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Disparities in Glaucoma Surgery: A Review of Current Evidence and Future Directions for Improvement

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There is a need to understand existing disparities in glaucoma surgery and to create strategies to eliminate these disparities. Disparities can exist in several aspects of glaucoma surgical management, including patient selection and timing of surgery, type of surgery performed, intra-operative and postoperative surgical complications, follow-up surgical care, and long-term surgical outcomes. Additionally, multiple types of disparities can exist within each of these realms, including disparities by race and ethnicity, age, gender, insurance type, people with disabilities, and other social, economic, and demographic factors. Disparities in glaucoma surgery have been examined in large scale datasets, retrospective clinical studies, and clinical trials, and several studies have identified likely racial and ethnic disparities in glaucoma surgical incidence and outcomes. We present existing literature on disparities in glaucoma surgery, analyze the advantages and limitations of various study designs for the investigation of these disparities, and propose directions for future research and interventions to identify and eliminate disparities in surgical glaucoma care.

Introduction

Glaucoma is a leading cause of irreversible vision loss in the United States and worldwide.^{1,2} Surgical management of glaucoma is used in several aspects of glaucoma care. Selective laser trabeculoplasty (SLT) can be used as an adjunct or alternative to medications for reduction of intraocular pressure (IOP) in individuals with glaucoma or ocular hypertension.³ Laser peripheral iridotomy (LPI) is used for the prevention or treatment of angle closure glaucoma.⁴ Minimally invasive glaucoma surgery (MIGS) is often used to lower IOP at the time of cataract surgery in individuals with glaucoma, and can also be used as a standalone procedure for IOP reduction in select clinical settings.⁵ Finally, incisional surgeries, which include trabeculectomy and tube shunt, are generally

reserved for individuals with glaucomatous disease progression despite maximally tolerated medical therapy.^{6,7}

Healthcare disparities refer to differences in healthcare that are linked to social or economic disadvantage, which can take place on the individual or structural levels.^{8–10} There are several aspects of glaucoma surgical management where disparities can exist, including patient selection and timing of surgery, type of surgery performed, intra-operative and postoperative surgical complications, follow-up surgical care, and long-term surgical outcomes. Within each of these realms, multiple types of disparities can exist, including disparities by race and ethnicity, age, gender, insurance type, geographic residence, people with disabilities, and other social, economic, and demographic factors.¹¹ Given the multiple settings and types of glaucoma surgical disparities that can occur, the study of these

disparities is complex and requires a multifaceted approach incorporating information from multiple data sources and using various study designs. To this end, the purpose of the present review is to synthesize existing literature in the United States on disparities in glaucoma surgery by study type, to analyze the advantages and limitations of each study design for the investigation of disparities in glaucoma surgery, and to identify future research directions for the identification and elimination of disparities in surgical glaucoma management.

Studies in Large Datasets

Several large datasets are available for examination of factors related to glaucoma surgery, including Medicare claims datasets,¹² the American Academy of Ophthalmology (AAO) Intelligent Research in Sight (IRIS) Registry,¹³ the Veterans Health Administration (VHA) database,¹⁴ and other claims-based datasets. Studies of disparities in glaucoma surgery have been performed utilizing several of these datasets, with a large proportion of studies examining disparities in surgical incidence and treatment patterns. In the Medicare population, Javitt et al.¹⁵ compared observed versus expected rates of laser, incisional, and cyclodestructive glaucoma surgery in Black versus White beneficiaries and concluded that the observed rate of glaucoma surgery among Black beneficiaries was 45% lower than the expected rate of surgery in this population despite higher rates of surgery observed in Black beneficiaries. Similarly, Devgan et al.¹⁶ found higher rates of argon laser trabeculoplasty and trabeculectomy in Black compared to White beneficiaries, but concluded that the observed rate of surgery in Black beneficiaries was nearly half the expected rate. In a dataset of Medicare beneficiaries linked to the National Long Term Care Survey, Ostermann et al.¹⁷ found similar rates of glaucoma diagnosis in Black and White beneficiaries but higher rates of surgery in Black beneficiaries, suggesting delayed onset of care or greater disease severity in Black beneficiaries with glaucoma. More recently, Halawa et al.¹⁸ examined rates of multiple types of glaucoma procedures by race and ethnicity after controlling for age, systemic comorbidities, and glaucoma severity, and found higher odds of glaucoma surgeries in Black versus White beneficiaries, and higher odds of SLT in Hispanic versus White beneficiaries. In addition to these possible racial and ethnic disparities, other types of disparities in patterns of glaucoma procedures have also been identified in the Medicare database.

Schultz et al.¹⁹ examined multivariable predictors of laser trabeculoplasty in Medicare beneficiaries with glaucoma, and found that younger age and North Central United States region of residence were associated with increased odds of laser trabeculoplasty.

In addition to the Medicare database, several studies of disparities in glaucoma surgical incidence and treatment patterns have been performed in other large datasets. Lee et al.²⁰ examined tertiary glaucoma care patterns in the VHA by provider type, and found statistically significant differences in the rate of LPI, laser trabeculoplasty, and filtration surgery in veterans who received care in optometry-only clinics, ophthalmology-only clinics, integrated clinics, and separate clinics in the VHA. Olivier et al.²¹ examined multivariable predictors of receiving MIGS at the time of cataract surgery in individuals with glaucoma in the AAO IRIS Registry, and found greater odds of MIGS use among individuals who were older, identified as Black versus White race and ethnicity, had Medicare versus private insurance, and lived in the Northeast versus South United States. Finally, Usmani et al.²² examined ophthalmic procedures performed in the ambulatory setting from 2012 to 2014 through the State Ambulatory Surgery Database, and found that the largest proportion of individuals undergoing glaucoma surgery were elderly, women, identified as Black race and ethnicity, from large metropolitan areas, and insured by Medicare.

Whereas most studies of disparities in glaucoma surgery in large databases have examined disparities in surgical incidence and treatment patterns, two studies have examined disparities in glaucoma surgical outcomes. In a study by Yang et al.²³ that evaluated the effectiveness of MIGS with and without concurrent phacoemulsification in the AAO IRIS Registry, Black versus White race and ethnicity and older age were associated with increased odds of re-operation in individuals who underwent MIGS. Another study in the AAO IRIS Registry by Ciociola et al.²⁴ compared the effectiveness of trabeculectomy and tube shunt with versus without phacoemulsification. In this study, older age was associated with lower odds of re-operation after trabeculectomy with phacoemulsification, tube shunt with phacoemulsification, and tube shunt alone, Black, Hispanic, and Asian race and ethnicity compared to White race and ethnicity was associated with higher odds of re-operation after trabeculectomy with phacoemulsification and trabeculectomy alone, and Black compared to White race and ethnicity was associated with higher odds of re-operation after tube shunt alone.

Based on these existing studies of glaucoma surgical disparities in large datasets, we conclude that there are likely racial and ethnic disparities in surgical incidence and treatment patterns for individuals with glaucoma, with higher rates of glaucoma procedures in Black compared to White individuals in several studies yet lower than expected rates of surgery in Black individuals based on the prevalence of glaucoma in this population. Further studies are needed to identify whether these surgical disparities are due to delayed diagnosis and later disease stage at presentation in Black individuals with glaucoma, and the role of individual and structural level social determinants of health in contributing to these disparities. In addition to likely racial and ethnic disparities, there may also be disparities in glaucoma surgical incidence and treatment by age, provider type, and insurance type, which merit further focused investigation in additional studies. Although information on disparities in glaucoma surgical outcomes is limited, several demographic factors may be associated with increased risk of re-operation for glaucoma surgery, but further information is needed on disparities in glaucoma surgical complications and long-term surgical outcomes. At this time, the majority of studies of disparities in glaucoma surgery in large datasets are focused on disparities in surgical incidence and treatment patterns rather than disparities in surgical outcomes, which may be due to the fact that several existing datasets are heavily claims-based with limited clinical information to assess long-term surgical outcomes.

Retrospective Clinical Studies

Several retrospective clinical studies have been performed to examine potential disparities in glaucoma surgery, with a large proportion of studies focused on surgical outcomes. A review by Taubenslaug and Kammer²⁵ included several retrospective clinical studies that compared surgical outcomes in Black versus White individuals with glaucoma who received trabeculectomy, Ex-PRESS shunt, tube shunt, and canaloplasty. The authors concluded that there may have been decreased success for Black individuals after several of these procedures, but that trabeculectomy remains the procedure of choice for primary surgical intervention to reduce IOP. Nguyen et al.²⁶ compared the incidence of trabeculectomy failure and bleb leaks in 105 Black individuals and 117 White individuals with trabeculectomy from a single academic center, and found higher rates of trabeculectomy failure and bleb leaks in Black individuals, with surgical failure

defined by a combination of IOP, percent IOP reduction, and use of glaucoma medication. Similarly, Shin et al.²⁷ examined 174 individuals with combined phacoemulsification and trabeculectomy and found that Black compared to White race and ethnicity was associated with increased risk of surgical failure by two different criteria based on a combination of re-operation, bleb appearance, and glaucoma medication use. In a case-control study by Soltau et al.²⁸ of 55 eyes with bleb-related infection and 55 control eyes without infection, Black race and ethnicity and younger age were associated with increased risk of infection. Ishida and Netland²⁹ compared rates of surgical failure after Ahmed valve implantation in 43 Black and 43 White individuals and found higher rates of failure in Black individuals with two different failure definitions based on a combination of IOP reduction, glaucoma medication use, re-operation, and vision loss. Edmiston et al.³⁰ examined rates of postoperative anterior uveitis after combined phacoemulsification and endoscopic cyclophotocoagulation in 223 individuals, and found higher rates of postoperative uveitis in Black compared to White individuals. Finally, Laroche et al. performed three studies to examine short-term surgical outcomes in Black and Hispanic individuals with glaucoma who received XEN gel stent with phacoemulsification,³¹ Hydrus microstent with phacoemulsification,³² and Kahook dual blade goniotomy with or without phacoemulsification.³³ Although they reported adequate IOP control for most individuals with Hydrus microstent and Kahook dual blade by 6 months postoperatively, a high proportion required re-operation by 12 months postoperative for individuals with the XEN gel stent.

In addition to the several studies of racial and ethnic disparities in glaucoma surgery outcomes, one study by Funk et al.³⁴ examined the association between travel distance and postoperative outcomes for 199 individuals with trabeculectomy or tube shunt from a single academic center. This study reported that compared to individuals who lived <25 miles from clinic, those who lived >50 miles away had increased odds of loss to follow-up and missed appointments. Additionally, those who lived >20 miles from interstate access had more loss to follow-up than those who lived <10 miles from access, and those with Medicaid coverage had more missed appointments than those with Medicare coverage.

In summary, several retrospective clinical studies have been performed to examine disparities in glaucoma surgery. Many of these studies compared glaucoma surgical outcomes in Black compared to White individuals, with several reporting higher rates of surgical failure and complications in Black

individuals, suggesting likely racial and ethnic disparities in glaucoma surgical outcomes. Although most of these studies were in single academic centers with a limited number of individuals available for the study, the availability of abundant clinical information, including visual acuity, IOP, glaucoma medication use, ocular examination data, and re-operation data allowed for detailed assessment of surgical failure using multiple types of failure criteria. Whereas there was one study that reported associations between increased distance traveled and increased risk of loss to follow-up after glaucoma surgery, there is a shortage of clinical studies examining other types of social, economic, and demographic disparities in outcomes after glaucoma surgery with detailed incorporation of clinical information.

Clinical Trials

Several clinical trials have been performed in the United States to evaluate the efficacy of different types of glaucoma surgery. In addition to inclusion policies for clinical research funded by the National Institutes of Health,³⁵ the National Institute on Minority Health and Health Disparities Strategic Plan for 2021 to 2025 includes a goal to promote individuals from minoritized populations in all federally funded research with human participation.³⁶ In this section, we will present existing pivotal trials in glaucoma surgery, characteristics of included participants in each trial, and the extent to which each trial presents outcomes for participants from minoritized populations.

The Advanced Glaucoma Intervention Study (AGIS)³⁷ included individuals 35 to 80 years old with primary open angle glaucoma (POAG) without previous glaucoma surgery or residual open angle glaucoma after laser iridotomy. Participants were randomized to argon laser trabeculoplasty (ALT)-trabeculectomy-trabeculectomy (ATT) or trabeculectomy-ALT-trabeculectomy (TAT) intervention sequences and followed for early and late treatment failure. Of 591 total participants in AGIS, there were 249 (42.1%) who were White, 332 (56.2%) who were Black, and 10 (1.7%) who were Other race and ethnicity.³⁸ Of the 581 White and Black participants, there were 117 (20.1%) who were women, 123 (21.2%) who were age ≥ 65 years, 110 (18.9%) who were married, and 129 (22.2%) who completed high school.³⁷ At 10-year follow-up, AGIS investigators reported that IOP was lower in both sequences in White and Black participants with medically uncontrolled glaucoma, but that the TAT sequence for White participants and the ATT sequence

for Black participants was better for long-term visual function outcomes.³⁷

The Collaborative Initial Glaucoma Treatment Study (CIGTS)³⁹ included individuals 25 to 75 years old with open angle glaucoma without previous intraocular surgery. Participants were randomized to initial trabeculectomy followed by a combination of argon laser trabeculoplasty, medications, and trabeculectomy if further IOP reduction was needed, versus initial medical therapy followed by a combination of argon laser trabeculoplasty, medications, and repeat trabeculectomy if further IOP reduction was needed. There were 607 participants enrolled at baseline, of whom 337 (55.5%) were White, 231 (39.0%) were Black, 10 (1.6%) were Asian, and 29 (4.8%) were Other race and ethnicity. There were 273 (45.0%) participants who were women and 191 (31.5%) who were 65 to 75 years old. In long-term follow-up reports, no specific information on surgical failure³⁹ or complications⁴⁰ was reported in participants from minoritized populations.

The Tube Versus Trabeculectomy (TVT) Study⁴¹ included individuals 18 to 85 years old with inadequately controlled glaucoma who had undergone previous cataract and/or glaucoma surgery. Participants were randomized to 350 mm² Baerveldt shunt implantation or trabeculectomy with mitomycin-C (MMC) 0.4 mg/mL for 4 minutes. Of 212 total participants at baseline, there were 95 (44.8%) who were White, 82 (38.7%) who were Black, 30 (14.2%) who were Hispanic, and 5 (2.5%) who were Other race and ethnicity. There were 112 (42.8%) participants who were women and the average participant age was 71.0 \pm 10.4 years. At 5 years of follow-up, there were no statistically significant associations among age, gender, or race and ethnicity and risk of surgical failure in multivariable analyses.⁶ The Primary Tube Versus Trabeculectomy (PTVT) Study⁴² was a new trial after the TVT that included participants 18 to 85 years old with inadequately controlled glaucoma who had not undergone previous intraocular surgery, and participants were randomized to 350 mm² Baerveldt shunt implantation or trabeculectomy with MMC 0.4 mg/mL for 2 minutes. At baseline, the study included 242 participants, of whom 95 (39.3%) were White, 116 (47.9%) were Black, 15 (6.2%) were Hispanic, 13 (5.4%) were Asian, and 3 (1.2%) were Other race and ethnicity. There were 82 (33.9%) participants who were women, and mean age was 62.0 \pm 11.4 years in the tube group and 60.8 \pm 12.3 years in the trabeculectomy group.⁴³ At 5 years of follow-up, there were no statistically significant associations among age, gender, or race and ethnicity and risk of surgical failure in multivariable analyses.⁷

The Ahmed Baerveldt Comparison (ABC) Study⁴⁴ enrolled individuals 18 to 85 years old with inadequately controlled glaucoma with a planned aqueous shunt procedure. Participants were randomized to aqueous shunt implantation with the Ahmed valve model FP7 versus the 350 mm² Baerveldt shunt. At baseline, the study enrolled 276 participants, of whom 134 (48.6%) were White, 68 (24.6%) were Black, 33 (12.0%) were Hispanic, 33 (12.0%) were Asian, and 8 (2.9%) were Other race and ethnicity. There were 142 participants (51.4%) who were men (the number of women was not reported) and mean age was 63.8 ± 13.6 years.⁴⁴ In 5-year follow-up reports, no specific information on surgical failure⁴⁵ or complications⁴⁶ was reported in participants from minoritized populations. The Ahmed Versus Baerveldt (AVB) Study⁴⁷ enrolled individuals 18 years and older with inadequately controlled glaucoma with a planned aqueous shunt procedure. At baseline, the study enrolled 238 participants, of whom 170 (71.4%) were White, 28 (11.8%) were Black, 19 (8.0%) were Indian, 12 (5.0%) were Hispanic, and 9 (3.8%) were Asian race and ethnicity. There were 132 (55%) participants who were women and mean age was 66 ± 16 years. In 5-year follow-up reports, no specific information on surgical failure or complications was reported in participants from minoritized populations.⁴⁸

The pivotal trial for the iStent inject⁴⁹ enrolled individuals with mild to moderate POAG and visually significant cataract, and randomized participants to phacoemulsification with versus without iStent inject implantation. The study enrolled 505 participants, of whom 368 (72.9%) were White, 96 (19.0%) were Black, 34 (6.7%) were Hispanic, 4 (0.8%) were Asian, 1 (0.2%) was American Indian, 1 (0.2%) was East Indian, and 1 (0.2%) was Portuguese race and ethnicity. There were 289 (57.2%) participants who were women and mean age was 69.0 ± 8.2 years in the phacoemulsification with iStent inject group and 70.1 ± 7.7 years in the phacoemulsification alone group. At 2-year follow-up, no specific information on surgical failure or complications was reported in participants from minoritized populations. The HORIZON Study⁵⁰ enrolled participants with mild to moderate POAG and visually significant cataract, and randomized participants to phacoemulsification with versus without Hydrus stent implantation. The study enrolled 556 participants, of whom 444 (79.9%) were White, 60 (10.8%) were Black, 32 (5.8%) were Asian, and 20 (3.6%) were Other race and ethnicity. There were 311 (55.9%) participants who were women and mean age was 71.1 ± 7.9 years in the phacoemulsification with Hydrus group and 71.2 ± 7.6 years in the phacoemulsification alone group. At

5-year follow-up, no specific information on surgical failure or complications was reported in minoritized populations.⁵¹

In summary, several pivotal clinical trials have been performed in glaucoma surgery and shape glaucoma surgical management in day-to-day practice. It appears that most trials have enrolled participants from diverse racial and ethnic backgrounds, included large proportions of female participants, and included participants of a wide range of ages. However, further investigation is needed on whether the distribution of these demographics is comparable to the demographic distributions of individuals receiving these glaucoma surgical interventions in the real-world clinical setting, and whether increased recruitment is needed of participants from minoritized populations. Additionally, to address other sources of health disparities, additional information is needed on socioeconomic status and other social determinants of health at the time of clinical trial recruitment to ensure representation of a wide range of social, economic, and demographic backgrounds in trial participants. Finally, whereas some existing trials presented surgical outcomes specific to racially and ethnically minoritized populations, focused efforts should be made in future glaucoma surgical trials to present expanded outcome information by race and ethnicity, gender, age, and other social, economic, and demographic factors in order to increase understanding of potential disparities in surgical outcomes by these factors.

Future Directions and Conclusions

The identification and elimination of disparities in glaucoma surgical care is of utmost importance to prevent glaucomatous vision loss for the most at-risk populations. We have presented current literature on disparities in glaucoma surgery from retrospective database and clinical studies and in clinical trials. Currently, there are likely racial and ethnic disparities in glaucoma surgical incidence, treatment patterns, and outcomes, but there is a need to understand the role of individual and structural level social determinants of health in contributing to these disparities, as well as a need for further understanding of the presence of other social, economic, and demographic disparities. Additionally, whereas the large glaucoma clinical trials report the frequency of enrollment by race and ethnicity, the majority of these trials have not compiled or reported the role of racial and ethnic and other disparities in trial outcomes.

To address these needs, we can apply several aspects of the framework to eliminate disparities in eye care outlined by the AAO Taskforce on Disparities in Eye Care.¹¹ Specifically, in retrospective studies of disparities in glaucoma surgery, the harmonization of medical data from claims and clinical practice, along with additional data outside the medical setting including measures of socioeconomic factors, lifestyle habits, air pollution, and other factors will improve the ability to increase understanding of the role of social determinants of health in contributing to disparities in glaucoma surgery. Additionally, whereas current large scale studies of disparities in glaucoma surgery mainly focus on surgical incidence and treatment patterns as measured by claims, with increased incorporation of clinical data measures, such as visual acuity, IOP, and ancillary testing, into large scale datasets, such as the AAO IRIS Registry and the Sight Outcomes Research (SOURCE) Collaborative,⁵² there is increased ability to examine disparities in glaucoma surgical outcomes with detailed clinical definitions of surgical failure in large populations. In the clinical trial setting, outcomes specific to participants from minoritized populations could be retrospectively analyzed and presented for completed trials, and future trials should continue to recruit a diverse group of participants and create specific plans to examine interventions and outcomes for participants from minoritized populations. Additionally, future study protocols could increase collection of information related to social determinants of health at the time of participant enrollment in trials. Finally, in addition to improving the collection and analysis of information related to disparities in glaucoma surgery in various research settings, there is a need to engage patients and their communities to reduce the disparities that are identified. Community-partnered approaches involving community centers, faith-based organizations, and other key community stakeholders may decrease barriers and improve outcomes for individuals undergoing glaucoma surgery, and future research and initiatives involving these approaches should be implemented.^{11,53–55}

In summary, several challenges exist in the identification and elimination of disparities associated with glaucoma surgery. A multifaceted approach involving the retrospective and prospective analysis of surgical incidence and outcomes with incorporation of social, economic, and demographic information, and contributions from the researcher, provider, patient, and community perspectives is needed if we are ever going to eliminate the healthcare disparities associated with glaucoma surgery occurring in minoritized populations in the United States.

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