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The Cost-Effectiveness of Glaucoma Interventions in Barbados and Ghana

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Abstract

Purpose—More than 90% of blindness worldwide exists in the developing world, but information on the social and economic burden and the cost-effectiveness of treatment in these settings is often limited or nonexistent. We demonstrate the use of computer modeling to simulate the current and future epidemiology, outcomes, and treatment of primary open-angle glaucoma in high-incidence developing world populations.

Methods—A previously validated vision model was modified to simulate the incidence progression and social and economic outcomes of glaucoma in Barbados, which was the source of epidemiology data; and Ghana, which has similar propensity for glaucoma but lower socioeconomic development. We then assessed the cost-effectiveness of hypothetical case-finding and treatment scenarios, including U.S. guideline-level care and one-time laser surgery.

Results—Barbados incurs relatively greater social and economic burden from glaucoma than Ghana. In Barbados, population screening followed by U.S. guideline levels of care appears to be highly cost-effective. Due to a younger population with higher mortality at younger ages, glaucoma appears to cause less visual impairment and blindness in Ghana than in Barbados, resulting in lower per capita disability and productivity losses. Population screening or guideline-level treatment scenarios were generally not cost-effective in Ghana, but treating self-referring patients with a hypothetical one-time laser surgery was highly cost-effective relative to WHO willingness to pay thresholds.

Conclusions—The social and economic burden of glaucoma is higher in more developed nations due to increased life expectancy, an older population age profile, and higher per capita gross domestic product. Likewise, lower mortality rates and higher per capita gross domestic product increase the relative cost-effectiveness of screening and treatment interventions intended to mitigate glaucoma burden.

Keywords

glaucoma; vision; simulation; cost effective; developing; Ghana; Barbados

Visual loss and blindness are estimated to contribute up to 8.2% of all years of life lived with a disability worldwide, and of the 161 million people who suffer from blindness due to disease, more than 90% are concentrated in the poorest parts of the developing world.¹⁻² Not

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only are citizens of developing nations disproportionately burdened with blindness, but the resulting productivity losses and care costs further tax the limited economic resources of these societies. However, policy makers in developing countries are faced with the difficult task of determining how to allocate finite blindness prevention resources to achieve the greatest long-term benefit.

For the poorest nations, infectious causes, uncorrected refractive error (URE), and untreated cataracts still cause the majority of visual impairment and blindness,³ and efforts to eliminate these conditions are likely the most cost-effective uses of vision loss prevention funds. However, it may be less clear whether and how a developing nation should address the prevention of future vision loss. As developing nations undergo epidemiological and demographic shifts, other chronic visual diseases, such as primary open-angle glaucoma (POAG), diabetic retinopathy (DR), and age-related macular degeneration (AMD), will increase in prevalence and in time will likely become the leading causes of visual loss and blindness. A paradoxical result of demographic development is that a country that focuses all of its vision care resources to successfully reduce visual loss from infection, cataract and refractive error may see the prevalence of blindness from other chronic causes increase in the future. For example, the Barbados Eye Study found glaucoma to be tied with cataract as the leading causes of vision loss. Unlike cataract and URE, visual loss from conditions such as POAG, DR, and AMD is generally not reversible and must be combated through prevention.

In this study, we demonstrate the feasibility of using simulation analysis to provide information policy makers previously lacked when determining how to shape blindness control policies in the developing world. Previous analyses have estimated existing blindness prevalence by extrapolating visual loss prevalence data and applying this to population estimates.² Our analysis builds on such work by estimating the current and future glaucoma incidence and progression in two countries (Barbados and Ghana), including the disability and economic impacts of glaucoma, the medical benefits and economic cost-effectiveness of strategies to mitigate glaucoma-attributable impairment and blindness, and the impact of uncertainty on these conclusions.

Methods

Analysis Overview

We used data from the Barbados Eye Studies to adapt an existing eye disease simulation model to the natural history of primary open angle glaucoma in a population of West African descent.⁴⁻⁵ Using demographic and economic data, we then evaluated the impact on visual loss, utility, disability, medical costs, and productivity losses of hypothetical interventions to treat glaucoma in Barbados. We then used the model to produce similar estimates for Ghana, whose population exhibits similar age-specific prevalence and may have similar genetic predisposition to glaucoma development, but has differing demographic and economic conditions.⁶⁻⁸

Current-year epidemiologic and socioeconomic burden estimates were derived by simulating the current population cross-section from birth until present. Cost-effectiveness estimates were based on simulating the current 40-year-old cohort from present until death or age 100. Outcomes were reported as incremental costs per disability-adjusted life year (DALY) gained, and productivity impacts. We present all costs in 2005 U.S. dollars and discount all outcomes to the current year with a 3% annual rate. We considered interventions to be highly cost-effective when their cost per DALY is less than or equal to the respective nation's per capita gross domestic product (GDP).⁹

Model Description

The model's glaucoma module is described in detail in Rein et al. (2009).¹⁰ Briefly, the model simulated glaucoma natural history in 3 parts: incidence, progression, and field loss. Incident glaucoma was defined as the emergence of a visual field decrement of −4 decibels (dBs) in one (75% of patients) or both (25% of patients) eyes. For this analysis, incidence rates of glaucoma were based on observed 4-year incidence rates by age and gender observed in Barbados.⁵ Individuals with glaucoma experienced a subsequent annual risk of visual field loss progression in each eye, which varied based on individual characteristics, such as age, ocular pressure, and progression history.¹¹ If an individual experienced glaucoma progression, the quantity of field lost measured in dBs of mean deviation (MD) from normal was randomly drawn from a density function derived from reported visual field degradation rates.¹¹⁻¹² Table 1 lists major model parameters. Table 2 details major assumptions we employ in the model structure.

Categories of Impairment and Disability Values

Empirical evidence equating visual field decrements to visual impairment categories and utility or disability values are very limited. We previously developed a process whereby we equated MD of visual field loss measured in dBs to their analogous Snellen acuity scale based on total perceived luminance.²² That paper conservatively estimated that an MD of −16 dBs in the better-seeing eye was analogous to the utility losses of World Health Organization (WHO)-defined visual impairment from acuity, and −26 dBs was analogous to the utility losses of WHO-defined blindness. For the purposes of this paper, we replace the U.S.-based utility losses with WHO-defined DALY values. Based on this, patients with an MD of −26 dBs or worse in the better seeing eye were assigned DALY values of 0.6, whereas patients with an MD of −16 to −25 dBs in the better seeing eye were assigned WHO country-specific DALY values of 0.244 in Barbados and 0.282 in Ghana.³

Costs

Nonpharmacologic medical costs included in the model were based on U.S. medical costs adjusted to represent costs in the target countries. We adjusted the “work” portion of the U.S. Current Procedural Terminology (CPT) cost for each country using country-specific primary hospital costs.²³⁻²⁴ To capture fixed capital costs, we used the U.S. non-facility CPT practice expense without adjustment.

Prescription costs were based on purchasing prices published in the International Drug Price Indicator Guide.²⁵ Missing prices were set based on the average of all listed prices for buyers in the same WHO region. No purchasing contracts were listed for alpha-2 agonists, so we estimated a price by discounting the 2005 U.S. average wholesale price (AWP) by the average difference between the target countries' prices and U.S. AWP for the other drugs.²⁶

Societal Costs

WHO states that economic evaluations should reflect costs and benefits of an intervention borne by all sectors of society.²⁷ In conformance with this recommendation, we estimated the non-medical costs of productivity losses, informal care costs for those with vision loss, and screening participation costs.

We estimated productivity losses using a similar methodology as a previous economic evaluation of a blindness prevention program in a developing nation context.²⁸ As in that study, we estimated that individual productivity was equal to growth-indexed real per capita GDP allocated across the population aged 15 or older with individuals aged 15 through 64 assigned a full unit of productivity and individuals aged 65 or older assigned a half unit of

productivity. We calculated visual loss-attributable productivity losses by multiplying individuals' annual expected production value by one-half of their DALY loss value.

We assigned informal care costs to each individual with WHO-defined blindness equal to one-tenth of the productivity of an individual aged 15 to 64.²⁸ To ensure conservative results, and because blindness likely disproportionately affects the poorer segments of society, we based per capita GDP on the mean incomes of the lower 90% of earners.²⁹⁻³⁰ We report productivity impacts separately from our cost per DALY estimates. We estimated program participation costs as the average daily wage rate of those aged 15 to 64 as calculated above.

Case-Finding and Diagnosis Scenarios

We tested 3 hypothetical case-finding or screening scenarios roughly corresponding to ideal case identification, syndromic self-referral, and screening intervention case finding, as summarized in Table 3. In the ideal identification scenario, patients were assumed to self-refer to care in the year following incident glaucomatous field loss of -4 dBs in either eye. In the syndromic self-referral scenario, patients self-refer to care when they develop an MD of -16 dBs in either eye, an analogous visual field decrement to visual impairment acuity losses.²² The screening intervention scenario assumes no patient self-referral. Cases may only be diagnosed during periodic universal ophthalmologic screenings scheduled at ages 45, 55, 65, 75, and 85. For all scenarios, diagnosis is defined as an MD of -4 dBs or greater in either eye identified using initial identification via ophthalmoscopy and confirmation with threshold perimetry. Diagnostic sensitivity and specificity increased with the severity of visual field loss.¹⁹

Medical Treatment Scenarios

For each case-finding/diagnosis scenario, we tested 2 hypothetical medical treatment scenarios: a full recommended treatment regimen and a hypothetical one-time treatment scenario. The full recommended treatment scenario is patterned on the American Academy of Ophthalmology's preferred practice patterns.³¹ The specification of this regimen (described previously¹⁰) includes continued care for the duration of a patient's life with a sequence of pharmacologic and surgical procedures. Advancement through the sequence is triggered by glaucoma progression, failure of treatment to control patient intraocular pressure, or patient intolerance to medication.

The second treatment scenario is a hypothetical low-cost intervention that calls for a single laser trabeculoplasty procedure and its associated examination and testing procedures upon diagnosis of glaucoma, but includes no ongoing follow-up or repeat care. Treatment was modeled to decrease both the probability of progression and the amount of visual field when progression occurred with an efficacy observed in the Early Manifest Glaucoma Trial (EMGT).¹¹ We selected these data to be conservative about the possible benefits of treatment in the developing world. The EMGT observed lower rates of treatment efficacy than the other major study of treatment efficacy, the Collaborative Initial Glaucoma Treatment Study (CIGTS).³²

National Settings

We conducted the analysis for Barbados and Ghana. Barbados was the source of major epidemiologic and progression parameters used by the model. WHO classifies Barbados as having a Global Burden of Disease (GBD) level "B," indicating low mortality strata. Ghana was chosen to demonstrate the extrapolative utility of the model. The population of Ghana may be similar to Barbados in its genetic predisposition to glaucoma but has widely

different economic and demographic characteristics.⁶ Ghana exhibits much higher mortality rates (WHO GBD level D) and much lower GDP per capita than Barbados.

Our study used age and gender distributions based on population pyramids published by the U.S. Census Bureau.³³ Future birth rates were extrapolated based on the current population under age 5. Mortality rates were calculated from WHO life tables for each country.³⁴ Per capita GDP and income distribution metrics were identified from United Nations Human Development Program data.³⁰ Major country-specific parameters are listed in Table 4.

Validation

We validated the model according to recommended standards outlined by the International Society for Pharmacoeconomics and Outcomes Research Task Force.³⁷ Earlier manuscripts describe the model's validity in reproducing rates of visual impairment and blindness in the United States.¹⁰ For this analysis, we tested the internal validity of the model by assessing its ability to recreate the incidence data from the Barbados Eye Studies (BES) used to create the model. We assessed external validity of the model by comparing model outcomes to BES data on age-specific glaucoma prevalence and visual loss, which were not directly used in the model.

Sensitivity Analysis

We previously performed sensitivity analyses on many of the underlying parameters of the glaucoma model.¹⁰ For this analysis, we performed sensitivity analyses to explore the impact of medical costs, reduced glaucoma incidence, substitution of quality-adjusted life years (QALYs) for DALYs, treatment efficacy, and changes in the discount rate.

Results

Validation

The model demonstrated internal validity by exactly recreating the incidence rates of the BES incidence data used to create it.⁵ The BES reported prevalence of glaucoma separately from incidence, and the two measures do not reconcile.⁴ Based on WHO life table mortality rates, published BES incidence rates predict higher overall and age-specific prevalence rates than the BES observed. Consequently, our model also predicts higher prevalence of glaucoma (9.6%) than was reported by the BES (6.8%). Some of this difference is accounted for by the higher mean age of the model's population (75.9 years) versus the mean age of the BES prevalence study (59 years)—for example, the model predicts 6.0% prevalence for patients at age 59.

We considered but ultimately rejected 2 options to calibrate the model to match the BES observed prevalence. One option was to disregard the incidence data and instead estimate lower incidence rates such that the model would recreate observed prevalence rates based on the model's age distribution. We also considered using higher mortality rates than are included in the WHO life tables. Ultimately, we decided against altering either the glaucoma incidence or the WHO mortality data, and thus the model results are based on higher overall glaucoma prevalence than was reported by the BES. We investigated the effects of this decision and found that while both calibration methods slightly decreased the cost-effectiveness of all interventions, none changed enough to alter the conclusions of the paper.

Although the model may predict higher glaucoma prevalence than was found in the BES, it nonetheless predicts lower levels of visual impairment and blindness.³⁸ The BES found 0.51% and 1.71% prevalence of glaucoma-attributable blindness and visual impairment, respectively. The model finds similar but lower prevalence rates of blindness (0.45%) and

visual impairment (1.23%). There are several reasons why the model could predict lower levels of visual impairment despite the higher levels of glaucoma prevalence. One explanation could be that we do not employ directly comparable definitions of glaucoma-attributable visual loss; the BES assigned visual status only on the basis of acuity, whereas we used visual field. Also, the algorithm we use to assign acuity-based visual loss categories to visual field decrements is intentionally conservative; mild visual impairment is assigned based on a threshold MD of -16 dBs. Our model would match BES visual impairment prevalence if we defined visual loss at a threshold MD of -12 dBs.

Burden of Illness

For the Barbados population aged 40 or older, we predicted a 2005 prevalence rate of glaucoma of 9.6%, a prevalence rate of glaucoma-attributable WHO-defined visual impairment of 1.23%, and a prevalence rate of glaucoma-attributable WHO-defined blindness of 0.45% (Table 5). These prevalence rates predicted that more than 8,700 Barbadians had glaucoma, of which about 1,122 suffered from visual impairment while about 414 were blind due to their glaucoma. We estimated that glaucoma-attributable visual loss resulted in 522 total DALYs lost and nearly \$4.6 million in productivity losses in 2005.

For the Ghanaian population aged 40 or older, we predicted a 2005 prevalence rate of glaucoma of 6.1%. We estimated the prevalence rates of glaucoma-attributable WHO-defined visual impairment and blindness at 0.5% and 0.12%, respectively. In 2005, we estimate that 242,000 persons had glaucoma, which resulted in 19,700 persons with visual impairment and 4,800 blind. This glaucoma-attributable visual loss resulted in over 8,400 DALYs lost and \$21 million in productivity losses.

Cost-Effectiveness of Interventions to Treat Glaucoma

In Barbados, immediate treatment upon incidence compared to no treatment results in a cost per DALY of \$7,728 for guideline-recommended care and \$1,528 for laser therapy (Table 6). In Ghana for the same scenario, the cost-effectiveness was \$6,896 and \$1,771 per DALY. For the scenario that evaluated the cost-effectiveness under an assumption of treatment following syndromic referral compared to no treatment, in Barbados the cost per DALY was \$4,690 for guideline-recommended care and \$1,272 for laser therapy. In Ghana for the same scenario, the cost-effectiveness was \$3,947 and \$1,407 per DALY for guideline-recommended care and laser therapy, respectively. Finally, for the scenario that evaluated the cost-effectiveness under an assumption of treatment following a universal screening program compared to no treatment, in Barbados the cost per DALY was \$12,108 for guideline-recommended care and \$6,632 for laser therapy. In Ghana for the same scenario, the cost-effectiveness was \$13,504 and \$9,808, respectively, per DALY gained.

The interpretation of the relative cost-effectiveness of interventions is complicated by the lack of consensus guidelines on the maximum willingness to pay for each DALY gained. WHO Commission on Macroeconomics and Health and the WHO CHOICE program have developed guidelines that specify the use of a nation's per capita GDP to set cost-effectiveness thresholds.³⁹ Although these guidelines are controversial and lack an empirical basis, they nonetheless provide a useful metric for observing the possible differences in cost-effectiveness of an intervention across different developing nations. Based on these guidelines, interventions that cost less than three times per capita GDP per DALY gained are likely to be cost-effective, and interventions that cost less than per capita GDP per each DALY gained are highly cost-effective. In U.S. dollars, the per capita GDP is \$15,720 in Barbados and \$2,240 in Ghana.²⁹ Thus, in Barbados we found all intervention scenarios to be highly cost-effective based on the WHO willingness-to-pay thresholds. In Ghana, only the hypothetical one-time laser surgery interventions following self-referral were highly

cost-effective, while guideline care after syndromic referral may be cost-effective. Neither screening intervention is cost-effective, with a willingness to pay less than 4.4 (screening with laser treatment) to 6 (screening with guideline care) times per capita GDP.

The cost-effectiveness ratios above do not consider estimated productivity gains, which were substantial. In Barbados, productivity gains exceeded medical costs for all scenarios except universal screening followed by guideline care. In Ghana, productivity gains exceeded medical costs for laser surgery only interventions following self-referral.

Sensitivity Analysis

Cost-effectiveness results were highly sensitive to screening and medical costs. Substituting U.S. screening and medical costs for country-specific costs resulted in cost-effectiveness ratios nearly doubling for most laser-only scenarios and increasing by 150% for guideline care scenarios. We found that if screening costs were halved in Ghana, the universal screening with laser-only intervention would be considered cost-effective, but even with zero screening costs, universal screening followed by guideline care still resulted in a cost per DALY equal to 4 times per capita GDP. The laser-only intervention was highly sensitive to increased treatment failure rates, with cost-effectiveness ratios increasing by 50%. Increasing treatment efficacy to that identified in the CIGTS study improved the cost-effectiveness of the universal screening with laser-only intervention in Ghana to approximately three times per capita GDP. Using a 5% discount rate increased the cost-effectiveness ratio by 20% to 30%, whereas not discounting lowered the ratio by 20% to 40%.

Discussion

Cost-effective health care to reduce disease burden is of the utmost importance in all nations, but in the developing world it may be particularly important to target debilitating conditions such as visual loss that impose a significant social and economic burden on society. However, health policy makers must have detailed knowledge on the burden and the cost-effectiveness of interventions to mitigate this burden to prioritize the use of scarce health care resources. Unfortunately, much of these data are not available for developing nations, and policy must be based on inferences from data and policy in other nations that may not exhibit similar conditions. Simulation modeling is one tool that may help policy makers understand the impacts of various health policy choices, by synthesizing data from multiple sources and providing a context to help identify where data are not available and which assumptions must be made.

In this analysis, we demonstrate the use of simulation modeling to expand on known epidemiological data from a relatively wealthy developing nation to estimate the social and economic burden of disease, and we estimate the cost-effectiveness of hypothetical treatment and population screening interventions in this context. We then repeat the analysis in another nation with similar genetic propensity for disease but significantly lower social and economic development. Our results show that developmental differences play an important role in the outcomes of our analysis. Glaucoma incidence increases after age 40 and then typically progresses slowly, requiring many years before perceptible levels of visual loss accrue. Thus, in a higher mortality population, fewer individuals survive to have incident glaucoma; those who do get glaucoma are less likely to experience visual loss, and those who experience visual loss will generally live fewer years with this condition. This result indicates that the burden of glaucoma, like many other chronic conditions associated with advancing age, will likely increase as a nation undergoes demographic and economic development.

Limitations

The intent of this paper is to demonstrate the use of simulation models to estimate burden and cost-effectiveness values of hypothetical interventions in observed and unobserved populations. Due to several limitations, this study should not be interpreted as estimating the cost-effectiveness of any existing vision or glaucoma screening intervention. Limitations include those of the underlying model, which have been previously described in detail, and the data and assumptions used to apply this model to Barbados and Ghana.¹⁰ We had limited country-specific data on medical resources, practices, quality, and costs. We found good data on pharmaceutical prices for Barbados, but prices in Ghana were implied based on other purchasing costs observed in the same region. Medical costs were partially adjusted from U.S. Medicare payment rates based on hospital unit costs and may overstate actual medical costs. We assume the population of Ghana experiences age-specific glaucoma incidence rates identical to those observed in Barbados. This population exhibits high glaucoma incidence and prevalence; the social and economic burden and cost-effectiveness results in populations with lower glaucoma incidence may be substantially lower. Our interventions included in the analysis are purely hypothetical. The incident and syndromic referral case-finding scenarios do not incorporate any case-finding costs and are more efficient than actual diagnoses will likely be for the majority of cases. The screening intervention did not include any recruitment, transportation, opportunity, or program costs beyond the actual cost of a routine ophthalmologic visit. We also do not consider the possible benefit of identifying other ocular conditions in the ophthalmologic exam. Finally, the productivity estimates should be considered only a very rough measure of the potential economic costs of visual loss.

Implications

Despite these limitations, our results demonstrate that demographic development, including lower mortality rates and an older population, can greatly increase the burden imposed by glaucoma. We show that in high-incidence populations such as Barbados and Ghana, glaucoma can impose a substantial social and economic cost. Our results also demonstrate that interventions to screen and treat glaucoma may be cost-effective in developing nations with high-incidence populations. The cost-effectiveness of the interventions is greatly affected by mortality rates, but the selection of willingness-to-pay thresholds for defining cost-effectiveness has an even greater impact. Relative to thresholds commonly used in developed nations, all of the simulated interventions appear highly cost-effective, and there is not a great deal of difference in cost-effectiveness between Barbados and Ghana. However, basing the willingness-to-pay threshold on per capita GDP as advised by WHO means that interventions that are highly cost-effective in Barbados are not cost-effective in Ghana, due to Ghana's lower per capita GDP.

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Table 1Model Parameters,^{5, 11, 13-21}

Parameter	Reference #	Value	
Glaucoma Incidence Rates		Females	Males
Age 40–49	5	0.0028	0.0035
Age 50–59	5	0.0030	0.0048
Age 60–69	5	0.0066	0.0112
Age 70+	5	0.0099	0.0114
Glaucoma Progression			
Annual probability of any field losses among people with glaucoma	11	0.149	
Hazard ratio for progression if intra ocular pressure greater than 21	11	1.67	
Hazard ratio for progression if field loss in both eyes	11	1.92	
Hazard ratio for progression if field loss the same eye	11	1.46	
Hazard ratio for progression if age over 68	11	1.42	
dBs lost given any field loss occurs; min, mode, max	11, Assumption	0.2, 0.8, 3.0	
Treatment Contraindications			
Asthma prevalence, males	13	0.077	
Asthma prevalence, females	13	0.101	
Reaction to Prostaglandin analogues	14	0.1	
Reaction to Alpha-2 agonists	15	0.3	
Treatment efficacy and duration of efficacy			
Treatment effect: relative risk of progression	11	0.60	
Treatment effect: relative risk for distribution of field loss	11	0.826	
Annual failure rate of betablockers	16	0.15	
Annual failure rate of prostaglandin	16	0.17	
Annual failure rate of alpha-2 agonists	17, Assumption	0.4	
Annual failure rate of carbonic anhydrase inhibitors	16	0.2	
Annual failure rate of laser trabeculoplasty	18	0.066	
Annual failure rate of trabeculotomy	18	0.052	
Sensitivity and specificity of examinations			
Sensitivity of ophthalmoscopy, <8 dBs lost	19	0.81	
Specificity of ophthalmoscopy, <8 dBs lost	19	0.90	
Sensitivity of Automated Threshold Perimetry, <8 dBs lost	20	0.93	
Specificity of ATP, <8 dBs lost	20	0.88	
Sensitivity of ophthalmoscopy, >8 dBs lost	Assumption	1.00	
Sensitivity of ATP, >8 dBs lost	21	0.97	

Table 2**Major Assumptions.**

Model event	Assumption
Glaucoma incidence	Ghana experiences the same incidence rates as observed in Barbados
Glaucoma progression	Persons with incident glaucoma in both countries experience same progression rates as found in the United States
Visual field losses	Degrees of visual field loss based on function of progression as identified in U.S. populations
Assignment of vision loss states	Visual field is converted to World Health Organization (WHO) acuity-based visual loss states based on total perceived luminance
Assignment of disability-adjusted life years (DALYs)	Based on WHO vision loss states
Non pharmaceutical costs	Converted from U.S. CPT costs; “work” components are adjusted based on relative per capita gross domestic product (GDP _{per} ; “capitol” cost components are not converted
Productivity values	Productivity based on the mean of the lower 90% of earners Persons aged 15 to 64 assumed to have equal, constant productivity; productivity of persons aged 65 or older assumed to be half of this value
Productivity costs	Linear reduction of productivity losses based on one half of their DALY losses
Discount rate	Constant 3% discount rate on costs, productivity losses and DALYs

Table 3

Case Finding and Treatment Scenarios.

Scenarios	Description
Case Finding	
Ideal identification	Self-referral by patient upon glaucoma incidence
Syndromic self-referral	Self-referral by patient upon reaching mild visual impairment
Universal screening	Examination of entire population at ages 45, 55, 65, 75, and 85
Medical Care	
Guideline care	American Academy of Ophthalmology guideline care, pharmaceuticals and incisional and laser trabeculoplasty surgery, with ongoing follow-up
One-time laser	Hypothetical one-time laser trabeculoplasty surgery, no ongoing follow-up care

Table 4Country-specific Parameters,^{3, 23, 25, 29-30, 34-36}

Parameter	Reference #	Barbados	Ghana
Population Demographics			
Population	35	279,912	22,409,572
Population age and gender pyramid	36		
Mortality	34		
Medical Costs			
New patient, adult medical eye exam	U.S. CPT 92002, 23	\$39.58	\$37.06
New patient, comprehensive adult medical eye exam	U.S. CPT 92004, 23	\$69.78	\$65.00
Established patient, comprehensive adult medical eye exam	U.S. CPT 92012, 23	\$41.18	\$39.26
Eye exam and treatment	U.S. CPT 92014, 23	\$56.96	\$53.81
Gonioscopy	U.S. CPT 92020, 23	\$14.07	\$13.01
Automatic threshold perimetry	U.S. CPT 92083, 23	\$55.79	\$54.36
Annual cost of beta blockers	25	\$8.36	\$5.35
Annual cost of prostaglandin analogues	25	\$126.48	\$56.32
Annual cost of alpha-2 agonists	Calculated from U.S. AWP	\$147.01	\$110.05
Annual cost of topical carbonic inhibitors	25	\$156.19	\$156.19
Trabeculectomy	U.S. CPT 3x92014, 3x92020, 23	\$503.56	\$468.79
Trabecuoplasty	U.S. CPT 92014, 92083, 92285, 23	\$176.03	\$165.03
Utility and Disability Parameters			
DALY, WHO blindness	3	0.60	0.60
DALY, WHO visual impairment	3	0.244	0.282
Productivity Parameters			
GDP real growth rate	29	2.10%	1.90%
GDP per capita	29	\$15,560	\$2,240
Gini coefficient	30	0.39	–
Share of GDP of wealthiest 10%	29	–	0.30

AWP = average wholesale price, CPT = Current Procedural Terminology, DALY = disability-adjusted life year, GDP = gross domestic product, WHO = World Health Organization

Table 5
Burden Results

Population	Barbados		Ghana	
	Per Person	Total	Per Person	Total
Over 40 population	0.326	91,000	0.176	3,948,000
Glaucoma	0.096	9,000	0.061	242,000
Visually impaired	0.012	1,100	0.005	20,000
Blind	0.005	400	0.001	5,000
DALYs lost	0.006	500	0.002	8,000
Productivity lost	\$50	\$5,000,000	\$5	\$21,000,000

DALY = disability-adjusted life year

Table 6

Per Person Medical Costs, Years of Visual Loss and Blindness, and the Cost-Effectiveness of Different Intervention and Treatment Strategies for Barbados and Ghana.

BARBADOS									
Scenario	Medical Costs *	Prevalence of Visual Loss	Prevalence of Blindness	Quality-Adjusted Life Years (QALYs) *	Cost per QALY Gained *	Disability-Adjusted Life Year (DALY) *	Cost per DALY Avoided *	Productivity Gains *	
No treatment	\$0	0.010	0.006	–	–	0.064	–	–	
Diagnosis upon incidence									
Guideline care	\$413	0.003	0.000	–	–	0.010	\$7,728	\$431	
Laser only	\$50	0.005	0.003	–	–	0.031	\$1,528	\$278	
Syndromic referral									
Guideline care	\$83	0.011	0.002	–	–	0.046	\$4,690	\$164	
Laser only	\$16	0.010	0.003	–	–	0.051	\$1,272	\$115	
Universal screening									
Guideline care	\$583	0.004	0.001	–	–	0.016	\$12,108	\$379	
Laser only	\$198	0.006	0.003	–	–	0.034	\$6,632	\$242	
GHANA									
No treatment	\$0	0.162	0.073	15,987	–	0.032	–	–	
Diagnosis upon incidence									
Guideline care	\$189	0.003	0.000	16,012	\$7,493	0.004	\$6,896	\$62	
Laser only	\$31	0.005	0.003	16,004	\$1,810	0.014	\$1,771	\$42	
Syndromic referral									
Guideline care	\$29	0.168	0.017	15,991	\$6,542	0.024	\$3,947	\$20	
Laser only	\$7	0.164	0.035	15,990	\$2,268	0.027	\$1,407	\$14	
Universal screening									
Guideline care	\$328	0.051	0.005	16,012	\$12,980	0.008	\$13,504	\$44	
Laser only	\$154	0.092	0.030	16,005	\$8,702	0.016	\$9,808	\$29	

* Discounted 3% annually

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