Nonpenetrating Glaucoma Surgeries and Recent Microinvasive Glaucoma Devices

Essay

Submitted For Partial Fulfillment of Master Degree in Ophthalmology

By

Mona Ibrahim Naguib El Refai

M.B., B.Ch. Faculty of Medicine - Ain Shams University

Supervised By

Prof. Dr. Khalid Abd AlWahab ElTagory

Professor of Ophthalmology

Faculty of Medicine - Ain Shams University

Dr. Momen Mahmoud Hamdi

Lecturer of Ophthalmology

Faculty of Medicine - Ain Shams University

Faculty of Medicine
Ain Shams University
Cairo
Egypt
2016

Acknowledgment

First and foremost, deep thanks to **ALLAH**, the most merciful, for his grace and mercy and for giving me the strength to complete this work.

I would like to express my deep gratitude and appreciation to:

Prof. Dr. Khalid Abd AlWahab ElTagory

Professor of Ophthalmology, Faculty of Medicine, Ain Shams University, for his continuous help, unlimited support, and providence of all facilities possible, to complete this work. It was an honor to work under his supervision.

My sincere thanks to:

Dr. Momen Mahmoud Hamdi

Lecturer of Ophthalmology, Faculty of Medicine, Ain Shams University, for his kind cooperation, continuous guidance, honest help, and endurance, which made this essay come to light.

I would like to thank my colleagues for their help during the preparation of this work.

Last but not least, I'm very thankful, and grateful, to my family, my husband "Ahmed" and my son "Mustafa", who have helped me in producing this work, and who always support me in my life.

Mona Ibrahim Naguib El Refai

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List of Abbreviations

Abbreviation	Description
AC	Anterior Chamber
AS-OCT	Anterior Segment Optical Coherence Tomography
ACG	Angle Closure Glaucoma
BAGS	Blebless Ab-externo Glaucoma Surgery
CP	Canaloplasty
DS	Deep Sclerectomy
DSCI	Deep Sclerectomy with Collagen Implant
FDA	Food and Drug Administration
FU	Fluorouracil
GMS	Gold Micro Shunt
GPC	Goniopuncture
HEMA	Hydroxy Ethyl methacrylate
IOL	Intraocular Lens
IOP	Intraocular Pressure
MIGS	Micro Invasive Glaucoma Surgery
MMC	Mitomycine C
Nd:YAG Laser	Neodymium:Yttrium Aluminum Garnet
NPGS	Nonpenetrating Glaucoma Surgery
NSAID	Nonsteroidal Anti Inflammatory Drug
NVG	Neovascular Glaucoma
OVD	Ocular Viscoelastic Device
PMMA	Polymethyl Methacrylate
POAG	Primary Open Angle Glaucoma
SC	Schlemm's Canal
TDM	Trabecular Descement Membrane
TM	Trabecular Meshwork
VSC	Viscocanalostomy

Introduction

Primary open-angle glaucoma (POAG)) is a progressive, chronic optic neuropathy in adults in which intraocular pressure (IOP) and other currently unknown factors contribute in the damage of optic nerve. [(1)]

Filtering surgery is effective in lowering IOP; it is generally indicated when medicine or laser therapy is insufficient to control disease and can be considered in selected cases as initial therapy. [(1)]

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. [(2)]

The main apparent advantages of the nonpenetrating sclerostomy over conventional trabeculectomy rely on the fact that the globe is not penetrated during the procedure as a thin layer of trabecular meshwork tissue is left. This should result in less early postoperative hypotony and associated complications such as choroidal effusion and, possibly, inflammation. It is possible that a reduction in inflammation may also result in less cataract progression. [(3)]

In the last few years, viscocanalostomy and deep sclerectomy 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. [(2)]

In order to maintain intrascleral bleb patency and to prevent a collapse of the superficial flap over the scleral bed, a space maintainer is often used in deep sclerectomy. The most commonly used space maintainer is a device made of degradable porcine collagen. Other

implants have been proposed, including viscoelastics, hydroxyethyl methacrylate (HEMA), high reticulated hyaluronic acid and polymethyl methacrylate (PMMA). [(4)]

The reticulated hyaluronic acid implant is called (SK-GEL). [(5)]

A hydrophilic acrylic implant (T-flux implant) that is non-absorbable has been developed. It is a T-shaped implant that creates an evacuating canal along the foot and each arm of the T shape, and is inserted into one of the surgically created openings of the Schlemm's canal. [(5)]

On the other hand, Stegmann described the viscocanalostomy, in which he used a high viscous viscoelastic substance to dilate the Schlemm's canal. [(6)]

Canaloplasty is a new nonperforating surgical technique for open-angle glaucoma. [(7)]

In recent years, the development of a new class of procedures, termed micro-invasive glaucoma surgery (MIGS), has raised excitement within the glaucoma community, by offering an alternative form of effective intraocular pressure reduction, associated with lower medication burden, and complication rates. [(8)]

Two MIGS procedures are approved by the Food and Drug Administration use the conventional outflow pathway through Schlemm's canal; first the Trabectome procedure (Neomedix) and more recently the iStent® trabecular micro-bypass (Glaukos). [(9)]

IStent® provides a channel for a direct transtrabecular aqueous outflow from the anterior chamber to collector channels [(10)], POAG remains the most common indication. [(8)]

The Ex-Press Mini Glaucoma Shunt is used to shunt aqueous from the anterior chamber to a subconjunctival reservoir in a similar

fashion as trabeculectomy, without removal of any sclera or iris tissue. [11]

Other MIGS devices such as the CyPass Micro-Stent, supraciliary microshunt (Transcend Medical) and the Hydrus (Ivantis) are in clinical trials. [12]

The Hydrus Microstent has been designed to bypass the trabecular meshwork and scaffold and dilate approximately one quadrant of Schlemm's canal, thus routing aqueous humor from the anterior chamber into open collector channels. [9]

The SOLX gold shunt (SOLX Ltd., Waltham, MA) is designed to transmit aqueous from the anterior chamber to the suprachoroidal space, where it will ultimately be redistributed and reabsorbed by the scleral channels or the choriocapillaris. [13]

The Aquashunt (OPKO Health Inc., Miami, FL, USA) is a suprachoroidal device designed to be inserted through a full thickness scleral incision with an integrated insertion tool. The key difference between the Aquashunt and the gold shunt is a single large lumen for the Aquashunt rather than several small channels. [13]

Aim of the Essay

The aim of this essay is to discuss nonpenetrating glaucoma surgeries in management of open angle glaucoma, and recent trends in this type of surgeries and recent updates in microinvasive glaucoma devices, and to compare them with the classic penetrating surgeries.

CHAPTER 1
Nonpenetrating Glaucoma Surgeries

Nonpenetrating Glaucoma Surgeries

Nonpenetrating glaucoma surgeries have been developed in recent years, in order to improve the safety of conventional filtering procedures. [14] Nonpenetrating glaucoma surgery (NPGS) refers to drainage procedures that restore aqueous humor filtration through a natural membrane, the trabeculo-Descemet's membrane (TDM). It targets the presumed site of pathology, namely Schlemm's canal and the juxtacanalicular meshwork. [15]

The concept of non-penetrating glaucoma surgery (NPGS) originated in 1964 when Krasnov published his first report on sinusotomy.[16] This operation consisted of removing a lamellar band of the sclera, opening the Schlemm's canal over 120º from 10 to two o'clock. The inner wall of the Schlemm's canal was untouched and the conjunctiva was closed. However, sinusotomy never became popular because it was a difficult operation, it needed a surgical microscope and the Schlemm's canal had to be found, which is not easy. [5]

In the late 1960s and for the next three decades, trabeculectomy, as described by Sugar [17] in 1961 and Cairns [18] in 1968, became the gold standard technique for filtering surgery. [5]

Several techniques of nonpenetrating filtering surgery based on sinusotomy have been described. Since the main aqueous outflow resistance is located at the juxtacanalicular trabeculum and the inner wall of Schlemm's canal, these two anatomical structures were targeted. [5]

Fyodorov encouraged the removal of the corneal stroma behind the anterior trabeculum and the Descemet's membrane, and called this deep sclerectomy (DS). [19] This was also described by Kozlov [20] and later by Stegmann. [21]

I. Deep Sclerectomy

Deep sclerectomy is a new nonpenetrating glaucoma surgery intended to lower the incidence of complications occurring after trabeculectomy. There are two goals in deep sclerectomy. First is to create a filtering membrane named trabeculo-Descemet's membrane (TDM) which will ensure a reproducible postoperative intraocular pressure. This will prevent an excessive over filtration and avoid almost all severe postoperative complications. The second goal is to create an intrascleral filtering space that decreases the reliance on a subconjunctival filtering bleb. The thin remaining scleral bed of the intrascleral bleb also allows redirecting part of the aqueous humor to the subchoroidal space and therefore promotes uveoscleral outflow. **(4)**

To maintain intrascleral bleb patency and to prevent a collapse of the superficial flap over the scleral bed, a space maintainer is often used in deep sclerectomy. **(4)**

The first to be used was the Aquaflow collagen implant (Collagen Glaucoma Drainage Device, STAAR Surgical AG, Nidau, Switzerland), which is a highly purified porcine collagen dehydrated into a cylinder (4mm x 1mm x 1mm). This device is placed radially in the center of the deep sclerectomy dissection, as far as possible anteriorly such that it is in contact with the remaining TDM membrane and secured in the scleral bed with a single 10/0 nylon suture . It swells rapidly once exposed to the aqueous humor and is resorbed within 6–9 months after surgery. **(15)**

Another device that has been proposed to maintain the scleral lake is the reticulated hyaluronic acid implant (SK-GEL, Corneal, Paris, France; an equilateral triangle 3.5 mm long and 500μm thick or an isosceles triangle of size 4.5 mm × 3 mm with the same thickness). The advantages of this implant are that it occupies a large volume in the filtration area while allowing for sufficient circulation of the