Sociodemographic and Economic Factors in Outcomes of Tube Shunts for Neovascular Glaucoma

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Abstract

Importance: Few studies have analyzed associations between sociodemographic factors and neovascular glaucoma (NVG) outcomes.

Aim and background: To determine the potential impact of sociodemographic and economic factors on the NVG tube shunt surgery outcomes.

Design: Retrospective, single-center, comparative case series.

Participants: Consecutive patients who underwent tube shunt surgery for NVG and had $\geq$6 months of follow-up.

Materials and methods: Regional average adjusted gross income (AGI) was determined by cross-referencing self-reported residential zip codes with average AGI per zip code supplied by the Internal Revenue Service. Two groups were created: (1) lower-income: individuals from neighborhoods with the lowest 10% of AGI (near the United States poverty line), (2) higher-income: the remaining 90% of individuals.

Main outcome measures: Visual acuity (VA), intraocular pressure (IOP), and glaucoma medication number at 6 months and the most recent visit.

Results: The mean annual AGI in the higher-income group (130 patients) was $69,596 $\pm$ 39,700 and the lower-income group (16 patients) was $27,487 $\pm$ 1,600 ($p < 0.001$). Age, sex, distance to the clinic, language, and all baseline clinical variables (including VA and IOP) were comparable between groups. Lower-income was associated with non-white race (81.3 vs 52.3%; $p = 0.024$). At month 6, VA in the lower-income group [median: HM (20/70–NLP)] was worse than the higher-income group [median: CF (20/25–NLP)] (log MAR VA: 2.32 $\pm$ 0.8 vs 1.77 $\pm$ 1.1; $p = 0.02$); these trends persisted through the most recent visit ($p = 0.043$). Follow-up IOP and medications were similar between groups.

Conclusions and relevance: Lower-income may be associated with worse VA outcomes following NVG tube shunt surgery.

Keywords: Ahmed glaucoma valve, Baerveldt glaucoma implant, Glaucoma surgery, Income, Neovascular glaucoma, Race, Sociodemographic, Socioeconomic, Tube shunt.

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Introduction

Neovascular glaucoma (NVG) is a type of secondary glaucoma that can result in catastrophic vision loss.[1] Neovascular glaucoma is most commonly preceded by proliferative diabetic retinopathy, central retinal vein occlusion, central retinal artery occlusion, or ocular ischemic syndrome.[1] The management of NVG includes medical or surgical reduction of intraocular pressure (IOP) and treatment of the underlying posterior segment ischemia-inducing neovascularization. Surgical interventions in the form of filtering procedures or cyclophotocoagulation are often necessary when medical therapy fails, especially in the presence of synechial angle closure.[2] Tube shunt implantation has been described in several studies as the mainstay of therapy for NVG.[3–5] Additionally, underlying retinal ischemia is treated by panretinal photocoagulation (PRP) and/or intravitreal injection of anti-vascular endothelial growth factor (anti-VEGF) agents, which reduce the production of angiogenic factors and induce regression of neovascularization.[6]

The impact of sociodemographic and economic factors on general health outcomes has been widely investigated.[7–12] The prevalence of nearly all chronic conditions, including stroke, heart disease, and arthritis has been shown to increase as income declines.[7] Economic inequality in the United States is among the highest of developed nations, and there is a life expectancy gap of 10–15 years between the wealthiest and poorest 1% of the American population.[11,12] In addition to income, factors including race, sex, ethnicity, primary language, education, housing, employment,

and health insurance status have been shown to have a significant association with general health outcomes.[13–19]

The literature on associations between sociodemographic and economic factors and ophthalmic health outcomes is limited.[13–18] Healthcare disparities in ophthalmology have been associated with race, sex, education, and income.[13–16] Although NVG is common secondary glaucoma and tends to affect those with poor general health,[1] few studies have analyzed associations between sociodemographic factors and NVG outcomes. This study

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aimed to investigate a potential relationship between income and visual acuity (VA) and IOP outcomes after glaucoma tube shunt implantation in patients with NVG.

MATERIALS AND METHODS

Study Design

This was a single-center, retrospective comparative case series. The study was approved by the Institutional Review Board of Wills Eye Hospital and was in accordance with Health Insurance Portability and Accountability Act Regulations. As this was a retrospective study with de-identified data, informed consent was not required. The medical records of consecutive patients diagnosed with NVG who were treated at Wills Eye Hospital with a glaucoma tube shunt [Ahmed glaucoma valve (New World Medical Inc., Rancho Cucamonga, CA, USA) or Baerveldt glaucoma implant (Advanced Medical Optics, Santa Ana, CA, USA)] between 2007 and 2019 were reviewed. Patients who had undergone tube shunt surgery for NVG in both eyes only had the first eye included. The diagnosis of NVG was based on the presence of neovascularization of the iris and/or anterior chamber angle and IOP >21 mm Hg. Neovascular glaucoma was considered refractory if the IOP was too high for the health of the optic nerve despite maximal tolerated medical therapy.

The yearly regional average adjusted gross income (AGI) was determined by cross-referencing the patient's self-reported residential zip code with the average AGI per zip code supplied by the Internal Revenue Service. Distance to Wills Eye Hospital was calculated using Google Maps (www.maps.google.com) by measuring the distance between the center of the patient's self-reported zip code and 840 Walnut Street, Philadelphia, Pennsylvania (location of Wills Eye Hospital). Two groups were created: lower AGI group—those living in neighborhoods with the lowest 10% of AGI ($N = 16$) with an average household income of $27,500 ± 1,600, and higher AGI group—the remaining 90% of individuals ($N = 130$) with an average household income of 69,600 ± 39,700. The United States government's federal poverty line is one of the most commonly-used markers of poverty and is calculated by finding the total cost of all the essential resources that an average human adult consumes in 1 year. Our classification was based on the United States poverty line guidelines in 2020, which classified a family of four with a household income of $26,200 as "poor". The lower-income group represented individuals who lived in neighborhoods with an average AGI near the United States poverty line, while the higher-income group represented those above the United States poverty line.[19,20]

Inclusion and Exclusion Criteria

Patients aged 18 years or older with refractory NVG (defined above) requiring glaucoma tube shunt surgery were included in the study. Exclusion criteria included patients with no light perception vision at baseline, prior tube shunt implantation or cyclophotocoagulation, and follow-up duration <6 months. Prior trabeculectomy or other non-glaucoma surgery, including cataract and vitreoretinal surgery, were not considered exclusionary criteria.

Patient Visits

Medical records were reviewed for the preoperative visit, as well as visits at postoperative day 1, week 1, months 1, 3, 6, and the most recent visit. Demographic data such as age, sex, race, and preferred language as well as medical and surgical history were collected.

Preoperative clinical data included VA, IOP, number of glaucoma medications, lens status, presence of peripheral anterior synechiae, and/or hyphema. Details of neovascular disease including laterality, NVG etiology, laterality of the underlying retinal pathology, and retinal treatment in the form of PRP or intravitreal injection of anti-VEGF within 2 weeks of surgery were also identified at baseline. Postoperative data included VA, IOP, and the need for glaucoma medications.

Outcome Measures

The primary outcome measures were VA, IOP, and the number of glaucoma medications at 6 months and the most recent visit. The severity of visual loss was also investigated. Visual loss was categorized according to the best-corrected Snellen VA into mild to moderate (≥20/200) or severe (<20/200) vision loss. Postoperative month 6 failure was defined as IOP >21 mm Hg on maximum tolerated medical therapy or <5 mm Hg with visual complications on two consecutive visits, progression to no light perception vision, and reoperation for glaucoma.

Statistical Analysis

Statistical analyses were performed using SPSS software version 27.0 (IBM Analytics, Chicago, IL, USA). One eye from each patient was chosen for inclusion; if a patient had tube shunt surgery in both eyes or multiple tube shunts in the same eye, the first eye and the first tube shunt were chosen for inclusion. Snellen VA measurements were converted to logarithm of the minimum angle of resolution (log MAR) VA equivalents for data analysis. Measures of center and dispersion were presented as mean ± standard deviation. Proportions (%) were used to describe categorical variables. Two-sided Student's t-tests and Chi-square tests (Fisher's exact tests) were used to compare treatment groups for continuous and categorical variables, respectively. Paired sample t-tests and the McNemar test were used to compare continuous and categorical variables within the same group, respectively. p values <0.05 were considered significant.

RESULTS

Baseline Characteristics

Baseline characteristics of both groups are displayed in Table 1. A total of 146 eyes of 146 patients with an average follow-up duration of 28.5 ± 25.4 months were included. Mean AGI in the higher income group (130 patients) was $69,596/year ± 39,700 and the lower-income group (16 patients) was $27,487/year ± 1,600 ($p < 0.001$). Patient demographics including age, sex, and distance to Wills Eye Hospital were comparable between groups. The preferred language as non-English was more common in the lower-income group (25.0 vs 13.8%), however, this difference was not significant ($p = 0.265$). Racial variations between both groups were present, but not significant ($p = 0.055$). When the race was presented as white vs non-white, the lower-income group had a significantly greater proportion of non-white individuals compared with the higher-income group (81.3 vs 52.3%; $p = 0.024$). Preoperative VA, IOP, number of glaucoma medications, lens status, presence of hyphema, an extension of synechial angle closure, NVG etiology, unilateral or bilateral underlying ischemic retinal pathology, choice of tube type, surgery by attending physicians vs trainees, and average follow-up duration were similar in both groups. Retinal treatment within 2 weeks of surgery with PRP or intravitreal injection of anti-VEGF was similar between groups.

Table 1: Baseline patient characteristics in the lower and higher average gross income groups

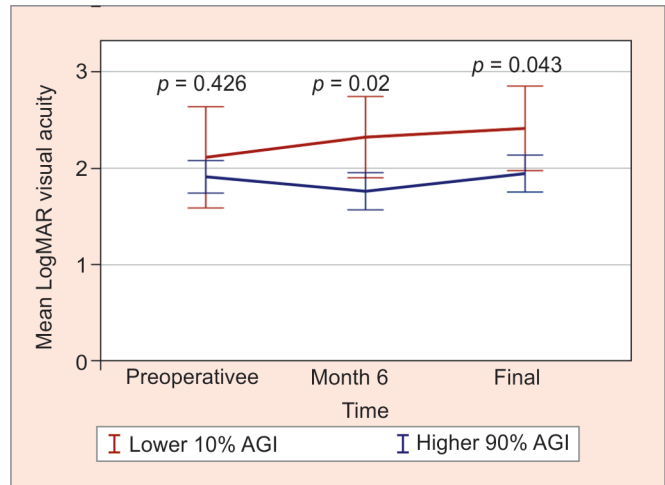|		Lower AGI (N = 16)	Higher AGI (N = 130)	Total (N = 146)	p value
Age, years		60.0 ± 13.5	65.4 ± 14.3	64.8 ± 14.3	0.157
Sex: females		6 (37.5)	49 (37.7)	55 (37.7)	0.608
Race: all	White	3 (18.8)	62 (47.7)	65 (44.5)	0.055
	Black	5 (31.3)	38 (29.2)	43 (29.5)	
	Asian	0 (0.0)	6 (4.6)	6 (4.1)	
	Hispanic	3 (18.8)	7 (5.4)	10 (6.8)	
	Indian	0 (0.0)	1 (0.8)	1 (0.7)	
	Unknown	5 (31.3)	16 (12.3)	21 (14.4)	
Race: white vs non-white	White	3 (18.8)	62 (47.7)	65 (44.5)	0.024
	Non-white	13 (81.3)	68 (52.3)	81 (55.5)	
Language	English	12 (75.0)	112 (86.2)	124 (84.9)	0.265
	Non-English	4 (25.0)	18 (13.8)	22 (15.1)	
Average gross income, $ in thousands		27.5 ± 1.6	69.6 ± 39.7	65.0 ± 39.7	<0.001
Distance from Wills Eye Hospital, Miles		12.4 ± 15.4	29.9 ± 47.5	28.0 ± 45.4	0.148
Tube type: Ahmed		11 (68.8)	82 (63.1)	93 (63.7)	0.441
Surgeon	Trainee	10 (62.5)	50 (38.5)	60 (41.1)	0.104
	Attending	6 (37.5)	80 (61.5)	86 (58.9)	
Surgical eye: right		7 (43.8)	64 (49.2)	71 (48.6)	0.442
NVG etiology	PDR	9 (56.3)	76 (58.5)	85 (58.2)	0.788
	CRVO	5 (31.3)	32 (24.6)	37 (25.3)	
	CRAO	0 (0.0)	8 (6.2)	8 (5.5)	
	OIS	0 (0.0)	3 (2.3)	3 (2.1)	
	Unknown	1 (6.3)	3 (2.3)	4 (2.7)	
	Combined	1 (6.3)	8 (6.2)	9 (6.2)	
Bilateral underlying ischemic retinal pathology		9 (65.3)	74 (56.9)	83 (56.8)	0.959
Preoperative visual acuity	Log MAR	2.11 ± 1	1.91 ± 0.9	1.94 ± 0.9	0.426
	Snellen median	HM	CF	CF	
	Snellen range	20/30–LP	20/25–LP	20/25–LP	
Preoperative IOP, mm Hg		41.8 ± 13.3	39.9 ± 11.4	40.1 ± 11.6	0.531
Number of preoperative medications		3.1 ± 1.0	3.4 ± 0.8	3.4 ± 0.8	0.251
Preoperative lens status	+1–2 Cataract	9 (56.3)	55 (42.3)	64 (43.8)	0.748
	+3–4 Cataract	1 (6.3)	9 (6.9)	10 (6.8)	
	Pseudophakia	6 (37.5)	65 (50.0)	71 (48.6)	
	Aphakia	0 (0.0)	1 (0.8)	1 (0.70)	
Preoperative hyphema		2 (12.5)	23 (17.7)	25 (17.1)	0.603
Preoperative peripheral anterior synechiae	None	1 (6.3)	11 (8.5)	12 (8.2)	0.277
	<180°	0 (0.0)	15 (11.5)	15 (10.3)	
	180–270°	2 (12.5)	24 (18.5)	26 (17.8)	
	360°	5 (31.3)	46 (35.4)	51 (34.9)	
	No view	8 (50.0)	34 (26.2)	42 (28.8)	
PRP within 2 weeks of surgery		13 (81.3)	87 (66.9)	100 (68.5)	0.244
Intravitreal injection within 2 weeks of surgery		11 (68.8)	91 (70.0)	102 (69.9)	0.918
Overall retina treatment within 2 weeks of surgery	None	2 (12.5)	15 (11.5)	17 (11.6)	0.494
	Intravitreal injection or PRP	4 (25.0)	52 (40.0)	56 (38.4)	
	Intravitreal injection and PRP	10 (62.5)	63 (48.5)	73 (50.0)	
Follow-up duration, months		28.5 ± 26.4	28.5 ± 25.4	28.5 ± 25.4	0.999

AGI, average gross income; NVG, neovascular glaucoma; IOP, intraocular pressure; Log MAR, logarithm of the minimum angle of resolution; PDR, proliferative diabetic retinopathy; CRVO, central retinal vein occlusion; CRAO, central retinal artery occlusion; OIS, ocular ischemic syndrome; PRP, panretinal photocoagulation; CF, counting fingers; HM, hand motion, LP, light perception
Parentheses denote percentages

Outcome Measures

The outcome measures at postoperative month 6 and most recent visits are displayed in Table 2. At postoperative month 6, VA in the lower-income group (median: HM, range: 20/70–NLP) was significantly lower than the higher-income group (median: CF, range: 20/25–NLP) (mean log MAR VA: 2.32 ± 0.8 vs 1.77 ± 1.1; $p = 0.02$). This trend continued through the most recent visit with lower VA in the lower-income group (median: HM, range: 20/100–NLP) compared with the higher-income group (median: CF, range: 20/25–NLP) (mean log MAR VA: 2.41 ± 0.8 vs 1.93 ± 1.1; $p = 0.043$) (Fig. 1).

Progression to severe vision loss is displayed in Supplemental Table 1. In the lower-income group, 75.0% of patients had severe vision loss at baseline, which increased to 81.3% at postoperative month 6 ($p = 1.00$) and further increased to 87.5% at the most recent visit ($p = 0.500$). On the other hand, 70.0% of patients in the higher income group had severe vision loss at baseline, but many of them achieved significant improvement at postoperative month 6 visit, reducing severe vision loss to 58.5% ($p = 0.003$). At the most recent visit, 64.6% of the higher income group had severe vision loss, which
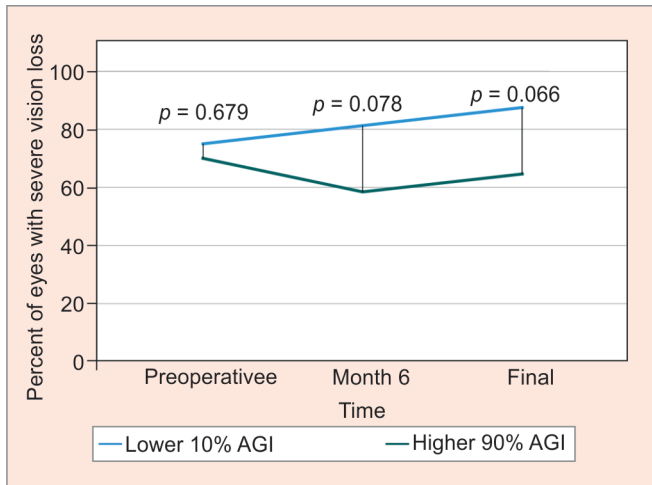

Fig. 1: Visual Acuity Changes over time in the lower and higher average growth income (AGI) groups

Table 2: Month 6 and final outcomes in the lower and higher average gross income groups

		Lower AGI (N = 16)	Higher AGI (N = 130)	Total (N = 146)	p value
Month 6 visual acuity	Log MAR	2.32 ± 0.8	1.77 ± 1.1	1.82 ± 1.0	0.020
	Snellen median	HM	CF	CF	
	Snellen range	20/70–NLP	20/25–NLP	20/25–NLP	
Month 6 IOP, mm Hg		16.0 ± 6.1	16.8 ± 7.4	16.7 ± 7.2	0.691
Month 6 lens status	+1–2 Cataract	6 (37.5)	47 (36.2)	53 (36.3)	0.426
	+3–4 Cataract	2 (12.5)	8 (6.2)	10 (6.8)	
	Pseudophakia	7 (43.8)	73 (56.2)	80 (54.8)	
	Aphakia	1 (6.3)	2 (1.5)	3 (2.1)	
Number of month 6 medications		1.5 ± 1.3	2.0 ± 1.4	1.9 ± 1.4	0.247
Month 6 reoperation		1 (6.3)	3 (2.3)	4 (2.7)	0.362
Month 6 failure	3 (18.8)	31 (23.8)	34 (23.3)	0.649
Reasons for failure	IOP >21 mm Hg	1 (33.3)	22 (71.0)	23 (67.6)	0.237
	Loss of LP vision	1 (33.3)	5 (16.1)	6 (17.6)	
	Reoperation	0 (0.0)	2 (6.5)	2 (5.9)	
	IOP <5 mm Hg	0 (0.0)	1 (3.2)	1 (2.9)	
	Combined	1 (33.3)	1 (3.2)	2 (5.9)	
Month 6 reoperation		1 (6.3)	3 (2.3)	4 (2.7)	0.375
Month 6 complications	Hypotony	0 (0.0)	1 (0.8)	1 (0.7)	1.00
	Suprachoroidal hemorrhage	0 (0.0)	8 (6.2)	8 (5.5)	0.599
	Tube erosions	1 (6.3)	2 (1.5)	3 (2.1)	0.269
	Endophthalmitis	0 (0.0)	0 (0.0)	0 (0.0)	–
Final visit visual acuity	Log MAR	2.41 ± 0.8	1.93 ± 1.1	1.98 ± 1.0	0.043
	Snellen median	HM	CF	CF	
	Snellen range	20/100–NLP	20/25–NLP	20/25–NLP	
Final visit IOP, mm Hg		16.1 ± 7.2	16.4 ± 8.3	16.3 ± 8.2	0.916
Final visit number of medications		1.7 ± 1.3	2.1 ± 1.6	2.1 ± 1.5	0.262
Final visit lens status	+1–2 Cataract	5 (31.3)	34 (26.2)	39 (26.7)	0.463
	+3–4 Cataract	3 (18.8)	12 (9.2)	15 (10.3)	
	Pseudophakia	7 (43.8)	80 (61.5)	87 (59.6)	
	Aphakia	1 (6.3)	4 (3.1)	5 (3.4)	

AGI, average gross income; Log MAR, logarithm of the minimum angle of resolution; IOP, intraocular pressure; LP, light perception; CF, counting fingers; HM, hand motion; NLP, no light perception
Parentheses denote percentages

Fig. 2: Progression to severe vision loss over time in the lower and higher average growth income (AGI) groups

was an improvement from their baseline (70.0%) but did not reach significance ($p = 0.248$). In comparing vision loss between the two groups, severe vision loss was greater in the lower-income group compared with the higher-income group at month 6 (81.3 vs 58.5%, respectively) and month 12 (87.5 vs 64.6%, respectively) but this difference was not statistically significant (Fig. 2). The disparities in severe vision loss were unlikely to be due to differences in lens status, as this was similar between the two groups at month 6 ($p = 0.426$) and the most recent visit ($p = 0.463$). Additionally, at postoperative month 6, 34 (23.3%) patients met the failure criteria, with no difference between income groups ($p = 0.649$). Reasons for failure were also similar between income groups ($p = 0.237$), with IOP >21 mm Hg the most common reason (67.6%) followed by loss of light perception (17.6%). Reoperation for glaucoma (second tube shunt or cyclophotocoagulation) at month 6 was required in one case in the lower-income group and three cases in the higher-income group with no significant difference ($p = 0.375$). Serious postoperative complications within 6 months postoperatively including hypotony ($p = 1.00$), suprachoroidal hemorrhage ($p = 0.599$), and tube erosions ($p = 0.269$) were also similar between the two groups, with no endophthalmitis in either group.

No difference in the IOP or medication use was detected between the higher- and lower-income groups at postoperative month 6 or the most recent visit ($p > 0.05$ for both). Both groups experienced a significant reduction in the IOP and medication number at postoperative month 6 and most recent visits. The lower-income group experienced an IOP reduction from baseline to postoperative month 6 (41.1 ± 12.4 vs 16.0 ± 6.1 mm Hg; $p < 0.001$), which was maintained at the most recent visit (41.1 ± 12.4 vs 16.1 ± 7.2 mm Hg; $p < 0.001$). The lower-income group's medication use was also reduced from baseline to postoperative month 6 (3.1 ± 1.0 vs 1.5 ± 1.3; $p < 0.001$), which was maintained at the most recent visit (3.1 ± 1.0 vs 1.7 ± 1.3; $p = 0.002$). The higher-income group experienced an IOP reduction from baseline to postoperative month 6 (39.9 ± 11.4 vs 16.8 ± 7.4 mm Hg; $p < 0.001$), which was maintained at the most recent visit (39.9 ± 11.4 vs 16.4 ± 8.3 mm Hg; $p < 0.001$). The higher-income group's medication use was also reduced from baseline to postoperative month 6 (3.4 ± 0.8 vs 2.0 ± 1.4; $p < 0.001$), which was maintained at the most recent visit (3.4 ± 0.8 vs 2.1 ± 1.6; $p < 0.001$).

DISCUSSION

Higher burdens of illness, disability, and mortality have been associated with lower socioeconomic status across the medical specialties.[7–12] The ophthalmic literature on the association between sociodemographic and economic factors and clinical presentation,[18,21,22] surgical outcomes,[17] and adherence to treatment is limited.[23,24] Our study analyzed a possible relationship between income and outcomes after surgery for NVG and found that despite similar preoperative characteristics in the two groups, those with lower income had significantly worse VA at postoperative month 6 and at their most recent visit.

To our knowledge, ours is the first study to investigate the association between sociodemographic and economic factors and surgical outcomes in NVG. Preoperative severe vision loss was dominant in both groups (75.0 and 70.0% in the lower- and higher-income groups, respectively, $p = 0.679$). However, the higher-income group experienced significant improvement in VA by postoperative month 6, while those in the lower-income group had increasingly larger proportions of severe vision loss over time. The potential reasons for these disparate outcomes are many. First, reversible causes of poor vision (e.g., corneal edema) before surgery may have led to decreased VA in the higher income group. Initial severe vision loss may have been due to reversible and irreversible causes including corneal edema, macular edema and/or ischemia, vitreous hemorrhage, and glaucoma. It is possible that the higher income group had more reversible causes of visual loss as their VA improved over the course of the study. Of note, the presence of cataracts at all time points was similar between the two groups, making it unlikely that lens opacity was more likely to be the etiology of worsening vision.

Additionally, the lower-income group may have had more severe retinal pathology at baseline or may have presented later in the course of disease with significant optic nerve damage and/or retinal ischemia. Our tertiary care center often receives urgent referrals for NVG patients from outside practices where patients may have initially presented, making it difficult to know the duration of NVG and retinal pathology, both of which may have had an impact on final VA outcomes. Poor outcomes may have been associated with more advanced presentation. Moreover, while both groups received similar perioperative retinal treatment (PRP or intravitreal injection within 2 weeks of surgery), it is possible that the lower-income group was not able to continue close retinal follow-up, although adherence to glaucoma visits was similar between the two groups. Notably, IOP reduction, 6-month surgical failure, and surgical complications were similar for both groups at all time points. Furthermore, the difference in the proportions of trainees performing surgery in each group was not statistically significant, and a prior study has shown that tube shunt surgery performed by residents are as effective and safe as surgeries performed by attendings.[25]

Furthermore, the lower-income group had a higher proportion of non-white race ($p = 0.024$), which may have affected surgical outcomes. Previous studies have suggested that the black race may be associated with a higher failure rate after trabeculectomy or tube shunt surgery, however, this is controversial.[26–30] Studies on intravitreal injections to treat proliferative diabetic retinopathy and retinal vein occlusion have suggested that African Americans and those with lower income are vulnerable to poor follow-up.[23,24] Notably, NVG is most commonly caused by these ischemic disorders,[1] which suggests that these results may be applied to NVG

patients as well. Although we included patients who had at least 6 months of follow-up with the glaucoma service after the tube shunt surgery, we did not investigate their postoperative retinal treatment schedule. Long-term adherence to repeated retinal treatment may have varied between the lower- and higher-income groups and may be reflected on their visual outcomes despite similar IOP control. Although the language may represent a barrier to healthcare access, potentially increasing the incidence of disease complications,[3] our sample showed no difference between the higher- and lower-income groups regarding the prevalence of the non-English speakers ($p = 0.265$).

Previous studies have investigated the impact of sociodemographic and economic status on ophthalmic outcomes.[17,18,21,22] Socioeconomic deprivation and African-Caribbean race have previously been associated with advanced disease on presentation, making these groups more likely to experience major vision loss from glaucoma.[21,22] Likewise, adverse economic conditions have been associated with blindness in NVG patients.[32] Moreover, studies on age-related macular degeneration have demonstrated that lower-income and non-white races are risk factors for severe vision loss at presentation.[18] Similarly, these are risk factors for the fovea-off presentation of rhegmatogenous retinal detachment, subsequent higher risk of reoperation, and worse postoperative VA.[17] Furthermore, a systematic review of studies that evaluated major acquired causes of visual loss (including cataract, diabetic eye disease, glaucoma, age-related macular degeneration, and ocular trauma) reported a higher risk of vision loss between these disease entities and socioeconomic deprivation.[33] While the disease process studied in our report is distinct from prior studies on income and health outcomes, a trend of worse VA outcomes in those with a lower income is consistent across the literature. Our findings suggest that NVG patients are also subject to these unfortunate associations between socioeconomic status and ocular health.

This study is not without limitations. These include its retrospective design and lack of information about diabetic control (as tight glycemic control in diabetic patients slows the progression of diabetic retinopathy with subsequent NVG[34]), and the inclusion of both Baerveldt glaucoma implants and Ahmed glaucoma valves. Additionally, this study, similar to those previously published,[17,18,23,24] used Internal Revenue Service data to calculate income, as opposed to patients' reports of income. Additionally, as we were comparing 10% of the sample to the remaining 90%, sample sizes were not balanced between the groups, which may have limited our ability to detect differences. Strengths include a considerable sample size given the subject matter and inclusion of consecutive patients.

Conclusion

To our knowledge, this is the first study to investigate an association between sociodemographic and economic factors and surgical outcomes in NVG. Our findings suggest that patients from neighborhoods with an average income near the United States poverty line are at higher risk of worse VA outcomes following tube shunt surgery for NVG than patients from more affluent neighborhoods. We further demonstrate that sociodemographic and economic inequalities are associated with health outcomes. Additional study on this potential association is warranted and may help guide clinicians in counseling patients and provide further insight regarding reasons for worse visual outcomes in the most vulnerable populations.

Clinical Significance

To our knowledge, this is the first study to investigate an association between sociodemographic and economic factors and surgical outcomes in NVG. This investigation demonstrated the potential relationship between low income and poor visual outcomes in NVG.

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Supplementary Table 1: Progression of severe vision loss in the lower and higher average gross income groups at month 6 and final visits compared to baseline

	Preoperative severe vision loss	Month 6 severe vision loss	Final severe vision loss
Lower AGI group	12 (75)	13 (81.3)	14 (87.5)
		$p = 1.00$	$p = 0.500$
Higher AGI group	91 (70)	76 (58.5)	84 (64.6)
		$p = 0.003$	$p = 0.248$

AGI, average gross income
Parentheses denote percentages