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POSTOPERATIVE PERIOD AFTER GLAUCOMA SURGERY

RESEARCH PAPER - LITERATURE REVIEW

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ABSTRACT

Background:

Primary open-angle glaucoma (POAG) has been described in the literature as a leading cause of irreversible blindness worldwide. The estimated increase in global POAG prevalence highlights the need for efficient and effective glaucoma management. The American Academy of Ophthalmology (AAO) and the European Glaucoma Society (EGS) have endorsed laser trabeculoplasty as a first-line alternative to medications since 2020. This recommendation offers a surgical management to more patients at an earlier stage. As a result, greater attention should be paid to the postoperative period, especially to possible postoperative complications. This literature review focuses on postoperative complication types, frequency, and timing after various glaucoma surgery modalities. In order to depict the variety of surgical glaucoma management, the following surgical modalities will be represented in this review: laser trabeculoplasties, penetrating, non-penetrating, minimally invasive (MIGS), micro-invasive filtration (MIFS), and cyclodestructive procedures.

Methods:

This literature review was conducted between May 2024 and June 2025. Primarily, PubMed, Cochrane, and JAMA Network databases were used to identify publications. To maintain an up-to-date representation of the progressive field, studies published mainly between 2015 and 2025 were included. In case of the absence of newer studies, older cornerstone studies were used instead. All included studies were analysed by complication type, incidence, timing (early, <90 days vs. late, >90 days), and the type of surgery performed.

Results:

Postoperative complications across different surgical modalities were found to be interestingly linked to common pathophysiological mechanisms. As all glaucoma surgeries share the common goal of lowering IOP and establishing long-term IOP control, surgical approaches aim at altering the production or outflow of aqueous humour. Therefore, similar complications can be observed after unlike surgical modalities. Those shared postoperative complications were hyphema, pressure spikes, hypotony, and its long-term sequelae. Incidence of complications depended primarily on the mechanism of alteration of aqueous dynamics (physiologic outflow vs. creating a bypass/shunt vs. inhibiting production), the manipulated anatomical location and function of the targeted tissue (angle, subconjunctival space, ciliary body), and the extent of thermal/mechanical injury.

Conclusions:

Postoperative complications were generally mild and self-limited in the early postoperative period. Most of the reported complications could be explained by the surgical-induced inflammatory response and a filtration imbalance. Long-term complications were often linked to fibrotic changes, device malfunction and failure, or persistent overfiltration. Awareness of possible complications can improve postoperative monitoring and timely intervention. In general, the chosen surgical management approach should be matched to the desired IOP reduction and patient profile to maximize safety and efficacy.

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ABBREVIATIONS

Abbreviation	Full Term
5-FU	5-Fluorouracil
AAO	American Academy of Ophthalmology
AC	Anterior Chamber
ALT	Argon Laser Trabeculoplasty
AS-OCT	Anterior Segment Optical Coherence Tomography
BCVA	Best-Corrected Visual Acuity
BMJ	British Medical Journal
CPC	Cyclophotocoagulation
CP	Canaloplasty
CW-TS-CPC / CW-TSCPC	Continuous-Wave Transscleral Cyclophotocoagulation
DS	Deep Sclerectomy
ECP	Endoscopic Cyclophotocoagulation
EGS	European Glaucoma Society
GATT	Gonioscopy-Assisted Transluminal Trabeculotomy
GDD / GDDs	Glaucoma Drainage Device(s)
IOP	Intraocular Pressure
LiGHT	Laser in Glaucoma and Ocular Hypertension
MIFS	Micro-Invasive Filtration Surgeries
MIGS	Minimally Invasive Glaucoma Surgeries
MMC	Mitomycin C
MP-CPC	Micropulse Cyclophotocoagulation
MP-TSCPC	Micropulse Transscleral Cyclophotocoagulation
Nd:YAG	Neodymium-doped Yttrium Aluminum Garnet
PAS	Peripheral Anterior Synechiae
POAG	Primary Open-Angle Glaucoma
PTVT	Primary Tube Versus Trabeculectomy
SIBS	poly(styrene-block-isobutylene-block-styrene)

Abbreviation	**Full Term**
SLT	Selective Laser Trabeculoplasty
TDM	Trabeculo-Descemet Membrane
TM	Trabecular Meshwork
Trab	Trabeculectomy
TS-CPC	Transscleral Cyclophotocoagulation

1 INTRODUCTION

Primary Open-Angle Glaucoma (POAG) is characterized by a chronic progressive optic neuropathy (Weinreb et al., 2014, p. 201). It has been described in the literature as a primary cause of irreversible blindness worldwide (Tham et al., 2014). The global prevalence of POAG was estimated at 2.4% over 20 years (2000-2020), with the highest prevalence in Africa at 4.0% (Zhang et al., 2021). A study by Tham et al. reported that, globally, approximately 64.3 million people aged 40 to 80 suffered from glaucoma in 2013. Moreover, this study estimated that the disease prevalence would increase to 76.0 million in 2020. The study further projected an increase to 111.8 million by 2040 (Tham et al., 2014). This development was explained by global population aging and growth, with a disproportionately large impact in Asia and Africa. The predicted increase in prevalence underscores the importance of early POAG diagnosis and effective management to prevent blindness.

In 2020, both the European Glaucoma Society (EGS) and the American Academy of Ophthalmology (AAO) recommended Selective Laser Trabeculoplasty (SLT) as an adequate first-line treatment alternative to medications for open-angle glaucoma (BMJ Publishing Group Ltd. BMA House, 2021; Gedde et al., 2021a). These guideline changes were mainly driven by the Laser in Glaucoma and Ocular Hypertension (LiGHT) trial and its reported positive results (Gazzard et al., 2019, 2023). The present guideline recommendations offer a surgical management to a larger patient group, even at an earlier stage of glaucoma. Thus, the question of safety becomes more clinically relevant, as all surgical procedures carry the potential for postoperative complications. Complications can impact patients' quality of life and influence postoperative management and long-term treatment success. Accordingly, the risk profiles of surgical interventions will be examined in this review. To encompass the clinical variations in POAG severity and their specific management modalities, this review will include various surgical intervention groups. Those are laser trabeculoplasties, penetrating surgeries, non-penetrating surgeries, minimally invasive glaucoma surgeries (MIGS), micro-invasive filtration surgeries (MIFS), and cyclodestructive procedures. The reported postoperative complications will be classified by incidence, timing (early vs. late), and relation to the type of surgical intervention.

2 Methodology

2.1 Research Aim

The purpose of this literature review is to identify commonly reported postoperative complications, incidence rates, and timing (early vs. late), and to analyze common pathophysiological or surgical-technique factors associated with reported postoperative complications.

2.2 Search Strategy

A review of the existing literature on POAG surgical modalities and its associated complications was conducted between May 2024 and June 2025, involving the search across multiple biomedical and research databases (PubMed/MEDLINE, the Cochrane Library, and the JAMA Network) and ophthalmological journals such as *Ophthalmology*, *American Journal of Ophthalmology*, *British Journal of Ophthalmology*, *Acta Ophthalmologica*, and *Journal of Glaucoma*, among others.

The search terms included various combinations of the following keywords and Medical Subject Headings (MeSH) terms:

- "primary open-angle glaucoma" or "POAG"
- "postoperative complications" or "surgical complications" or "complications"
- "safety" or "adverse events"
- Names of specific surgical procedures (e.g., "trabeculectomy", "tube shunt", "Ahmed valve", "Baerveldt implant", "Preserflo microshunt", "XEN gel stent", "iStent", "Hydrus microstent", "deep sclerectomy", "canaloplasty", "SLT", "ALT", "cyclophotocoagulation")

Boolean operators (AND, OR) were used to filter and refine the search results and obtain relevant literature.

2.3 Inclusion and Exclusion Criteria

Eligibility criteria were established to focus on high-quality, clinically relevant studies.

<u>Inclusion criteria:</u>

- Studies published between 2015 and 2025.

- Older cornerstone studies were included when more recent, high-quality data were unavailable.
- Publications written in English with full-text access.
- Meta-analysis, Systematic reviews, Clinical trials, cohort studies, observational studies, and comparative studies reporting postoperative complication rates.
- Studies directly assessing the complications or safety of surgical techniques for POAG.

Exclusion criteria:

- Case reports, small case series, editorials, letters to the editor, and conference abstracts (without full-text access).
- Studies not reporting postoperative complications or safety outcomes.
- Animal or in vitro studies.

2.4 Study Selection and Data Extraction

The study selection process was designed in two steps:

I. Title and Abstract Screening: Preliminary eligibility was determined by reviewing study titles and abstracts.

II. Full-Text Review: Eligible full-text articles were reviewed, and data on postoperative complications were extracted.

Data extracted from each eligible study included:

- Type of surgical procedure.
- Patient population and inclusion criteria.
- Postoperative complications (type and rates).
- Classification of complications (early or late, when described).

2.5 Classification and Synthesis of Complications

Postoperative complications were classified according to the following:

- Type of postoperative complication.
- Timing: Early (< 90 days postoperatively) vs. late (> 90 days postoperatively).

- Frequency: Reported as incidence rates (percentages) as provided by the original study.

2.6 Limitations of the Methodology

Variability in study designs, definitions of complications and their reporting, and follow-up durations may affect the consistency of reported outcomes.

2.7 Language proofreading

The final text was reviewed using Grammarly (Grammarly Inc.) to ensure academic linguistic accuracy, including grammar, spelling, and stylistic consistency. No content was generated or modified.

3 Overview of Surgical Modalities

This chapter provides an overview of all included surgical approaches and techniques used in the management of POAG, including their effects on IOP reduction and postoperative complications.

3.1 Laser trabeculoplasties

Laser trabeculoplasties are surgical procedures that target the trabecular meshwork with laser beams. Consequently, local tissue inflammation follows, which is presumed to further lead to extracellular matrix remodelling. This remodelling opens the trabecular meshwork and ultimately enhances aqueous humour outflow, thereby reducing IOP (Stein & Challa, 2007). The two representative surgical techniques in the group of laser trabeculoplasties are Selective Laser Trabeculoplasty (SLT) and Argon Laser Trabeculoplasty (ALT). Their primary difference resides in the properties of the laser used. SLT uses a neodymium-doped yttrium aluminum garnet (Nd:YAG) laser at 532 nm, employing Q-switching and frequency doubling to target pigmented cells in the trabecular meshwork selectively (Gedde et al., 2021a). Conversely, ALT uses a continuous wave argon laser with wavelengths ranging from 488 to 514 nm. The continuous exposure and shorter wavelengths of the ALT laser produce a higher energy output, resulting in a greater incidence of thermal coagulative injury to the trabecular meshwork and greater long-term tissue alteration (Cvenkel et al., 2003; Kramer & Noecker, 2001). ALT's higher tissue alteration has been linked to a reduced success rate in repeated procedures. This stands in contrast to SLT, which has been demonstrated to be more effective with repeated procedures (Gedde et al., 2021a). EGS and AAO recommend SLT as the preferred choice in POAG management. However, if SLT is unavailable or unsuccessful, ALT can be considered as a management option. Both procedures are indicated for mild-to-moderate POAG.

Laser trabeculoplasties are contraindicated in patients with angle-closure glaucoma, patients with active ocular infections, or significant angle abnormalities. Caution should be exercised in selecting patients with marked pigmentation of the trabecular meshwork, given the increased risk of postoperative IOP spikes, particularly following ALT (Gedde et al., 2021a). IOP reduction after SLT or ALT showed similar results of 20–30% IOP reduction below baseline levels at 6 to 12 months (Wang et al., 2013). The LiGHT trial demonstrated that approximately 75% of participants who received primary SLT maintained drug-free disease control within three years (Gazzard et al., 2019). The 2023 published six-year follow-up showed that 69.8%

of eyes treated with SLT maintained target IOP without medication or surgical intervention (Gazzard et al., 2023). Furthermore, patients treated with SLT had lower rates of further surgical intervention, such as trabeculectomy, compared to those treated only medically (Gazzard et al., 2023). In contrast, ALT showed higher reoperation rates, with 30–50% of eyes requiring surgical intervention within five years (Gedde et al., 2021b; Wang et al., 2013).

Postoperative complications after SLT and ALT (*Table 1*) are primarily influenced by the degree of thermal energy delivered and the induced tissue injury (Gazzard et al., 2019). Early postoperative complications (≤ 90 days) are characterized by a short-term inflammatory reaction and its influence on intraocular pressure. The most commonly reported postoperative event following SLT is transient ocular discomfort, blurred vision, photophobia, and hyperemia. This occurred in approximately 34.4% of cases (Gazzard et al., 2019). These symptoms can be explained by the laser-induced mild anterior segment inflammation (De Keyser et al., 2017). Transient intraocular pressure (IOP) spikes were reported in 1.7% of SLT (Gazzard et al., 2019) and up to 12% of ALT treatments (Feldman et al., 1991, p. 19). These IOP spikes have been linked to temporary obstruction of the trabecular channels by pigment granules and cellular debris, which are released during photostimulation. This was generally self-limited. It has been reported that IOP spikes occur more frequently in patients with heavily pigmented or advanced glaucomatous eyes (Gedde et al., 2021a). Other early complications include microhyphema, corneal edema, or bleeding within the anterior chamber angle. These complications occur infrequently (<0.2%) and are rarely vision-threatening (Ojanen et al., 2025). ALT has shown a higher frequency of reported early pressure spikes, which have been linked to more severe postoperative inflammation (Cvenkel et al., 2003; Kramer & Noecker, 2001).

Late complications (> 90 days) are generally infrequent but tend to be structural and progressive. The most significant delayed finding after ALT is peripheral anterior synechiae (PAS). They have been reported in up to 32% of ALT-treated eyes (Rolim-de-Moura et al., 2022). PAS describes the formation of adhesions between the iris root and the TM at lasered sites. This structural alteration can compromise aqueous outflow and diminish the long-term efficacy of ALT. In SLT, comparable late events are rare due to minimal tissue disruption. However, isolated cases of chronic uveitis (0.6%) and reactivation of herpes simplex keratitis (0.3%) have been described (Gazzard et al., 2019). These are thought to arise from localized immune activation in predisposed individuals. Exceptionally rare events such as permanent corneal thinning, irregular astigmatism, or irreversible vision deterioration (<0.2/1000) were linked to inadvertent overexposure or pre-existing endothelial vulnerability (Ojanen et al., 2025).

In summary, SLT's selective photothermolytic mechanism limits collateral tissue damage, making it safer and repeatable. ALT's greater thermal load predisposes to angle scarring and PAS formation. Overall, both modalities have a low occurrence of vision-threatening complications.

3.2 Penetrating Surgeries

Penetrating surgeries are surgical modalities characterized by the creation of an alternative aqueous outflow pathway to reduce IOP. Direct ocular tissue penetration, leading to alterations in aqueous drainage, is a hallmark of this surgical group. The creation of a separate outflow tract makes penetrating surgeries especially important in patients with moderate to advanced glaucoma, in need of a drastic and long-lasting reduction in IOP. The group of penetrating surgical approaches is comprised of Trabeculectomy and Glaucoma Drainage Devices (GDDs), including Ahmed, Baerveldt, and Molteno implants. In trabeculectomy, a fistula is created between the anterior chamber and the subconjunctival space. The dissection of scleral tissue allows aqueous humor to drain into the subconjunctival space and form a cavity beneath a remaining conjunctival flap, creating a so-called filtering bleb (Kirwan et al., 2013). Surgical success depends on bleb formation, stability, and longevity. Therefore, Mitomycin C (MMC) or other antimetabolites are frequently used to suppress subconjunctival fibrosis and aid in bleb formation. Drainage devices aim to establish a connection between the anterior chamber and the subconjunctival space. The tubes used shunt aqueous humor from the anterior chamber to a subconjunctival plate, where it is gradually absorbed. Instead of a bleb, a fibrous capsule forms around the device endplate (Tseng et al., 2017). The difference between GDDs lies in their flow dynamics. They can be valved (Ahmed) or non-valved (Baerveldt and Molteno). The Primary Tube Versus Trabeculectomy Study (PTVT) reported a mean postoperative IOP of 14.0 ± 4.2 mmHg in the tube group and 12.1 ± 4.8 mmHg in the trabeculectomy group at three years (Gedde et al., 2020). The mean postoperative IOP was found to be similar between the two groups at five years. Nevertheless, trabeculectomy has been associated with a lower medication burden compared to the tube group (Gedde et al., 2020; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, Banitt, et al., 2022). Complete surgical success, defined as IOP ≤ 18 mmHg without medications, was reported in the PTVT Study at five years in 30% of patients after trabeculectomy with MMC and 14% after tube shunt implantation (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, Banitt, et al., 2022). The Ahmed versus Baerveldt Study reported complete success rates of 24% and 36% at five years, respectively (Christakis et al., 2016, 2017). In the Primary Tube Versus Trabeculectomy Study (PTVT), reoperation rates for glaucoma were lower in the tube group (9%) than in the trabeculectomy group (29%) (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, Banitt, et al., 2022), while in the Ahmed versus Baerveldt study, cumulative reoperation rates were 18% and 11%, respectively (Christakis et al., 2016, 2017).

The patency of the created fistula, the tube/bleb pathway, and long-term wound healing vastly influence postoperative complications after penetrating glaucoma surgery (*Table 2*). Early events (≤90 days) are related to pressure disequilibrium (overfiltration) and wound instability caused by an immature bleb, which lacks sufficient resistance to control aqueous outflow. Hypotony is a commonly reported postoperative complication. It has been reported in approximately 9% after trabeculectomy, 8% with Ahmed valves, and up to 17% with Baerveldt implants. It is assumed to arise due to overfiltration before the bleb capsule or plate capsule provides sufficient resistance to control the outflow of aqueous humor (Budenz et al., 2011; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022).

Another postoperative complication is choroidal effusion (1.1-6% after trabeculectomy; 2-9% after Baerveldt). It is caused by low IOP, which leads to transudation into the suprachoroidal space. If hypotony persists, the effusion can progress to choroidal detachment (Budenz et al., 2011; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022; Olayanju et al., 2015). Shallow or flat anterior chamber (up to 10% with Baerveldt (Budenz et al., 2011)) reflects forward displacement of the lens-iris diaphragm under hypotonic conditions. Bleb or wound leaks (≈6%) result from inadequate conjunctival closure or overfiltration. Leaks pose a risk of infection because they provide a gateway for bacteria. Endophthalmitis has been reported in approximately 1% of cases postoperatively (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022; Molteno, 2011). Early complications are typically reversible and non-sight-threatening with adequate pressure control (atropine, viscoelastic, compression sutures, or tube ligation), leak closure, and infection prophylaxis (Gedde et al., 2021b).

Late complications (>90 days) are associated with tissue remodelling and device-tissue interactions. The most common reported postoperative event after penetrative surgeries is cataract progression. It has been reported in 24–44% of cases after trabeculectomy, 22% of cases after Molteno and up to 52% of cases after Baerveldt implantation. Postoperative cataract is assumed to be caused by postoperative inflammation, often conjoined with sustained corticosteroid exposure. Additionally, persistent hypotony induces metabolic stress on the lens, fostering cataract progression (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022; Molteno, 2011).

Another later postoperative complication is corneal edema/decompensation (≈20% with GDD). This complication has been linked to endothelial cell loss caused by tube–cornea proximity (Budenz et al., 2016). An interesting complication is diplopia, which has been reported in approximately 12% of tube surgeries. Diplopia can be linked to the mechanical and fibrotic interaction between extraocular muscles and tube plates, where the plates adhere to adjacent extraocular muscles and limit their mobility (Budenz et al., 2016; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022). Long-term friction between the tube/plates and the conjunctiva can cause conjunctival thinning and eventually result in tube exposure/erosion (≈1–3%) (Budenz et al., 2011). Tube exposure can increase the risk of infections, such as endophthalmitis. To avoid infection, prompt treatment of tube exposure/erosion with patch-graft revision is required. Another reported late complication after trabeculectomy is bleb failure, requiring reoperation (≈8–9%). Bleb failure has been linked to fibrotic changes (fibroblast proliferation), causing narrowing of the filtration pathway. This complication can be reduced with the use of antimetabolites, but the risk of bleb failure still remains (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022; Molteno, 2011). A rare reported complication was chronic hypotony, where long-standing hypotony can lead to phthisis bulbi, accompanied by irreversible vision loss. (Molteno, 2011).

Among devices, the Baerveldt implant has the highest incidence of both early hypotony and late endothelial stress. This can be explained by its non-valved design and large plate surface. On the contrary, the Ahmed valve demonstrates a lower rate of early hypotony. Trabeculectomy presented with unique bleb-related complications such as bleb leaks, endophthalmitis, and long-term fibrotic failure. Overall, penetrating procedures achieve good IOP reduction but also cause long-term structural alterations that may lead to complications and morbidity (Gedde et al., 2021b).

3.3 Non-Penetrating Surgeries

Non-penetrating surgeries differ from penetrating surgeries by not creating a new outflow pathway, but instead increasing the permeability of physiological outflow pathways (e.g., the trabecular meshwork and Schlemm's canal) (Mendrinos et al., 2008). Non-penetrative procedures included in this review are deep sclerectomy (DS) and canaloplasty (CP). Both procedures share a similar initial approach, creating superficial and deep scleral flaps. Thereafter, the outer wall of Schlemm's canal is unroofed. An important feature is the preservation of the integrity of the Trabeculo-Descemet membrane (TDM). The TDM builds a pressure resistance barrier, allowing controlled aqueous percolation (Mendrinos et al., 2008). In DS, collagen implants and antifibrotic agents are often additionally used as adjuvant measures to ensure successful surgical outcomes (Khairy et al., 2006). In CP, the surgical technique is extended by performing circumferential cannulation of Schlemm's canal, which is followed by viscodilation with a microcatheter. After viscodilation, tension sutures are placed within Schlemm's canal to maintain its patency and provide sustained enhancement of aqueous outflow (Grieshaber et al., 2010; Lewis et al., 2011). Both procedures are indicated for patients with mild to moderate POAG (Gedde et al., 2021b).

Contraindications for non-penetrating procedures include angle-closure glaucoma, neovascular glaucoma, uveitic glaucoma, advanced angle pathology, and very low target IOP. DS and CP have been shown in studies to reduce IOP by 30–40% from baseline, with postoperative IOP values typically in the low-to-mid teens at one to three years (Bull et al., 2011; Grieshaber et al., 2010; Lewis et al., 2011). When comparing outcomes, CP and DS are shown to achieve a similar degree of IOP reduction (Rękas et al., 2015). Five-year data for DS reports an overall complete success rate of 33% in POAG and 12% in pseudoexfoliation glaucoma, with reoperation rates of 8% and 21%, respectively (Fiore et al., 2024). For CP, a three-year study reported a complete surgical success rate of 58.74% and a reoperation rate of 4.4% (Konopińska et al., 2024).

Postoperative complications after non-penetrating surgeries (*Table 3*) are comparatively milder than those of penetrating surgeries. The intact TDM provides a natural resistance barrier, counteracting rapid pressure drops, resulting in lower rates of hypotony and minimizing the risk of infections. Early and late postoperative complications are primarily linked to the surgical manipulation of Schlemm's canal and the ongoing wound-healing response at the intrascleral level (Brusini et al., 2016; Khairy et al., 2006; Mercieca et al., 2025).

Early postoperative complications (≤ 90 days) are typically transient and technique-related. In DS, the most common early postoperative events are hyphema (2–7.5%), transient hypotony (≈5%), and microperforation or detachment of the TDM (2.5–7%) (Grieshaber et al., 2010; Khairy et al., 2006). Microperforation describes the creation of a shunt through the TDM into the anterior chamber during dissection. This temporarily converts the non-penetrating approach into a partially penetrating procedure. Such defects, as they are minor, generally close spontaneously. However, due to the TDM's lack of integrity, uncontrolled filtration can occur (similar to penetrating surgeries), resulting in short-term shallowing of the anterior chamber (Grieshaber et al., 2010; Khairy et al., 2006). Hyphema (2–7.5%) is assumed to result from reflux bleeding from Schlemm's canal or collector channels, which are exposed during the surgery. This complication is self-limited and will spontaneously resolve within a few days. Transient hypotony occurs when early aqueous percolation exceeds episcleral venous outflow before the tissue resistance equilibrates. In CP, hyphema is the most common reported early complication, affecting 10–24% of cases (Brusini et al., 2016; Mercieca et al., 2025). It is caused by viscodilation or microcatheter-related injury to the Schlemm's canal wall. It is usually self-limited and rarely affects vision. Microperforation (3–5.5%) and transient hypotony (≈4–5%) can also be observed after CP; both complications resolve with conservative management (Brusini et al., 2016; Mercieca et al., 2025).

Late complications (> 90 days) are associated with fibrotic changes. Post DS, laser goniopuncture was performed in one-third of cases at one year and in up to two-thirds of cases by six years (Rabiolo et al., 2023). Goniopuncture was performed in order to restore filtration through the TDM, which can become less permeable over time due to fibrotic closure. While this is technically an intervention rather than a complication, its frequency suggests a gradual reduction in membrane permeability. Chronic hypotony is infrequently reported after DS, seen in approximately 13% at five years, with only 5–6% developing sequelae such as choroidal folds or maculopathy (Rabiolo et al., 2023). Hypotony can be explained by inadequate resistance in the intrascleral space or thinning of the TDM. Other late events include bleb fibrosis (≈12%), needling (15%), and 5-fluorouracil injections (≈ 13%). These complications and interventions can be linked to the wound healing of subconjunctival tissue. Suture lysis (≈10%) is occasionally performed to improve filtration (Mercieca et al., 2025). In CP, long-term complications are rare because the viscodilated Schlemm's canal and tension sutures maintain the patency of the physiological outflow pathway. Late failure after CP usually presents as a gradual rise in IOP, attributed to fibrotic closure of collector channels (Brusini et al., 2016).

Non-penetrative surgical modalities present with early complications, which can be attributed to mechanical trauma or transient flow disequilibrium. Late events/complications are often the result of fibrotic remodelling and gradual loss of outflow permeability. Those can often be resolved with secondary interventions to restore patency of the TDM. The overall severity of complications and visual impact (vision-threatening complications) remains low. The non-penetrative technique, which preserves anterior chamber integrity and uses physiological drainage pathways, results in fewer overall complications. In summary, DS and CP provide a favorable safety profile compared with penetrating surgeries.

3.4 Minimally Invasive Glaucoma Surgeries (MIGS)

Minimally invasive glaucoma surgeries (MIGS) are *ab interno* procedures that cause less tissue alteration than traditional penetrating filtration surgeries (e.g., trabeculectomy). Furthermore, these procedures do not create a filtering bleb (Coleman & Richter, 2016; Konopińska et al., 2021). The filtration bleb distinguishes it from microinvasive filtration surgeries (MIFS), which will be covered in the next chapter. MIGS work on the trabecular meshwork and Schlemm's canal by facilitating aqueous humor outflow while preserving the integrity of the conjunctiva and sclera (Coleman & Richter, 2016). MIGS are indicated in patients with mild to moderate primary open-angle glaucoma (POAG) (Gedde et al., 2021b). MIGS techniques included in this review are trabecular bypass stents, such as iStent and Hydrus, and meshwork ablation procedures, such as Trabectome and gonioscopy-assisted transluminal trabeculotomy (GATT).

Trabecular bypass stents enable aqueous drainage directly into Schlemm's canal. In gonioscopy-assisted transluminal trabeculotomy (GATT) a 360° trabeculotomy is performed using a suture or microcatheter under direct gonioscopic visualization (Yuan et al., 2025). MIGS can be easily combined with phacoemulsification (cataract surgery) in a single operative session (Richter et al., 2024). A 20–40% IOP reduction at one to two years of follow-up was reported after MIGS procedures. This resulted in final IOP values in the mid-teens (Lavia et al., 2017). Among various MIGS procedures, GATT has been shown to produce the greatest IOP reduction, lowering IOP from approximately 22 mmHg to 12.5 mmHg at 12 months. This equals an estimated 43% decrease (Lavia et al., 2017). Trabectome and trabecular stent procedures (iStent and Hydrus) have been shown to achieve IOP reductions of 30–35% from baseline with mean postoperative IOP levels of approximately 14.5–15 mmHg (Lavia et al., 2017).

Compared with trabeculectomy, MIGS offer a less drastic IOP reduction. Long-term data support the sustained efficacy of MIGS procedures. The HORIZON five-year randomized controlled trial for the Hydrus Microstent reported that 49.5% of patients achieved IOP <18 mmHg without medication at five years. Only 2.4% of patients required reoperations, compared to 6.2% in patients with POAG who underwent cataract surgery alone (Ahmed et al., 2022; Bicket et al., 2021; Otarola et al., 2020). Standalone iStent implantation in mild-to-moderate POAG patients resulted in medication-free IOP control in 86.2% of patients at five years, with no eyes requiring reoperation (Clement et al., 2022; Hengerer et al., 2022; Popovic et al., 2018). Trabectome procedures have been shown to achieve complete success (defined as mean IOP <18 mmHg and a ≥20% reduction from baseline) in approximately 35% of patients at six years, with most patients continuing topical therapy (Kono et al., 2020; Weber et al., 2023). After GATT, patients with moderate glaucoma achieved a 43.8% complete success rate at one year and 37.6% in advanced cases. Whilst the overall surgical success rate was around 75% at three years of follow-up. However, some patients continued to rely on medications (Aktas et al., 2022; Magacho et al., 2024).

Reported postoperative complications after MIGS (*Table 4*) procedures are generally mild and self-limited. This is probably linked to the tissue-sparing, less invasive approach. However, localized haemorrhagic and device-related complications may occur. Early postoperative complications (≤ 90 days) are predominantly mild, transient, and can be linked to intraoperative trauma to the trabecular meshwork or Schlemm's canal. The most reported complication is transient hyphema. It has been reported in up to 40% of Hydrus Microstent cases, 11–33% with Trabectome, and approximately 30% following GATT (Grover et al., 2014; Hu et al., 2021; Otarola et al., 2020). The occurrence of hyphema can be explained by blood reflux through Schlemm's canal after ab interno trabeculotomy or viscodilation. The hyphema usually clears spontaneously within a few days without sequelae. IOP spikes represent the second most common event, occurring in 1–33% of iStent eyes, 6% after Hydrus implantation, and up to 26% after Trabectome procedures (Le et al., 2019; Yook et al., 2018). These transient IOP elevations are described to be caused by inflammatory debris or pigment obstruction at the stent ostium or collector channels. Moreover, the effect of IOP rise postoperatively can occasionally be potentiated by steroid response. Corneal edema and anterior chamber erythrocytes (reported in 1–28% of eyes) stem from transient endothelial stress during intraoperative gonioscopic manipulation or ablation-based energy use in Trabectome (Jabłońska et al., 2023). These effects resolve spontaneously, and long-term endothelial loss is uncommon.

Late complications (> 90 days) are largely device- or fibrosis-related. The most frequently reported late complications are stent obstruction and malposition, occurring in up to 13% and 18% of iStent cases, respectively (Le et al., 2019). Obstruction is usually caused by pigment deposition, endothelial overgrowth, or fibrin accumulation. Device malposition, on the other hand, reflects suboptimal placement or postoperative angle shift. Both contribute to diminished IOP control and reduced procedural long-term success. Peripheral anterior synechiae (PAS) have occurred in 1.8–20% of eyes, particularly with Hydrus. PAS are fibrotic adhesions of the iris to the stented region after localized inflammation (Otarola et al., 2020). Secondary (revision) surgery is required in less than 1% of iStent or Hydrus cases, but up to 23% following Trabectome and 9% after GATT. This has been linked to late canal fibrosis or inadequate angle opening (Grover et al., 2014; Hu et al., 2021). Cataract progression (> 5%) and minor best-corrected visual acuity (BCVA) decline (> 5%) are rare and typically attributed to concomitant phacoemulsification rather than the MIGS procedure itself (Samuelson et al., 2019).

In summary, postoperative complications following MIGS are generally mild, reversible, and non-sight-threatening. Hyphema and IOP spikes are common in the early postoperative period, while stent obstruction, PAS, and secondary surgical interventions are reported as late outcomes. The overall improved safety profile compared with trabeculectomy makes MIGS a low-risk glaucoma surgery. Thereby offering effective IOP reduction with minimal postoperative morbidity and preservation of ocular integrity.

3.5 Micro-Invasive Filtration Surgeries (MIFS)

Widely considered as part of MIGS procedures are Micro-invasive filtration surgeries (MIFS). In this review, they are separated into their own category due to their surgical distinction from MIGS in the formation of a subconjunctival bleb. This resembles the technique of traditional penetrating filtration surgeries, such as trabeculectomy (Pillunat et al., 2017; Saeed et al., 2023). MIFS create a filtration pathway to the subconjunctival space. The key difference from a classic trabeculectomy is the avoidance of full-thickness tissue penetration, making MIFS a minimally invasive surgical modality. Two representatives of MIFS are Preserflo MicroShunt and Xen

Gel Stent. The Xen Gel Stent is implanted using an ab interno approach, with a preloaded injector. The soft gelatin tube is delivered through the trabecular meshwork into the subconjunctival space. This approach preserves the conjunctiva (Lewis, 2014). In contrast to Xen Gel stents, the Preserflo MicroShunt is implanted using an ab externo approach. This involves a conjunctival peritomy and scleral dissection to place the 8.5 mm SIBS (poly[styrene-block-isobutylene-block-styrene]) tube connecting the anterior chamber to the sub-Tenon space, thereby creating a new filtration pathway (Fea et al., 2022). Both procedures are indicated for patients with mild to moderate POAG. Especially for patients with inadequately controlled POAG with maximal medical and/or prior laser therapy (SLT) (Gedde et al., 2021b). Contraindications are angle-closure glaucoma, neovascular glaucoma, active ocular infection, and moderate to severe conjunctival scarring at the intended surgical site (Gedde et al., 2021b).

Direct comparative studies have shown similar IOP reductions with both devices. Martínez-de-la-Casa et al. (2025) reported that at 12 months, IOP decreased from 20.8 ± 3.6 mmHg to 14.2 ± 4.5 mmHg using the Xen Gel Stent, and from 19.1 ± 3.8 mmHg to 12.8 ± 2.3 mmHg using the Preserflo MicroShunt (Martínez-de-la-Casa et al., 2025). Also, Lüke et al. (2024) reported comparable results in a prior study, with both devices producing similar IOP reductions, noting that the Preserflo MicroShunt showed a slightly lower absolute IOP reduction compared to the Xen Gel Stent (Lüke et al., 2024). Five-year studies, reporting long-term outcomes for the Xen Gel Stent, showed that complete success has been achieved in approximately 24% of cases. 20% of patients required additional surgical interventions over 5 years (Ansari, 2021; Lenzhofer et al., 2024; Torbey et al., 2023). Complete success studies was defined as unmedicated IOP ≤15 mmHg with a ≥20% reduction from baseline. Five-year data for the Preserflo MicroShunt show an overall complete success rate of over 61%. Additionally, lower reoperation rates have been reported (Batlle et al., 2016; Scheres et al., 2025).

Postoperative complications (*Table 5*) are linked to the technique used in MIFS. The combination of a minimally invasive approach and bleb filtration influences postoperative complications. Early complications are predominantly linked to overfiltration, and late complications are associated with postoperative wound-healing (Gan et al., 2024; Tanner et al., 2023). Early postoperative complications (≤ 90 days) are mainly linked to unregulated aqueous outflow through the newly established drainage pathway. The most frequently reported complications are transient hypotony (1–19%) and choroidal effusion or detachment (2–13%).

Those complications occur in the early postoperative phase, before the bleb capsule is sufficiently mature to provide adequate outflow resistance and stabilize aqueous outflow (Mieno et al., 2025; Tanner et al., 2023). Choroidal effusion or even detachment can be explained by postoperative hypotony. Hypotony enables fluid to transudate into the suprachoroidal space. This reported complication often resolves with conservative management. As is common in other surgical modalities, post-MIFS hyphaema can also occur. Hyphaema has been reported in 2–12%. It may accompany early postoperative inflammation due to microvascular trauma at the scleral or subconjunctival site (Mieno et al., 2025; Tanner et al., 2023). Bleb leaks occur in 0–6% of cases postoperatively. Leaks reflect incomplete conjunctival closure or bleb overfiltration (Gan et al., 2024; Park et al., 2023; Scheres et al., 2021; Tanner et al., 2023). Although rare, bleb leaks pose an infectious risk, and cases of blebitis or endophthalmitis (up to 3% in Xen) have been documented (Gan et al., 2024). In 2-5% of cases, hypotony maculopathy has been reported. In the literature, it has been noted that this occurs more frequently in eyes with thin sclera or after surgeries in which the postoperative period is dominated by an excessive filtration pathway (Governatori et al., 2025; Scheres et al., 2021). The resulting retinal folds and choroidal thickening are reversible if treated promptly. In case of persistent hypotony, irreversible visual changes could occur. Malignant glaucoma (~2%) is a rare complication. It is caused by overfiltration leading to anterior chamber shallowing (Gan et al., 2024).

Late postoperative complications (> 90 days) are primarily linked to fibroproliferative healing, influencing bleb maturation. The most frequent late postoperative complications are bleb fibrosis and encapsulation. They were reported as the incidence of performed needling or antifibrotic usage. Needling has been reported in up to 29% and 5-fluorouracil (5-FU) injections in up to 34% of eyes (Scheres et al., 2021; Tanner et al., 2023). These interventions try to counteract fibrosis and restore bleb permeability. Revision surgery was reported in roughly 10–12% of patients, most often within the first postoperative year. In the XEN Gel Stent, stent occlusion (4–9%) and migration (1.5%) were notable late device-related complications. They were explained as causes of tissue ingrowth, inflammatory debris, or poor fixation (Gan et al., 2024). In contrast, the Preserflo MicroShunt demonstrated fewer occlusive complications but a slightly higher tendency towards low-grade chronic hypotony (≈0.4%). This was explained by the device's wider lumen (Park et al., 2023).

A complication similar to penetrating surgeries is Cataract progression. It was reported in 3–17% after Preserflo and 7% after XEN Gel stent implantation. Cataract progression is assumed to be driven by a chronic low-grade inflammation. Additionally, corticosteroid exposure was reported as an influencing factor rather than mechanical stress caused by the implant itself (Mieno et al., 2025). Vision-threatening complications, including persistent hypotony with maculopathy, remain rare (<5%). From a clinical perspective, the severity of MIFS complications is moderate but manageable. Early issues such as hypotony and effusion are transient, whereas late complications (fibrosis, occlusion) often necessitate minor interventions. Compared to trabeculectomy and tube shunts, both the Preserflo and XEN achieve a favorable safety-to-efficacy ratio, making them safer alternatives to traditional filtering surgeries.

3.6 Cyclodestructive Procedures

The final surgical category in this review is cyclodestructive procedures. These procedures target the ciliary epithelium, which produces aqueous humour. Because epithelial destruction is irreversible, cyclodestructive modalities are often considered last-line therapy for advanced or uncontrolled POAG (Gedde et al., 2021b). Two representative procedures for this modality included in this review are Transscleral Cyclophotocoagulation (TS-CPC) and Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC). Both share the same basic principle but differ in the way laser energy is delivered. TS-CPC uses a continuous-wave 810 nm diode laser. Laser thermal energy is used to ablate the ciliary epithelium through the sclera without direct visualization. This is described as causing broader tissue ablation, with the potential for collateral tissue damage and alteration. (Chavez et al., 2025, p. 25). MP-TSCPC uses the same approach but modulates the laser beam intensity, using low-energy, repetitive laser pulses separated by rest periods. This causes less thermal damage and minimizes the collateral tissue damage (Aquino et al., 2015).

Kelada et al. (2024) reported that TS-CPC reduced IOP by up to 45% from baseline at 24 months postoperatively (Kelada et al., 2024). Similarly, several studies have shown relative IOP reductions between 30–45% from baseline following ECP and MP-CPC during 12–24 months of follow-up (Elhusseiny et al., 2024; Preda et al., 2020; Zaarour et al., 2019).
Despite their effective IOP-lowering potential, many patients do not maintain target IOP levels without adjunctive medical therapy (de Vries et al., 2022). Reported retreatment rates are approximately 30–40% at two years post-procedure (Bolek et al., 2023; Rasmuson et al., 2019).

Postoperative complications (*Table 6*) are influenced by the extent of tissue ablation and the resulting inhibition of aqueous humor production. Moreover, tissue alteration and collateral tissue destruction influence the postoperative profile of cyclodestructive procedures (Chavez et al., 2025; Souissi et al., 2021).

Early postoperative complications (≤ 90 days) can be explained by inflammation reactions, ocular hypotony, and pain, all of which are significantly more frequent and severe following continuous-wave TS-CPC (Chavez et al., 2025; Souissi et al., 2021). As previously described, this is probably linked to TS-CPC's higher thermal energy, which induces broader tissue inflammation. Anterior uveitis has been reported by Souissi et al. to occur in 5–30% of TS-CPC cases, but in less than 5% of patients after MP-TSCPC (Souissi et al., 2021). The reason for this is assumed to be the difference between full-thickness coagulative necrosis with continuous-wave delivery and reduced, pulsed photostimulation in MP-TSCPC. The difference in the magnitude of tissue inflammation and disruption of the blood-aqueous barrier is considered a central factor driving the development of anterior uveitis. Another reported postoperative complication in the literature is pain. Pain has been reported in 5–10% of TS-CPC eyes. The postprocedural pain is assumed to arise from irritation of ciliary nerves and scleral thermal spread. Post-MP TSCPC pain was only reported in <5% as mild, transient discomfort. This is again hypothesized to be traceable back to lower thermal energy delivered. (Chavez et al., 2025). Similar to all other glaucoma surgery modalities, after cyclodestructive surgeries, ocular hypotony can also occur. It has been reported as a common early complication, observed in ~7% of TS-CPC versus ~1% of MP-TSCPC procedures (Chavez et al., 2025). The mechanism behind its occurrence is assumed to be linked to the suppression of aqueous secretion induced by ciliary epithelial ablation. Due to irreversible inhibition of aqueous humor production, hypotony may persist and become a long-term complication. Other early but less frequently reported complications include cystoid macular edema (CME) (1–5%) and mild corneal edema (Souissi et al., 2021). CME occurrence is described as secondary to inflammatory disruption of the blood–retinal barrier. Corneal edema usually resolves with topical steroid treatment (Souissi et al., 2021).

Late postoperative complications (> 90 days) are primarily influenced by the destruction and inhibition of aqueous humor production. The most serious reported complications are prolonged hypotony (2–10%) leading to phthisis bulbi (2–10%), and eventually irreversible vision loss (up to 10%) (Chavez et al., 2025). All parts of this sequel are linked to the hypotony caused by ciliary body atrophy. Persistent, prolonged hypotony can further cause secondary ciliochoroidal effusion and retinal folds (Chavez et al., 2025). Interestingly, after MP-TSCPC, the incidence of phtisis bulbi was reported to be <1%. This can be explained by the reduced extent of tissue ablation, which prevents uncontrolled IOP reduction.

In summary, postoperative complications following cyclodestructive surgery are linked primarily to the energy delivery profile of the method used. Continuous-wave TS-CPC carries a high risk of irreversible structural ciliary atrophy with higher reported rates of long-term hypotony. Micropulse TS-CPC shows a tendency to minimize collateral injury, reflected in lower rates of postoperative hypotony and progression to vision-threatening complications. Similar to other surgical modalities, early postoperative complications, such as ocular inflammation or transient hypotony, are reversible and self-limited. On the contrary, late uncontrolled complications manifest as irreversible, vision-threatening complications. The generally lower rates of vision-threatening complications reported suggest that micropulse TS-CPC is a safer surgical technique.

4 Discussion

Postoperative complications across different surgical modalities were found to be interestingly linked to common pathophysiological mechanisms. Glaucoma surgeries share the common goal of lowering IOP and establishing long-term IOP control; all surgical approaches alter either the production or outflow of aqueous humour. Therefore, similar complications can be observed after unlike surgical modalities. Common postoperative complications were hyphema, pressure spikes, hypotony, and its long-term sequelae. Incidents of complications depended primarily on the mechanism of alteration of aqueous dynamics (physiologic outflow vs. creating a bypass/shunt vs. inhibiting production), the manipulated anatomical location and function of the targeted tissue (angle, subconjunctival space, ciliary body), and the extent of thermal/mechanical injury.

4.1 Comparative outcomes

Laser trabeculoplasties have been shown to balance an effective IOP reduction with a lower risk of postoperative complications. SLT's selective photothermolysis primarily caused early, self-limited complications, such as discomfort/blur/hyperemia (~34%), and rare IOP spikes (~1.7%) (Gazzard et al., 2019). Late, vision-threatening events were uncommon. ALT's higher energy thermal coagulation manifested in an increased likelihood of early postoperative IOP spikes (12%) and late PAS (32%) formation (Feldman et al., 1991; Rolim-de-Moura et al., 2022). PAS have been rarely reported to lead to visual impairment. The higher extent of angle scarring after ALT diminished the success in repeated procedures. The primary transient and self-limiting complications in both laser trabeculoplasties make them a generally safe, first-line treatment modality for mild-to-moderate POAG (Gedde et al., 2021b).

Penetrating surgeries (trabeculectomy, Ahmed, Baerveldt, Molteno) achieved greater IOP reduction and control than laser trabeculoplasties. This has been reflected in the guidelines, which recommend penetrating surgeries for moderate-to-severe POAG (Gedde et al., 2021b). The greater invasiveness of trabeculectomy has been associated with more severe postoperative complications. Early hypotony was a commonly reported early postoperative complication (Trab 9%, Ahmed 8%, Baerveldt 17%) (Budenz et al., 2011; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022). Here, an immature capsule/bleb is created, with insufficient counterpressure to prevent uncontrolled aqueous humor outflow, leading to a pressure disequilibrium, causing overfiltration. As the bleb/capsule matures, this complication usually resolves on its own (Budenz et al., 2011; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022). Hypotony can result in flattening of the anterior chamber and choroidal effusions/detachment. Late complications reported were mainly cataract progression (Trab 24–44%, Baerveldt 52%), corneal edema/ decompensation with tubes (up to 20%), tube exposure (1–5%), and diplopia (≈12%) (Budenz et al., 2011; Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022; Molteno, 2011). The mentioned complications have been shown to be associated with tube plate size and location (Budenz et al., 2016). Overall, early complications after penetrating surgeries are typically reversible, whereas late lens/cornea-related complications can be progressive and even vision-threatening without intervention.

Non-penetrating surgeries (deep sclerectomy, canaloplasty) maintain the integrity of the Trabeculo-Descemet membrane (TDM). The preservation of this natural filtration barrier has been shown to reduce the risks of postoperative hypotony and infection. Early hyphema is a common complication after non-penetrating surgeries (DS 2–7%, CP 10–24%) (Brusini et al., 2016; Khairy et al., 2006, p. 202; Mercieca et al., 2025). Intraoperative microperforation of the TDM (DS 2.5–7%) can occur, but usually does not require any intervention (Brusini et al., 2016; Grieshaber et al., 2010; Khairy et al., 2006, p. 202; Mercieca et al., 2025). The main late complications were procedures to counteract fibrosis and reduced filtration. This has been reported in the literature as the number of performed goniopuncture (DS 33% at 1 year → 63% by 6 years) and needling (10–15%) (Mercieca et al., 2025; Rabiolo et al., 2023). Those interventions were typically successful in restoring the aqueous drainage. In general, vision-threatening complications were uncommonly reported after non-penetrating surgeries.

MIGS reduce tissue disruption, making it a minimally invasive modality. Early transient hyphema has been reported after Hydrus/Trabectome/GATT (≈11–40%) (Grover et al., 2014; Hu et al., 2021; Le et al., 2019; Otarola et al., 2020; Weber et al., 2023). IOP spikes (iStent 1–33%) were also typically noted in the early postoperative period, similar to those in laser trabeculoplasties (Le et al., 2019). Complications were transient and self-limited, rarely requiring intervention. Late complications have been associated with device functionality, e.g., stent obstruction/malposition (iStent 1–18%; Hydrus obstruction 1–12%, PAS 9–20%) or need for secondary surgery (Trabectome ~23% at 36 months, GATT ~9%) (Grover et al., 2014; Hu et al., 2021; Le et al., 2019; Otarola et al., 2020).

Micro-invasive filtration surgeries (Preserflo, XEN) combine the minimally invasive approach of MIGS with the creation of a subconjunctival filtration bleb. Complications were associated with bleb formation and early, uncontrolled drainage, similar to those seen with trabeculectomy. Early postoperative complications included hypotony (to ~19%) and choroidal effusion/detachment (10–15%), which have been attributed to the immaturity of the bleb (Mieno et al., 2025; Park et al., 2023; Scheres et al., 2021; Tanner et al., 2023). Late complications were bleb fibrosis requiring needling (12–29%) and 5-FU injection (to ~34%) (Scheres et al., 2021; Tanner et al., 2023). Long-term complications after XEN implantation were stent occlusion (4–9%) and stent migration (Gan et al., 2024). A severe vision-threatening complication was hypotony maculopathy (~2–5% XEN), which was shown to be reversible with timely medical management (Gan et al., 2024; Governatori et al., 2025).

Cyclodestructive surgeries are recommended for advanced, refractory POAG (Gedde et al., 2021b). As the ciliary endothelium is irreversibly ablated, it poses a postoperative risk for hypotony. Continuous-wave TS-CPC has been associated with postoperative inflammation, pain, hypotony, and high rates of prolonged hypotony, leading even to phthisis and irreversible vision loss (up to ~10%) (Chavez et al., 2025; Souissi et al., 2021).

MP-TSCPC demonstrated a reduced incidence of late hypotony and its sequel (<1%), which has been attributed to the lesser extent of collateral tissue ablation. This makes MP-TSCPC a safer choice in refractory glaucoma treatment (Chavez et al., 2025; Souissi et al., 2021).

4.2 Complication patterns

Early complications have been generally linked to acute physiologic disruption of aqueous drainage, leading to pressure imbalance (over- or underfiltration), bleeding after surgical manipulation, and local inflammatory reaction from tissue manipulation or thermal energy. Early complications were usually self-limited and only needed medical intervention in selected cases.

Late complications were often linked to postsurgical structural changes and wound healing, influencing tissue remodelling. This further affected the patency of the created drainage pathway and device functioning/positioning. Late complications were often progressive and eventually vision-threatening without targeted intervention.

4.3 Risk stratification for procedure safety

The lowest risk of vision-threatening complications has been reported after Laser trabeculoplasties (especially SLT) and MIGS. They presented mainly with mild, transient complications, not posing any long-term risks.

Non-penetrating and micro-invasive filtration surgeries demonstrated a moderate safety profile. These procedures required greater maintenance (goniopuncture/needling, 5-FU injection) to achieve long-term treatment success. However, vision-threatening events have not been frequently reported.

Penetrating surgeries showed a higher incidence of cataract and corneal complications, posing a potential threat to vision if they go unrecognised.

The highest risk of vision-threatening postoperative complications was found after CW-TS-CPC. Due to the inhibition of aqueous production, this surgical modality had great effect on IOP reduction, making it a useful tool in the management of advanced, refractory glaucoma. Simultaneously, it has been shown that CW-TSCPC has a higher risk of prolonged hypotony and phthisis due to a severe IOP reduction. On the contrary, MP-TSCPC has been shown to achieve similar IOP results, but with fewer cases of reported hypotony and sequelae, resulting in an overall better safety profile.

5 Clinical Takeaways

In this chapter, the literature-reported results will be applied to a clinical setting, focusing on how knowledge of postoperative complications can influence the postoperative period and its management.

Matching procedure to the desired target IOP

- Mild–moderate POAG: SLT or MIGS. Consider non-penetrating surgeries if larger IOP reduction is needed (Gedde et al., 2021b).
- Moderate-severe POAG: trabeculectomy or tubes; MIFS to decrease morbidity compared with penetrating procedures (Gedde et al., 2021b).
- Advanced, refractory glaucoma: MP-TSCPC.

Patient eduction

- Educate the patient on possible, commonly occurring postoperative complications.

Proactive surveillance for postoperative complications

- First 4–6 weeks: detect hypotony/flat AC/effusions (trab/tubes/MIFS), hyphema/IOP spikes (MIGS), Day-1 IOP spikes after laser (SLT/ALT), pain/inflammation after CPC (Gedde et al., 2021b).
- After 3–6 months and long term: monitor bleb fibrosis (needling/5-FU), tube–cornea proximity (specular/AS-OCT as needed), PAS/device obstruction (gonioscopy), and lens changes (cataract) (Gedde et al., 2021b).

Decisive treatment of pressure instability

- Hypotony: atropine, viscoelastic/AC reformation, flow restriction (tube ligation), pressure patch; management before maculopathy develops (Gedde et al., 2021b; Samuelson & Liaboe, 2021).
- Spikes: short-term topical IOP therapy; review steroids; clear lumen/angle debris if device present (Gedde et al., 2021b).

Tube positioning to protect the cornea and lens

- Prioritize posterior/pars plana or sulcus placement when anatomy allows
- Monitor endothelial counts if the tube is anterior

- Counsel on early cataract extraction when progression accelerates (Godinho et al., 2021; Iwasaki et al., 2018).

Early mitigation of fibrosis

- Needling/5-FU for MIFS and trab blebs
- Suture lysis after DS
- Prompt Nd:YAG clearing or reposition for obstructed MIGS
- Optimize anti-inflammatory regimen to reduce scarring drivers (Gedde et al., 2021b; Jayaram et al., 2023).

In general, the surgical management modality that delivers the desired IOP reduction with the lowest acceptable complication risk should be chosen. Proactive management of inflammation, pressure instability, fibrosis, and device function ensures positive outcomes and protects vision (BMJ Publishing Group Ltd. BMA House, 2021; Gedde et al., 2021b).

6 Conclusion

As glaucoma is a progressive disease, each patient's needs should be individually assessed and tailored to the desired management outcomes. Emphasis should be placed on patient education and close postoperative follow-up, early detection of vision-threatening complications, and enabling timely medical intervention.

The included literature describes an increase in POAG prevalence, posing a great challenge to health care systems. As stated in the current AAO and EGS guidelines, laser trabeculoplasties pose a low risk for vision-threatening complications and present mainly with transient, self-limited early complications. It is estimated that 80% of glaucoma patients are suitable candidates for SLT treatment (Gazzard et al., 2019).

Moreover, laser trabeculoplasties have been reported to have additional financial advantages, reducing potential costs for patients and the healthcare system. Kim et al. reported that SLT is cost-equal to timolol in real-world settings (Kim, 2012). Accounting for medication adherence, SLT became even more effective by reducing medication needs, reducing clinical visits, and reducing the need for further medical interventions (Kim, 2012). It is estimated that by employing SLT as a first-line treatment modality for POAG, approximately £458 (€552) per patient over 3 years could be saved (Gazzard et al., 2019).

The increased exposure of patients to surgical management underscores the importance of patient and physician awareness of potential postoperative complications and perioperative management.

In conclusion, early diagnosis, targeted intervention, and prevention of disease progression are cornerstones of POAG management. Early intervention with generally safer procedures prevents the need for more invasive procedures with potentially vision-threatening complications.

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8 APPENDICES

Complication	SLT (Selective Laser Trabeculoplasty)	ALT (Argon Laser Trabeculoplasty)
Early (≤ 90 days)		
Transient discomfort, blurred vision, photophobia, hyperaemia	34.4% [1]	
IOP spike (>5 mm Hg rise on day of treatment)	1.7% [1]	12% [3]
IOP spike requiring treatment	0.3% [1]	
Bleeding in anterior chamber angle	2/1000 SLT treatments [2]	
Corneal edema/ Descemet's membrane folds	1/1000 SLT treatments [2]	
Hyphema	0.7/1000 SLT treatments [2]	
Late (> 90 days)		
Peripheral anterior synechiae		32% [4]
Uveitis	0.6% [1]	
Reactivation of herpes simplex keratitis	0.3% [1]	
Permanent corneal scarring/thinning	<0.2/1000 SLT treatments [2]	
Irregular astigmatism/hyperopic shift	<0.2/1000 SLT treatments [2]	
Permanent vision deterioration	<0.2/1000 SLT treatments [2]	

Table 1 - ***Postoperative Complications after Laser Trabeculoplasties***

[1] (Gazzard et al., 2019)

[2] (Ojanen et al., 2025)

[3] (Feldman et al., 1991)

[4] (Rolim-de-Moura et al., 2022)

Complication	Trabeculectomy	Ahmed Glaucoma Valve	Baerveldt Glaucoma Implant	Molteno Implant
Early (≤ 90 days)				
Hypotony (≤5 mmHg)	9% [1]	8% [3]	2% [1], 17% [3]	
Bleb leak	6% [1]		0% [1]	
Choroidal effusion/detachment	6% [1], 1.1% [4]	4% [3]	2% [1], 9% [3]	0.8% [4]
Endophthalmitis	1% [1], 5% (1-9%) [5]	0% [3]	0% [1], 1% [3]	
Hyphema	4% [1]		2% [1]	
Subtotal hyphema	4.5% [4]			1.2% [4]
Shallow/flat anterior chamber	1.8% [4]	4% [3]	10% [3]	2.3% [4]
Corneal edema	1% [1]	2% [3]	2% [1], 2% [3]	
Suprachoroidal hemorrhage	1% [1]	1% [3]	0% [1], 2% [3]	
Diplopia	0% [1]		2% [1]	
Iritis	0% [1]		1% [1]	
Encapsulated bleb/plate	0% [1]		2% [1]	
Wound leak		2% [3]	2% [3]	
Blebitis	2% (0-4%) [5]			
Tube occlusion		2% [3]	5% [3]	
Tube exposure/erosion	0% [1]		1% [1]	
Late (> 90 days)				
Cataract progression	24% [4], 44% [1]		52% [1]	22% [4]
Repeat drainage procedure (reoperation)	8% [1], 9% [4]		2% [1]	2.3% [4]
Hypotony	3% [1]		2% [1]	
Bleb leak	2% [1]		0% [1]	
Choroidal effusion	2% [1]		1% [1]	
Tube exposure/erosion	0% [1]	1% [2]	2% [1], 3% [2]	
Corneal edema	2% [1]	20% [2]	2% [1], 20% [2]	
Endophthalmitis	0% [1]		0% [1]	
Suprachoroidal hemorrhage	0% [1]		0% [1]	
Diplopia	0% [1]	12% [2]	2% [1], 12% [2]	
Iritis	0% [1]		1% [1]	
Encapsulated bleb/plate	0% [1]		2% [1]	
Tube occlusion		0.8% [2]	5.7% [2]	
Tube reposition/removal				0.8% [4]
Phtisis/enucleation	1.1% [4]			0.8% [4]

Table 2 - ***Postoperative Complications after Penetrating Surgeries***

[1] (Gedde, Feuer, Lim, Barton, Goyal, Ahmed, Brandt, & Primary Tube Versus Trabeculectomy Study Group, 2022)

[2] (Budenz et al., 2016, p. 2)

[3] (Budenz et al., 2011)

[4] (Molteno, 2011)

[5] (Olayanju et al., 2015)

Complication	Deep Sclerectomy	Canaloplasty
Early (≤ 90 days)		
IOP spike (IOP >10 mm Hg)	1.7% [6]	6.1% [4]
Hyphaema	~2.3% [1], 7.5% [5]	10.4% [5], 23.7% [4]
Microperforation/Detachment of TDM	2.5% [5], 3.3% [6], 7.0% [1]	3.0% [5], 5.5% [4]
Transient Hypotony	5.0% [5]	4.5% [5]
Bleb encapsulation	4.7% [1]	
Ciliary body prolapse	2.3% [1]	
Shallow anterior chamber	~2.3% [1]	
Late (> 90 days)		
Laser goniopuncture required	33.3% at 1 year, 62.8% at 6 years [3]	
Chronic hypotony (IOP ≤5 mmHg)	13.4% at 5 years [2]	
Clinical hypotony (with sequelae)	5.6% at 5 years [2]	
Bleb fibrosis	12.0% [5]	
Bleb needling	15% [5]	
5-FU injection	13.5% [5]	
Suture lysis	10.0% [5]	

Table 3 - ***Postoperative Complications after Non-penetrating Surgeries***

[1] (Khairy et al., 2006) *[3] (Rabiolo et al., 2023)* *[5] (Mercieca et al., 2025)*

[2] (Rabiolo et al., 2021) *[4] (Brusini et al., 2016)* *[6] (Grieshaber et al., 2010)*

Complication	iStent	Hydrus Microstent	Trabectome	GATT
Early (≤ 90 days)				
IOP spike (>15 mmHg above baseline)	1-33.3% [2], 2-4.3% [4]	6% [4], 0.5% - 20% [5]	6-26% [6], 8.3% [7]	
Erythrocytes in anterior chamber		40.0% [1]		
Hyphema	1.2 - 1.9% [2]	19.3–40.0% [5]	11-33% [6], 4.2% [7]	30% [8]
Corneal edema		1.4 - 28.0% [5]		
Corneal injury	3.1% [2]			
Fibrinous uveitis			2.3% [7]	
Cyclodialysis cleft	1.2% [2]			
Late (> 90 days)				
Peripheral anterior synechiae	1.8% [2]	8.7 - 20.0% [5]		
Cataract progression	>5% [3]			
Loss of best-corrected visual acuity	>5% [3]			
Stent obstruction	1 - 13.2% [2]	1.1-12.2% [5]		
Stent malposition	3 - 18% [2]	1.1% [5]		
Need for secondary glaucoma surgery		<1% [5]	22.9% (over 36 mo) [6]	9% [8]

Table 4 - ***Postoperative Complications after Minimally Invasive Glaucoma Surgeries***

[1] (Jabłońska et al., 2023)

[2] (Le et al., 2019)

[3] (Samuelson et al., 2019)

[4] (Yook et al., 2018)

[5] (Otarola et al., 2020)

[6] (Hu et al., 2021)

[7] (Weber et al., 2023)

[8] (Grover et al., 2014)

Complication	Preserflo MicroShunt	XEN Gel Stent
Early (≤ 90 days)		
Hypotony	1.1% [3], 5% [6], 18.7% [1], 19.2% [2]	7% [6]
Hyphema	2% [6], 5.8% [2], 6-12% [1]	2% [6]
Choroidal effusion	10-13% [1]	
Choroidal Detachment	2% [6], 10.6% [2]	0-15% [5], 2% [6]
Bleb leak	0% [6], 0.6% [3], 5.8% [2]	2% [6], 2.1% [5]
Hypertrophic bleb		8.8% [5]
Hypotony maculopathy	2-3% [4]	1.9-4.6% [5]
Macular edema		1.5-4.3% [5]
Malignant glaucoma (MG)		2.2% [5]
Choroidal erosion/exposure		1.1-2.3% [5]
Endophthalmitis		0.4-3% [5]
Shallow anterior chamber	0.8% [3]	
Late (> 90 days)		
Cataract progression	3.7% (1-5 years) [3], 5% [6], 16.7% [1]	7% [6]
Bleb Needling	12.5% [2], 27% [6]	29% [6]
5-FU injection	33.7% [2]	
Revision Surgery	11.5% [2]	
Stent occlusion		3.9-8.8% [5]
Stent migration		1.5% [5]
Chronic Hypotony	0.4% [3]	
Ptosis		1.2% [5]

*Table 5 - **Postoperative Complications after Micro-Invasive Filtration Surgeries***

[1] (Mieno et al., 2025)

[2] (Tanner et al., 2023)

[3] (Park et al., 2023)

[4] (Governatori et al., 2025)

[5] (Gan et al., 2024)

[6] (Scheres et al., 2021)

Complication	TS-CPC (Continuous Wave)	MP-TSCPC (Micropulse)
Early (≤ 90 days)		
Inflammation (anterior uveitis)	5.8% [2], up to 30% [1]	0.9% [2], <5% [1]
Ocular hypotony	7.2% [2]	1.1% [2]
Severe pain	5-10% [1]	<5% [1]
Hyphema	<5% [1]	<2% [1]
Cystoid macular edema	<1% [2], 1-5% [1]	<1% [2], <2% [1]
Late (> 90 days)		
Prolonged ocular hypotony	2-10% [1], 3.1% [2]	<1% [1], 0.2% [2]
Prolonged inflammation	2.4% [2]	0.1% [2]
Phtisis bulbi	2-10% [1], 2.1% [2]	<1% [1], 0.1% [2]
Irreversible vision loss	2-10% [1]	<1% [1]

Table 6 - ***Postoperative Complications after Cyclodestructive Surgeries***

[1] (Souissi et al., 2021)

[2] (Chavez et al., 2025)

Declaration

I, Kenny Kruber, hereby certify that this research paper on the topic

„Pēcoperācijas periods pēc glaukomas operācijas"
(title of the research paper in Latvian)

„Postoperative period after glaucoma surgery"
(title of the research paper in English)

is my own independent research. All other sources of data, definitions and quotations in my research paper are referenced accordingly. The text of this research paper has never been submitted in any way to any other National Examination Board for evaluation in its entirety or parts, and has never been published in its entirety.

_____________________ /Kenny Kruber/
(student's signature) (name, surname)

04.11.2025