INTRODUCTION

The Discovery Period

The use of setons to “wick” aqueous humor from the anterior chamber dates back to 1906, with horsehair being used to drain aqueous humor via paracentesis.[1] Various materials, including sutures, glass, metals, plastic, and biologic materials have been used and have ultimately failed due to the problems with inflammation, fibrosis, and infection. In the 1960s and 1970s, Dr. Anthony Molteno pioneered the development of a tube shunt implant, with a plate implanted posterior to the limbus and connected to the anterior chamber by a long silicone tube, thereby initiating the modern glaucoma drainage implant era.[2,3]

Development of Variations in Devices and Techniques

The Molteno drainage implant device was a non-restrictive implant that allowed the aqueous humor to flow into the plate-reservoir through an open tube. The Molteno implants comprised a single polypropylene plate (133 mm²), with the later development of double-plate, pressure ridge, pediatric versions, and finally the flexible, single, larger (175 or 230 mm²) plate designs (IOP, Inc., Costa Mesa, CA, USA, and Molteno Ophthalmic Limited, Dunedin, New Zealand). In 1990, Dr. George Baerveldt introduced the Baerveldt implant,[6] which is also a non-restrictive implant with larger (250 and 350 mm²) plates comprising softer silicone material (Advanced Medical Optics, Inc., Santa Ana, CA, USA). Non-restrictive devices require the use of intraluminal occlusion sutures and external ligation of the tube, or even two-stage implantation, in order to avoid postoperative hypotony.

An alternative method employed to avoid the problem of early postoperative hypotony was the
development of flow-restricted implants. In 1976, Dr. Theodore Krupin described an implant with a pressure-sensitive slit opening in the tube. [7] However, this slit “valve” was prone to variable efficacy as well as obstruction by debris, and the Krupin implant is no longer commercially available. Dr. Mateen Ahmed developed the Ahmed Glaucoma Valve (New World Medical, Rancho Cucamonga, CA, USA), which was introduced for clinical use in 1993. [8] The Ahmed Glaucoma Valve (AGV) comprises two thin silicone elastomer membranes positioned in a Venturi-shaped chamber. Different models of the AGV were developed, including the single- and double-plate models, pediatric versions, and polypropylene or silicone plates. The silicone single-plate model (FP-7) has been popular among clinicians. Currently, the AGV is the only commercially available flow-restricted glaucoma drainage implant. Various other glaucoma drainage implants, such as the Schöcket, Joseph, White, and Optimed glaucoma implants were developed, each with their own advantages. In a Darwinian process of selection, these other devices did not achieve widespread clinical use and are no longer commercially available.

Clinical Experience and Refinement of Techniques

Following the development of glaucoma drainage implants, the clinical experience of using them allowed an understanding of their efficacies and limitations. During the period of increasing clinical experience with these devices, indications for the use of glaucoma drainage implants were identified, including the failure of primary glaucoma surgery, and extensive limbal-conjunctival scarring. Success with glaucoma drainage devices found them to be superior to trabeculectomy in eyes with prior surgery. As clinicians became comfortable with the use of drainage implants in intractable glaucoma, the use of these devices for primary surgery was explored. Glaucoma drainage implants compared favorably to trabeculectomy in randomized clinical trials and are increasingly accepted as a choice for primary glaucoma surgery. [9-11]

With increasing clinical experience, various factors associated with the success and failure of these devices have been identified, which has clarified the role of drainage implants in the clinical management of glaucoma patients and has prompted modifications of the procedure to improve clinical outcomes [Table 1]. [12]

The factors associated with the success and failure of glaucoma drainage implant surgery has varied compared to trabeculectomy and has helped surgeons choose the appropriate procedure for clinical management of patients. While the valveless Baerveldt implant has been shown to achieve slightly lower intraocular pressures, this advantage comes at the expense of higher rates of complications such as persistent hypotony or loss of light perception. [13-15] As drainage implants have become more popular, surgeons have developed methods for avoiding complications, including reducing the occurrences of postoperative hypotony with two-stage implantation, luminal occlusion sutures, external ligation, and valves, and effectively treating common problems such as occluded, exposed, or retracted tubes. These techniques have led to improved safety and better outcomes associated with these devices. This has led to an improved prognosis for glaucoma cases previously considered refractory to other surgical treatments, such as glaucoma associated with silicone oil endotamponade, severe ocular surface disease, and epithelial ingrowth, as well as neovascular, uveitic, and pediatric glaucoma. [12]

The Growth of Clinical Utilization

Increase in clinical experience and refinement of surgical techniques has led to an explosion in the popularity of glaucoma drainage implants. Since 2003, the number of glaucoma incisional procedures performed annually in the United States has remained relatively stable, ranging from 55,000 to 61,000. [16] However, from 1994 until 2012, the use of trabeculectomy has decreased by 77%. Glaucoma drainage implants have largely made up the difference, with usage increasing 410% over the same time period. The ratio of trabeculectomy to glaucoma drainage implants decreased from 27:1 in 1994 to 3:2 in 2012. [14]

| Table 1. Variables influencing the success or failure of glaucoma drainage implant surgery* |
|-----------------------------------------------|
| **Patient-related**                           |
| Race, Diagnosis                               |
| Silicone oil endotamponade                    |
| Neovascular glaucoma                          |
| **Implant-related**                           |
| Implant plate size                            |
| Implant plate material                        |
| Presence or absence of valve                  |
| **Little or no effect on success or failure** |
| Age, Previous surgery                         |
| Diagnosis                                     |
| Controlled uveitis                            |
| Severe ocular surface disease                 |
| Adjunctive antifibrosis drugs                 |
| Location of the implant (superior vs. inferior) |

*Studies of variables influencing success and failure of glaucoma drainage implant surgery described in Netland PA. The Ahmed Glaucoma Valve in neovascular glaucoma. Trans Am Ophthalmic Soc 2009;107:325-42.
The Future

Glaucoma drainage implants and their clinical use have evolved over the years [Figure 1], and the incremental changes, advances, and setbacks associated with their use will certainly continue in the future. Their use could be reduced in the future, with the emergence of alternative surgical techniques, or if they are replaced by transformative discoveries about glaucoma. However, a brighter future can be imagined with the use of improved materials and nanomaterials, better modulation of biological responses, or more advanced technology involving micro-valves, pumps, or sensors. In the near future, we are likely to see their continued and even expanded use in clinical management of glaucoma patients.

Since the introduction and evolution of glaucoma drainage implants, better techniques for implantation and management of adverse events have led to improved safety and efficacy. Adverse events can be prevented or corrected, and complication rates have been reduced. Indications have broadened to include treatment of glaucoma that would likely fail the initial treatment with other procedures and even primary surgery. These implants have improved success rates in the treatment of patients with glaucoma refractory to other medical treatments, and their clinical use has greatly increased in the recent years. Glaucoma drainage implants now have a well-established role in glaucoma treatment.

Conflicts of Interest

There are no conflicts of interest.

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