SURVEY OF OPHTHALMOLOGY VOLUME 53 • NUMBER 6 • NOVEMBER–DECEMBER 2008

ELSEVIER

DIAGNOSTIC AND SURGICAL TECHNIQUES

MARCO ZARBIN AND DAVID CHU, EDITORS

Nonpenetrating Glaucoma Surgery

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Abstract. Nonpenetrating glaucoma surgeries have been developed in recent years in order to improve the safety of conventional filtering procedures. The goal of nonpenetrating filtering procedures is to reduce intraocular pressure by enhancing the natural aqueous outflow channels, while reducing outflow resistance located in the inner wall of the Schlemm's canal and the juxtacanalicular trabecular meshwork. In the last few years viscocanalostomy and deep sclerectomy with external trabeculectomy have become the most popular nonpenetrating filtering procedures. Both involve removal of a deep scleral flap, the external wall of Schlemm's canal and corneal stroma behind the anterior trabeculum and Descemet's membrane, thus creating an intrascleral space. The aqueous humour leaves the anterior chamber through the intact trabeculo-Descemet's membrane into the scleral space, from where it will egress into different pathways. The technique is associated with a long learning curve. Published clinical trials comparing nonpenetrating glaucoma surgery to full-thickness trabeculectomy have a consensus on the superior safety profile of nonpenetrating glaucoma surgery but are not in agreement when it comes to efficacy, where conflicting results have been found. This article reviews the nonpenetrating surgical techniques, mechanisms of action, indications, contraindications, complications, and results. (**Surv Ophthalmol** 53:592–630, 2008.

Key words. ab-externo trabeculectomy • deep sclerectomy • goniopuncture • implants • nonpenetration of the anterior chamber • trabeculodescemetic membrane • viscocanalostomy

I. Historical Review of Nonpenetrating Glaucoma Surgery

In 1964 Krasnov published his first report on sinusotomy.[148–152] This operation consisted of removing a lamellar band of the sclera, opening the Schlemm's canal over 120 degrees from 10 to 2 o'clock. The inner wall of Schlemm's canal was untouched and then the conjunctiva was closed. Krasnov believed that the aqueous outflow resistance in the majority of primary open-angle glaucoma (POAG) was situated at the level of scleral aqueous drainage veins and not in the trabeculum. In the same year Walker published a paper about surgery of the Schlemm's canal.[284] Other authors also reported on nonpenetrating filtering surgery, leaving in place the trabeculum and the inner wall of Schlemm's canal.[1,14,22,249] When there was no percolation of aqueous through the trabeculum and Schlemm's canal inner wall, Krasnov would enter the anterior chamber and perform a peripheral

0039-6257/08/$–see front matter
doi:10.1016/j.survophthal.2008.08.023

iridectomy creating a full-thickness procedure, which was the standard filtering surgery at that time. Sinusotomy was relatively safer than full-thickness surgery with almost no postoperative complications. This was certainly not the case with standard full-thickness procedures, which often lead to a major hypotony followed in many cases by a flat anterior chamber, choroidal detachments, and cataract formation. Krasnov also reported that the filtering blebs were more diffuse after sinusotomy and that they tended to disappear with time. Sinusotomy never became popular because it was a difficult operation. It needed a surgical microscope at a time when this was not readily available. Moreover the surgical results were not convincing.[23,44,132,142,149,150–153,170,188–190,196,199,200,217,229,230,249,264,280] Kraznov reported an 83% success rate with no data regarding the success criteria, the number of patients followed, and the time of follow-up.[151] In 1967 Postic et al[217] reported a 50% success rate in 12 glaucoma patients operated with sinusotomy with a maximum follow-up of 10 months. Six patients had low intraocular pressure (IOP) with filtering blebs. The other 50% presented a primary drop in IOP after the surgery, and then an IOP rise due to fibrosis of the filtering bleb. In the late 1960s, and for the next three decades, trabeculectomy described by Sugar in 1961[261] and Cairns in 1968[38] became the standard technique for filtering surgery, providing satisfactory IOP control with fewer postoperative complications than full-thickness filtering procedures. However, even with the numerous modifications proposed to the original trabeculectomy, the lack of a reproducible postoperative IOP reduction as well as the early postoperative complications led several surgeons to reconsider Kraznov's work.[1,2,41,84,126] Several techniques of nonpenetrating filtering surgery based on sinusotomy have been described. Nonpenetrating trabeculectomy was proposed by Zimmermann[308,309] in 1984 and Arenas first published the term ab-externo trabeculectomy in 1991.[11] Fyodorov stressed on removing the corneal stroma behind the anterior trabeculum and Descemet's membrane and termed this as deep sclerectomy.[87] This was also described by Kozlov[87,143,144] and later by Stegmann.[259]

II. Ab-externo Trabeculectomy

This technique is similar to sinusotomy except for the presence of a superficial scleral flap and the removal of the inner wall of Schlemm's canal and the juxtacanalicular trabeculum.[308,309] In sinusotomy, Schlemm's canal is unroofed with no superficial scleral flap to cover the sclerectomy whereas the inner wall of Schlemm's canal is untouched. In ab-externo trabeculectomy, a deep sclerectomy unroofing Schlemm's canal is performed and covered by a superficial scleral flap. The inner wall of Schlemm's canal and the juxtacanalicular trabeculum, where the main outflow resistance is located, are removed.

The conjunctiva is opened either at the fornix or at the limbus in the superior quadrant. A 4 × 4 mm superficial scleral flap is created at the 12 o'clock position (but the size of the superficial scleral flap may be variable from one surgeon to another). The depth of this scleral flap corresponds approximately to one-third of the full-scleral thickness. A radial cut is performed on the edge of the flap at the limbus to localize Schlemm's canal. Once Schlemm's canal is found, it is unroofed in the same manner as Krasnov did sinusotomy. At this stage, there is a 4-mm-long Schlemm's canal parallel to the limbus. To remove the inner wall of Schlemm's canal, different techniques have been proposed. A fine forceps ended with two small plates may be used to grab the endothelium and to peel it off from one side to the other.[179,180,182] Trabeculo-aspiration has been proposed by Bechetoille who used a fine canula connected to a phaco infusion-aspiration system (personal communication). Dahan advocated the use of a fine diamond-coated spatula, which allows one to scrape the endothelium (personal communication), and Arenas uses a diamond burr.[10]

All of these maneuvers have been grouped into the so-called ab-externo trabeculectomy because the juxtacanalicular trabeculum is removed and the corneo-scleral and uveo-scleral trabecula are left in situ. Hamard et al[113] showed by the means of confocal microscopy that the tissues removed corresponded to the inner wall of Schlemm's canal, the juxtacanalicular trabecular meshwork, and also part of the corneoscleral trabeculum, in agreement with the findings reported by Sun et al.[262]

III. Deep Sclerectomy

A. CONJUCTIVAL AND SUPERFICIAL SCLERAL FLAPS

The conjunctiva may be opened either at the fornix or at the limbus. A 5 × 5 mm superficial scleral flap is performed including one-third of the scleral thickness (300 μm) (Fig. 1).[5,17,26,33,36,49,67–69,78,84,87,108,111,129,133] To be able to reach Descemet's membrane later in the dissection, the superficial scleral flap has to be cut 1–1.5 mm anteriorly into the clear cornea (Fig. 2). The initial incision is made with a no. 11 stainless steel blade and the horizontal dissection with a ruby blade. In patients with a high risk of scleroconjunctival scar formation,