration of bacteria across the bleb, ten years after trabeculectomy with mitomycin C

Figure 5:

Silicon catheter in the anterior chamber of the eye after implantation of a glaucoma implant in the nasal lower quadrant of the globe

effect of the procedure, because aqueous humor no longer bathes the lens. As a large portion of the filtering bleb can be scarred by wound healing, trabeculectomy is now usually combined with the intraoperative local application of mitomycin C to inhibit fibroblast activity (e14). In patients at special risk, this is sometimes supplemented with the postoperative, subconjunctival administration of 5-fluorouracil (e15). The procedure is performed under general anesthesia in children and adolescents, but adults and older patients can have it under local, preferably subconjunctival anesthesia.

Unlike modern, "bloodless" cataract surgery, however, this procedure requires a temporary interruption or discontinuation of any anticoagulants the patient may be taking, as heavy bleeding worsens the functional result of this type of filtration surgery.

Regular postoperative follow-up is needed even when the procedure initially meets with success: after the application of mitomycin C, the filtering bleb can develop microlesions, even years later, through which

bacteria can enter the bleb, migrate across it, and cause secondary endophthalmitis (Figure 4) (17, 18). The risk of bacterial blebitis or endophthalmitis after glaucoma surgery is 1% to 1.5% per patient-year (19, 20). Endophthalmitis can also be a complication of implants for glaucoma; this occurs up to five times more frequently in children (21).

Implants for glaucoma

Glaucoma implant surgery is being increasingly used around the world as a method of last resort after failed trabeculectomy. In these procedures, the aqueous humor is shunted out of the anterior chamber (Figure 5) through a thin silicon tube (inner diameter, 300 µm) to an episcleral footplate located behind the equator of the globe. No clinical trials have yet shown any type of implant to be better than any other with a high level of evidence (e16). Many patients treated with glaucoma implants still need local treatment for glaucoma thereafter (16). While precise figures are unavailable, glaucoma implants certainly account for no more than a small percentage (<2%) of the operations now being performed for open-angle glaucoma in Germany, with filtration surgery making up the rest. The percentage is higher for intractable types of glaucoma. The largest clinical trial comparing glaucoma implants with filtration surgery as the current standard treatment has shown comparably good results from both treatments with respect to success rates at 1 year (ca. 90%), intraocular pressure (ca. 12 mm Hg), and safety, although the implant group received more medications postoperatively (the "Tube Versus Trabeculectomy" [TVT] study). A long-term observational study of a large collective of insured patients revealed, however, that difficult problems such as corneal opacification can arise years after implant surgery, and then in every fourth patient (20).

Trabeculectomy/goniotomy

Trabeculectomy and goniotomy are the usual surgical treatments of congenital glaucoma (22). The trabecular meshwork is surgically opened either from within (goniotomy) or from without (trabeculectomy) to create a direct communication between the anterior chamber of the eye and Schlemm's canal. Trabeculectomy is also sometimes performed as the primary surgical treatment of congenital glaucoma and seems to be comparably effective (23). For congenital glaucoma, in distinction to other types of glaucoma, surgery is generally the best primary treatment.

Surgical treatment to lower the intraocular pressure

If glaucomatous optic neuropathy or visual field defects should progress in a patient with chronic open-angle glaucoma despite the administration of two or three topical treatments, it is generally time to consider surgical intervention.

Trabeculectomy with mitomycin C

Trabeculectomy with mitomycin C is the method of first choice for the surgical treatment of medically intractable glaucoma.

Laser techniques

Laser cyclophotocoagulation

Unlike the other techniques discussed above, whose purpose is to lower the intraocular pressure by increasing the outflow of aqueous humor from the anterior chamber, cyclophotocoagulation is intended rather to decrease its inflow by destroying the non-pigmented epithelial cells of the ciliary body that produce it. The ciliary body is coagulated with a laser, either from inside the eye under endoscopic visualization, or else through the sclera without opening the globe. No clear dose-effect relationship has been shown (e17), and overtreatment carries the risk of phthisis bulbi (shrinking of the globe); thus, the treatment is usually applied in underdosed and fractionated fashion, and a single application only rarely brings long-term success. There is wide disagreement among surgical ophthalmologists as to the value of this treatment: both its effectiveness and its underlying principle have been called into question (e17, e18).

Laser trabeculoplasty

Selective laser trabeculoplasty with a double-frequency neodymium:YAG laser is about as effective as argon laser trabeculoplasty but applies far less energy overall and therefore has less severe side effects. Laser trabeculoplasty reduces the intraocular pressure by no more than 5–6 mm Hg, a much smaller amount than filtration surgery (e19). Therefore, it is typically used in patients whose glaucoma is not yet very advanced and who cannot tolerate locally applied medications, patients whose intraocular pressure is no higher than 25 mm Hg at the outset, or patients who decline intraocular surgery, e.g., persons of very advanced age.

Selective laser trabeculoplasty yields a 20% reduction in intraocular pressure for one year in 60% to 80% of the eyes treated (24, e20), though some published success rates are markedly lower (e21).

New surgical methods

New surgical methods have been developed recently at a number of centers; their value is currently uncertain, as randomized comparisons with standard treatment are lacking. One of these methods is viscocanaloplasty, in which, after 360° viscodilatation of Schlemm's canal, a loop of nonresorbable Prolene suture is placed in it and knotted under light tension (e22).

Another method, deep sclerectomy with or without resorbable implants, is related to trabeculectomy, differ-

ing from it in that a deep scleral flap is excised, but the trabecular meshwork is not completely opened. As the anterior chamber of the eye remains primarily unopened, this operation produces less postoperative irritation within the eye, but it may not reduce the intraocular pressure quite as effectively as trabeculectomy with mitomycin C (e23).

Surgery for narrow-angle glaucoma

The oldest surgical treatment of glaucoma is iridectomy, which was introduced by Albrecht von Graefe in the 19th century and is now mainly performed as laser iridotomy with a neodymium:YAG laser. It is the treatment of choice for the prevention of pupillary block in narrow-angle glaucoma (25).

Pupillary block can also arise in uveitis because of circumferential adhesion of the pupil to the anterior surface of the lens (posterior synechia), resulting in a massive rise of the intraocular pressure. Iridectomy is needed in this situation but should be performed surgically, as the smaller opening produced by laser iridotomy will close again in more than half of all cases.

The prognosis after glaucoma surgery

The risk of blindness in the first 12 months after glaucoma surgery is very low, especially in comparison to the natural history of untreated glaucoma; after primary trabeculectomy, this risk is approximately 0.4% (20). Blindness is caused by postoperative endophthalmitis or by a postoperative intra- or subchoroidal hemorrhage. Hemorrhage is most likely to occur when the intraocular pressure has been extremely high (above 50 mm Hg) for a long time and is suddenly reduced by surgery to less than 4 mm Hg.

Though blindness is rare, a postoperative loss of central visual acuity is more common, occurring at a frequency of 20% to 30% (16). Its various causes range from cataract, macular edema, and retinal wrinkling (Figure 6) to a late-onset visual field defect that may arise months after surgery, but is still due to the high intraocular pressure present preoperatively.

Patients rightly associate the diagnosis of glaucoma with a lifelong need for treatment and with the possibility of blindness in the future. They therefore need not just ophthalmological care in the narrow sense of medical problem-solving, but also individualized psychological guidance. This is particularly so because, in the first year of treatment, well over half of all patients have problems

Implants for glaucoma

No clinical trials have yet shown any type of implant to be better than any other with a high level of evidence.

Congenital glaucoma

Trabeculotomy and goniotomy are the usual surgical treatments of congenital glaucoma.

Figure 6:

(a) This infrared photograph of the posterior pole of the eye reveals tortuosity of the retinal vessels secondary to low intraocular pressure.
(b) In an eye with low intraocular pressure after glaucoma surgery, ocular coherence tomography of a central retinal section reveals a saw-tooth pattern due to the low pressure.

complying with their prescribed antiglaucomatous medication (e24).

Conflict of interest statement

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New surgical techniques

In recent years, new surgical techniques have been developed at a number of surgical centers. Their clinical utility is still uncertain, as there are as yet no data from randomized studies comparing them to the standard procedures.

The prognosis after glaucoma surgery

The risk of blindness in the first 12 months after glaucoma surgery is very low, especially in comparison to the natural history of untreated glaucoma.

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Further Information on CME

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The solutions to the following questions will be published in volume 45/2009.

The CME unit "Acute Infectious Diarrhea in Children" (issue 33/2009) can be accessed until 25 September 2009.

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Solutions to the CME questionnaire in volume 28–29/2009:

Westphal et al.: Infective Endocarditis—Prophylaxis, Diagnostic Criteria, and Treatment.

Solutions: 1b, 2d, 3b, 4a, 5c, 6a, 7d, 8c, 9a, 10e

Please answer the following questions to participate in our certified Continuing Medical Education program. Only one answer is possible per question. Please select the answer that is most appropriate.

Question 1

Which of the following is a typical symptom or sign of a glaucoma attack, i.e., an episode of acute pupillary block, in a patient with narrow-angle glaucoma?

- a) Low body-mass index
- b) Evidence of vasospasm
- c) Oculomotor disturbance with diplopia
- d) Corneal opacification
- e) Arterial hypertension

Question 2

Which of the following is a typical sign of congenital glaucoma in a 2-month-old baby?

- a) White pupillary reflex (leucocoria)
- b) Vertical strabismus
- c) Increased corneal radii
- d) Epicanthus
- e) Micropapilla

Question 3

What constellation of risk factors is typically observed in normal-pressure glaucoma?

- a) Arterial hypertension, high BMI, marked farsightedness
- b) Elevated intraocular pressure, marked farsightedness, nystagmus
- c) Short eye, thick cornea, high BMI
- d) Arterial hypertension, type 2 diabetes, thick cornea
- e) Migraine, low blood pressure, thin cornea

Question 4

Which of the following is a typical change of the optic nerve head in glaucoma?

- a) Temporal displacement of the vascular trunk
- b) Hemorrhages at the periphery of the papilla
- c) Hyperemia of the papilla
- d) A thickened neuroretinal rim
- e) Prepapillary vitreous opacification

Question 5

Which of the following can affect the measured values in applanation tonometry?

- a) The biomechanical properties of the cornea
- b) The size of the iris
- c) The width of the pupil
- d) The magnitude of the anisometry
- e) The age of the patient

Question 6

What topical medication for lowering the intraocular pressure is contraindicated in children because of its adverse effects on the central nervous system?

- a) Tafluprost
- b) Brimonidine
- c) Dorzolamide
- d) Pilocarpine
- e) Brinzolamide

Question 7

What class of topical anti-glaucoma drugs is contraindicated in patients that are allergic to sulfonamides?

- a) Prostaglandins
- b) beta-blockers
- c) Miotic agents
- d) alpha-agonists
- e) Carbonic anhydrase inhibitors

Question 8

In which type of glaucoma is surgical treatment generally indicated as a primary measure, without a previous attempt to control the intraocular pressure with medications?

- a) Pigment-dispersion glaucoma
- b) Pseudoexfoliation glaucoma
- c) Traumatic secondary glaucoma
- d) Primary congenital glaucoma
- e) Primary open-angle glaucoma

Question 9

For what disease is surgical iridectomy or laser iridotomy the treatment of choice?

- a) Primary congenital glaucoma
- b) Primary open-angle glaucoma
- c) Pseudoexfoliation glaucoma
- d) Narrow-angle glaucoma
- e) Traumatic secondary glaucoma

Question 10

What are typical postoperative complications after trabeculectomy with mitomycin C?

- a) Cataract, scarring of the filtering bleb, and blebitis
- b) Retinal foramen, retinal detachment, and macular edema
- c) Secondary vertical strabismus, head tilt, and diplopia
- d) Photophobia, epiphora, and lacrimal duct stenosis
- e) Eyelash growth, periocular discoloration, and change of iris color

CONTINUING MEDICAL EDUCATION

The Medical and Surgical Treatment of Glaucoma

Thomas S. Dietlein, Manuel M. Hermann, Jens F. Jordan

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