Appendix C: THE COSTS OF SCREENING FOR OPEN-ANGLE GLAUCOMA

To fully analyze the costs and effectiveness of alternative screening methods in preventing visual disability, one must know:

- the costs of screening, diagnostic workup, and treatment,
- the effectiveness of the screening technologies in identifying established or potential cases of open-angle glaucoma (OAG), and
- the effectiveness of treatment in preventing disability in the identified cases.

None of these factors is adequately known. Some tenuous but reasonable assumptions regarding cost can be made about the cost of screening and diagnostic workup. There is a basis for estimating the effectiveness of the three screening technologies in identifying OAG (or its precursor, high intraocular pressure (IOP)), although there is great uncertainty about the estimates, especially as they apply to different settings and different examiners. Most uncertain of all is the effectiveness of treatment. Treatment is probably effective, but how effective it might be is not yet established.

Because of the tremendous uncertainties in the basic assumptions necessary to a full cost-effectiveness analysis, particularly the uncertainties regarding treatment effectiveness, the analysis forming the bulk of this appendix is limited to the comparative costs of identifying and verifying a case of manifest OAG. Following the analysis of the cost of screening for manifest OAG is a parallel analysis of the cost of screening for high IOP with tonometry.

The purpose of these analyses is to estimate the rough magnitude of the total national health care costs of screening for OAG in the over-65 population, and the number of cases of OAG or high IOP that might be detected through such a program. The analyses are structured so that these cost estimates, in turn, can be used as a basis for estimating the likely magnitude of Medicare program costs in the event of a decision to cover OAG screening for the Medicare population. OTA has reasonable confidence that the true costs of a screening program to identify OAG cases (or cases of high IOP) lie between the upper and lower bounds specified here, but there is at present no factual basis for assessing where in that range the true costs lie.

The

Table 9 describes the steps of the simple model used to estimate the number of OAG cases detected in a screening program and the average costs of detecting an OAG case. In this model, the screening program includes both the screening episode itself and the workup of all people testing positive. Three basic assumptions of the model do not vary. These are:

- the size of the overall elderly population (31 ,697,000),
- the frequency of screening (every 2 years), and
- the proportion of the population participating in the program (75 percent).

Changes in these assumptions have little effect on the average cost per OAG case detected, although they do affect the total number of cases found and the total cost of a screening program.[1] The program implications of these assumptions are described in chapter 5.

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1 Screening less frequently would have three major effects. First, total program costs would be less because fewer people would be screened each year. Second, the average severity of OAG cases detected through the screening program would be greater, because the length of time between screening visits is greater. Third, it would become more likely that cases of manifest OAG would be diagnosed due to the onset of symptoms (e. g., decreased vision), rather than being detected when a symptomatic through the screening program. This last factor does affect the average cost per case detected in the screening program, since these cases are not diagnosed as a result of the program. However, the magnitude of the effect is likely to be small unless screening is very infrequent.

Table 9--- Calculation of Estimated Cost per Confirmed Case of Open-Angle Glaucoma and Number of Cases Diagnosed

Step	Calculation	Description
1.	(population) x (utilization rate) x (screening frequency rate)	Number of people screened
2.	(prevalence or incidence) x (sensitivity of screening test)	Rate of true positive cases
3.	[1 - (prevalence or incidence)] x [1 - (specificity)]	Rate of false positive cases
4.	(STEP 2) + (STEP 3)	Proportion of all screenees testing positive and referred for followup
5.	(STEP 4) x (cost per followup visit)	Followup cost rate (followup cost averaged across all screened persons)
6.	(sTEP 5) + (cost per screening episode)	Screening cost plus followup cost rate per screened person
7.	(STEP 1) x (STEP 6)	Total cost
8.	(STEP 1) x (STEP 2)	Total number of true positive cases
9.	(STEP 7) / (STEP 8)	Cost per true confirmed positive case

SOURCE: Office of Technology Assessment, 1988.

Other variables in the model are described below.

Prevalence and Incidence

In the beginning of a screening program, relatively few cases of OAG are known; most await detection by the program. Thus, the estimated costs in the first 2 years of an every-other year program are based on the *prevalence* of OAG. OTA estimated costs based on both 2 percent and 3 percent prevalence of disease in the elderly.

In the subsequent years of a screening program, only new cases and a small, constant number of false negatives from previous screenings exist to be detected by the program. The *incidence is* thus the basis for cost estimates of an ongoing program.

A summary of OTA's calculation of the incidence of OAG in the elderly is presented in table 10. In this calculation, OTA first derived annual age-specific incidence estimates from the five-year incidence rates for ages 65-79 estimated by Podgor et al. (see ch. **2,** table 1) (94). (For example, where these researchers estimated the five-year incidence of OAG at 5 cases per thousand population for the age 65-69 cohort, OTA assumed an annual incidence of 1 cases per thousand). No OAG incidence estimates for people overage 79 exist. OTA assumed that the incidence continues to rise at an increasing rate with age and arbitrarily chose annual incidence rates of 3.4 and 5 per thousand for ages 80-84 and 85 and over, respectively. (These rates are consistent with the trend in the younger age groups.) From these age-specific incidence rates, OTA then calculated the overall incidence rate for the elderly. This rate was 2 cases per thousand per year (4 cases per thousand per screening period for the model case of every-other-year screening).

This incidence rate is likely to underestimate the true number of cases available to be detected by an ongoing screening program, for two reasons. First, the overall incidence of OAG in the elderly is likely to increase over time as the proportion of the elderly in the oldest cohorts increases. Sec-

end, the OTA model does not adequately account for the OAG cases that eluded detection in previous screening years (i. e., were false negatives) but might be detected in the current year. Thus, OTA also estimated screening costs under the assumption that, for every thousand population, 4 OAG cases per year (8 cases per screening period) exist to be detected by the screening program.

Screening Accuracy

An examiner screening for OAG would most likely use one of five possible combinations of screening technologies:

- tonometry alone;
- ophthalmoscopy alone;
- both tonometry and ophthalmoscopy, referring for workup all persons testing positive on either test (henceforth designated "tonometry/ophthalmoscopy in parallel");
- both tonometry and ophthalmoscopy, referring for workup only persons positive on both tests (henceforth designated "tonometry/ophthalmoscopy in series"); or
- perimetry alone.

The sensitivity and specificity of OAG screening depend heavily on which technology is used, how it is used, and who uses it. There are, unfortunately, very few studies of the accuracy and predictive value of OAG screening tests, and the results of those studies cannot be inferred to different examiners and different settings. OTA has thus chosen only to examine the extremes of the values presented in the literature for these technologies, recognizing that the true value is unknown and greatly depends on who performs the screening and the conditions under which they do so. Table 11 lists the high and low bounds of sensitivity and specificity for each technology that OTA used in this analysis.

Tonometry, as a test for manifest OAG, has a natural limit to accuracy because most people with high IOPs do not have manifest OAG, and many people with OAG do not have high IOP when they are screened. OTA estimated a theoretical upper limit for the accuracy of tonometry (see box B) and used this as the upper bound in the analysis.

Table 10.--Calculation of Incidence of Open-Angle Glaucoma (OAG) in the Elderly Population

Age group	Population in 1990[a]	2-year OAG incidence per thousand	Total number of cases per 2 years	Number of OAG cases per year in screened population[c]
65-69	9,996,000	2.0	19,992	7,497
70-74	8,039,000	2.8	22,509	8,441
75-79	6,260,000	4.4	27,544	10,329
80-84	4,089,000	6.8	27,805	10,427
85+	3,313,000	10.0	33,130	12,424
TOTAL	31,697,000	4.1	130,980	49,118

[a] Estimates from U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 952, Projections of the Population of the United States, by Age, Sex, and Race: 1983 to 2080 (Washington, DC: U.S. Government Printing Office, 1984).

[b] Cases per year of open-angle glaucoma in the relevant age group. Estimates for ages 65-79 from M.J. Podgor, M.C. Leske, and F. Ederer, "Incidence Estimates for Lens Changes, Macular Changes, Open-Angle Glaucoma, and Diabetic Retinopathy," Am. J. Epidemiology 118(2):206-212, August 1983. Estimates forages 80 and over are undocumented assumptions of the Office of Technology Assessment.

[c] Assumes that 75 percent of the elderly in each age group would avail themselves of the screening benefit, and that half of this group would be screened each year.

SOURCE: Office of Technology Assessment.

Table 11.--Glaucoma Screening Test Accuracy Assumptions.

	Upper bound (Low cost)		Lower bound (High cost)		Source of figures	
	Specificity	Sensitivity	Specificity	Sensitivity	Upper bound	Lower bound
Tests for Open-angle Glaucoma						
Tonometry over 21 mm Hg)	0.76	0.78	0.72	0.30	see box B	Ford et al., 1982
Ophthalmoscopy	0.84	0.97	0.72	0.64	Hoskins and Gelber, 1975	Ford et al., 1982
Tonometry + ophthalmoscopy, dual positives referred	0.64	0.99	0.52	0.75	calculated from above	calculated from above
Tonometry + ophthalmoscopy, single positives referred	0.96	0.76	0.92	0.19	calculated from above	calculated from above
Automated perimetry	0.96	0.89	0.92	0.46	Rock et al., 1972	Ford et al 1982
Tests for High Intraocular Pressure						
om over 21 mm Hg	1 °°	1 °°	°.71	0.97	absolute maximum	Bengtsson, 1972

SOURCE Office of Technology Assessment, 1988. See references for sources of selected individual figures.

Box B--- Estimation of Theoretical Upper Limits of Accuracy of Tonometry (21 mm Hg or Greater) for Identifying People with Open-Angle Glaucoma

A natural upper bound to use for the accuracy of tonometry in identifying cases of manifest OAG is the theoretical maximum accuracy of high IOP in predicting manifest OAG. Since most people with high IOP do not have manifest OAG, and many people with OAG do not have high IOP, tonometry is clearly less than 100 percent sensitive and specific when used to identify cases of manifest OAG, even if the technology itself accurately identifies all people with high IOP.

To estimate the theoretical limits to accuracy of tonometry used for this purpose, first recall that approximately 24 percent of the elderly in one study were found to have IOPs of 20 mm Hg or greater. This figure provides a maximum--probably a considerable overestimate--for the proportion of elderly people in the United States as a whole who would test positive by tonometry at the slightly higher cutoff level of 21 mm Hg.

Next, one needs to know the proportion of this group that actually has OAG (true positives). Recall from table 4 (chapter 2) that approximately 3 to 10 percent of all individuals with IOP 20 mm Hg or greater will get manifest OAG within 5 years. This group therefore represents the absolute maximum number of people with high IOPs that actually have manifest OAG already. Take the higher end of this range and assume that, at the absolute maximum, 10 percent of the elderly with high IOPs also have manifest OAG. Multiplying .10 by .24 (the proportion of elderly people with high IOPs) gives a total of .024, the maximum proportion of all elderly who have high IOPs *and* manifest OAG.

Now, recall (also from table 4, chapter 2) that less than 1 percent of all individuals with normal IOPs will get OAG within 5 years. Again, assume that 1 percent therefore represents the absolute maximum number of elderly people with normal IOP that could have manifest OAG at the time of screening. Since 76 percent of elderly people have normal IOPs, the maximum rate of false negatives is (.76)*(.01), or .0076.

Adding false negatives and true positives yields the total proportion of elderly in the population with OAG. The maximum proportion of the elderly with OAG is thus (.024)+(.0076)=.0316; the proportion without OAG is (l)-(.0316)=.9684.

Lastly, one needs to know the proportion of true negatives (i.e., people with normal IOPs and no OAG). This proportion is all negatives minus false negatives, or (.76)-(.0076)=.7524. Then, the upper bounds of tonometry (cutoff 21 mm Hg) for detecting OAG are:

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{All persons with OAG}} = \frac{.024}{.0316} = 76\%$$

$$\text{Specificity} = \frac{\text{True negatives}}{\text{All persons without OAG}} = \frac{.7524}{.9684} = 78\%$$

Cost

OTA analyzed five different potential screening settings: mass screening in community facilities (e.g., screening clinics at senior citizens' centers), and the offices of family practitioners, internists, ophthalmologists, and optometrists.

In the model, costs for services provided in offices settings are based on Medicare average allowed charges[1] for office visits and procedures. For the purpose of estimating the social costs of screening, these average allowed charges are assumed to represent real resource costs, although the extent to which this assumption is true is unknown.

The true cost of OAG screening done in physicians' or optometrists' offices depends on how much of the visit is due to the screening procedure. If screening is only one of many services performed during the visit, the cost of screening is only the cost of the screening procedure itself. If, on the other hand, the visit is made only for screening, then OAG screening must bear the entire cost of that visit. OTA thus tested two basic cost alternatives: one in which the screening cost is simply the Medicare average allowed charge for the procedure itself, and one in which the cost is the charge for a brief visit plus the charge for the screening procedure. Table 12 outlines these cost assumptions in greater detail.

Within either of these two basic assumptions, costs vary depending on who does the screening. A visit to a family practitioner, for example, costs less (on average) than a visit to an ophthalmologist. OTA used the examiner-specific charges when running the model to give the most accurate estimation of the extremes. However, *the true inter-examiner costs per case diagnosed cannot be compared with existing information.* An examiner who charges more for screening, for example, may also be more skilled, resulting in fewer false positives referred and consequent lower cost per diagnosed case overall. Since the actual relative accuracy of testing among examiners is unknown, specific inferences about which setting results in the overall lowest true costs cannot be drawn.

The use of Medicare average allowed charges applies only to office settings. For community facilities, OTA relied on a cost analysis of charitable glaucoma screening programs in northern California (56). These costs underestimate true resource costs, since the programs rely in part on volunteer labor. The baseline cost from this source was assumed to apply to either tonometry or ophthalmoscopy (see table 12). The programs do not currently use perimetry for screening; OTA assumed that, as with office-based examiners, perimetry would be about twice as expensive as the baseline cost. Since it was assumed that, in offices, the cost of performing both tonometry and ophthalmoscopy would be double the cost of providing either one alone, the same assumption was made for community facilities.

Followup rates

In the model, it was assumed that all persons with a positive screening test result would be referred to an ophthalmologist for a comprehensive visit, at which the definitive diagnosis (OAG/no OAG) would be made. (For patients screened by an ophthalmologist, it was assumed that the patient would return for a confirmatory comprehensive visit). OTA tested two extreme alternative assumptions of the rate at which people referred would actually show up for the visit: a 100 percent compliance rate, in which all people show up, and a 40 percent rate. The lower bound is slightly less than that reported for a current mass screening program (85). OTA assumed that compliance was independent of whether an individual had a true or false positive result on the screening test.

1 Medicare average allowed charges are used as the basis of Medicare payments to physicians; Medicare pays a proportion of the allowed charge for all covered services. Since the most recent charge data available are from 1985, OTA updated all charges by the Medicare Economic Index for participating primary-care physicians. Medicare average allowed charges underestimate actual average physician charges, since some physicians charge more than the level allowed for Medicare payment.

Table 12.--Cost Assumptions

Service	Low-cost estimate		High cost estimate	
	Proxy measure	value	Proxy measure	value
Screening episode				
Tonometry Ophthalmoscopy	Medicare average allowed charge for serial tonometry, by specialty	$12.63 (FP) $16.52 (Int) $10.55 (Opt) $19.07 (Oph)	Medicare average allowed charge for limited visit + charge for serial tonometry, by specialty	$30.36 (FP) $39.34 (Int) $29.96 (Opt) $40.34 (Oph)
	Average screening cost in Northern California mass screening programs	$ 5 75 (Comm)	Average screening cost in Northern California mass screening program	$ 5.75 (Comm)
Tonometry + ophthalmoscopy	2 x (Medicare average allowed charge for serial tonometry, by specialty)	$25.26 (FP) $33.04 (Int) $21.10 (Opt) $38.14 (Oph)	Medicare average allowed charge for limited visit + (2 x charge for serial tonometry), by specialty	$42.99 (FP) $55.86 (Int) $40.51 (Opt) $59.41 (Oph)
	2 x (average screening cost in Northern California mass screening programs	$11 50 (Comm)	2 x (average screening cost in Northern California screening programs)	$11.50 (Comm
Automated perimetry	Medicare average allowed charge for diagnostic perimetry, by specialty	$28.59 (FP) $30.22 (Int) $23.81 (Opt) $34.38 (Oph)	Medicare average allowed charge for limited visit + charge for automated perimetry, by specialty	$46.32 (FP) $53.04 (Int) $43.22 (Opt) $55.65 (Oph)
	2 x (average screening cost in Northern California mass screening programs)	$11.50 (Comm)	2 x (average screening cost in Northern California mass screening programs)	$11.50 mm
Followup visit				
Visit to ophthalmologist	Medicare average allowed charge for a comprehensive visit + diagnostic perimetry (ophthalmologist only	$75 85	Medicare average allowed charge for a comprehensive visit + diagnostic perimetry (ophthalmologist only	$75 85

ABBREVIATIONS: FP--family practitioner; Int--internist; Opt--optometrist; Oph--ophthalmologist; mm screening in community settings

SOURCE: Office of Technology Assessment. Values for office practitioners are 1985 national average Medicare allowed charges from Health Care Financing Administration BMAD database, inflated to 1988 dollars. Values for mass screening in community settings are from P. Jamgochian, "Northern California Society to Prevent Blindness, 1984 Glaucoma Program, Cost Benefit Analysis," unpublished paper, May 1986. These values are also inflated to 1988 dollars.

Results

Number of OAG Cases Diagnosed

As shown in table 13, the number of cases that might be diagnosed annually by an every-other- year screening program range from approximately 50,000 to 340,000 cases **in initial years and from 10,000 to 90,000 cases in later years.** The actual numbers depend heavily on the true prevalence and incidence of OAG in the elderly.

In addition, the effectiveness of a screening program in identifying cases depends on the sensitivity of the screening procedure in whatever setting it is used. Perimetry and tonometry/opthalmoscopy in parallel (anyone testing positive on either test referred for follow up) are equal in their potential to detect a maximum number of cases. Tonometry/ophthalmoscopy in series is likely to detect the least number of cases under anyone set of assumptions. This result leads to the conclusion that, while tonometry and ophthalmoscopy used in combination have the potential to be highly effective in identifying previously unknown cases of OAG, maximum effectiveness is likely to be achieved only if all persons testing positive on either test are referred for followup.

cost

Tables 14 and 15 set out the high and low estimates of the model for total screening program costs and for average cost per case of manifest OAG detected, respectively, in the initial years of a screening program. Tables 16 and 17 present the same information for subsequent years. In the tables, setting-specific charges were used, resulting in five double columns for the five settings. In each double column, the low-cost estimate assumes:

- 100 percent followup rate for people with positive tests,
- maximum test accuracy for the respective screening procedure,
- high incidence (4 per thousand per year) or prevalence (3 percent), and
- screening episode costs that include only a procedure-specific charge.

The high-cost estimate assumes:

- *40* percent followup rate for people with positive tests,
- minimum test accuracy for the respective screening procedure,
- low incidence (2 per thousand per year) or prevalence (2 percent), and
- screening episode costs that include a visit charge as well as a procedure-specific charge.

Table 13--- Number of Open-Angle Glaucoma Cases Diagnosed Under Extreme Assumptions of Test Accuracy and Followup Rates

	Low-cost model: 100% followup, high prevalence/incidence, high test accuracy		High-cost model: 40% followup, low prevalence/incidence, low test accuracy	
Technology	Initial years	Later years	Initial years	Later years
Tonometry	271,000	72,300	68,500	13,700
Ophthalmoscopy	300,000	80,000	68,500	13,700
Tonometry/ophthalmoscopy in series	228,000	60,700	49,300	9,900
Tonometry/ophthalmoscopy in parallel	343,000	91,400	87,600	17,500
Perimetry	342,000	91,300	87,500	17,500

SOURCE : Office of Technology Assessment, 1988.

Table 14--- High and Low Bounds[a] of Total Costs of Screening and Confirmatory Followup for Open-Angle Glaucoma in Initial Years of a Screening Program (In millions of dollars)

Technology	Family Practice		Internist		Optometrist		Ophthalmologist		Community Facility[b]	
	Low	High	Low	High	Low	High	Low	High	"Low"	"High"
Tonometry	$363	$613	$409	$720	$338	%09	$440	$732	$700	$321
Ophthalmoscopy	(276)[c]	493	(276)[c]	600	(276)[c]	489	276	612	403	201
Tonometry/ophthalmoscopy in series	(476)[c]	604	(476)[c]	757	(476)[c]	574	476	799	371	229
Tonometry/ophthalmoscopy in parallel	(692)[c]	803	(692)[c]	956	(692)[c]	774	692	998	868	429
Perimetry	462	748	481	828	405	711	531	859	634	334

[a] High bound assumes lowest relevant reported sensitivities and specificities of the respective screening procedure, 40% followup rate for positive cases referred, prevalence rate of 2 percent per year, and screening episode costs that include both visit and procedure-specific charges (for office settings). Low bound assumes highest relevant reported sensitivities and specificities of the respective screening procedure, 100% followup rate for positive cases referral, prevalence rate of 3 per thousand per year, and b screening episode costs that include only procedure-specific charges (for office settings).

High and low bounds for community facilities vary only by assumptions regarding followup rates and incidence rates assumed; costs per screening episode and test specificities and sensitivities did not vary. Because of this, the average per-case cost varies little between the bounds, but the total number of cases varies drastically. Thus, unlike the other settings, the model variant producing the most number of cases diagnosed ("low" variant) actually produces much higher total costs than does the model variant producing the least number of cases ("high").

[c] For procedures involving ophthalmoscopy, OTA assumed that only very experienced ophthalmologists could attain the levels of sensitivity and specificity used for the low bound. Thus, despite the fact that ophthalmologists' charges for ophthalmoscopy are higher than charges of other professionals, OTA assumed that other specialties could perform the procedure no less cheaply overall than could opthalmologists. The lowest cost per case found for ophthalmologists was thus assumed to be also the lowest attainable cost per case for any other profession.

SOURCE: Office of Technology Assessment, 1988.

Table 15.--High and Low Bounds[a] of Cost Per Confirmed Case of Open-Angle Glaucoma in Initial Years of a Screening Program

Technology	Family Practice		Internist		Optometrist		Ophthalmologist		Community Facility[b]	
	Lou	High	Lou	High	Lou	High	Low	High	"Low"	"High"
Tonometry	$1,300	$9,000	$1,500	$10,500	$1,200	$8,900	$1,600	$10,700	$2,700	$4,700
Ophthalmoscopy[c]	(900)	7,200	(900)	8,800	(900)	7,100	900	8,900	1,600	2,900
Tonometry/ophthalmoscopy[c] in series	(2,100)	12,200	(2,100)	15,400	(2,100)	11,700	2,100	16,200	2,000	4,700
Tonometry/ophthalmoscopy[c] in parallel	(2,000)	9,200	(2,000)	10,900	(2,000)	8,800	2,000	11,400	2,600	4,900
Perimetry	1,300	8,600	1,400	9,500	1,200	8,100	1,600	9,800	1,900	3,800

[a] High bound assumes lowest relevant reported sensitivities and specificities of the respective screening procedure, 40% followup rate for positive cases referred, incidence rate of 2 per thousand per year, and screening episode costs that include both visit and procedure-specific charges (for office settings). Low bound assumes highest relevant reported sensitivities and specificities of the respective screening procedure, 100% followup rate for positive cases referred, incidence rate of 4 per thousand per year, and screening episode costs that include only procedure-specific charges (for office settings).

[b] High and low bounds for community facilities vary only by assumptions regarding followup rates and incidence rates assumed; costs per screening episode and test specificities and sensitivities did not vary.

[c] For procedures involving ophthalmoscopy, OTA assumed that only very experienced ophthalmologists could attain the levels of sensitivity and specificity used for the low bound. Thus, despite the fact that opthalmologists' charges for ophthalmoscopy are higher than charges of other professionals, OTA assumed that other specialties could perform the procedure no less cheaply overall than could opthalmologists. The lowest cost per case found for ophthalmologists was thus assumed to be also the lowest attainable cost per case for any other profession.

SOURCE: Office of Technology Assessment, 1988.

Table 16--- High and Low Bounds[a] of Total Costs of Screening and Confirmatory Followup for Open-Angle Glaucoma in Later Years of a Screening Program (In millions of dollars)

Technology	Family Practice		Internist		Optometrist		Ophthalmologist		Community Facility[b]	
	Low	High	Low	High	Lou	High	Lou	High	"Low"	"High"
Tonometry	$231	$613	$277	$720	$206	$609	$308	$732	$700	$321
Ophthalmoscopy	(240)[c]	491	(240)[c]	598	(240)[c]	486	240	610	396	199
Tonometry/ophthalmoscopy in series	(458)[c]	602	(458)[c]	755	(458)[c]	573	458	797	366	228
Tonometry/ophthalmoscopy in parallel	(543)[c]	802	(543)[c]	956	(543)[c]	773	543	998	866	428
Perimetry	382	746	401	826	325	709	451	857	626	333

[a] High bound assumes lowest relevant reported sensitivities and specificities of the respective screening procedure, 40% followup rate for positive cases referred, incidence rate of 2 per thousand per year, and screening episode costs that include both visit and procedure-specific charges (for office settings). Low bound assumes highest relevant reported sensitivities and specificities of the respective screening procedure, 100% followup rate for positive cases referred, incidence rate of 4 per thousand per year, and screening episode costs that include only procedure-specific charges (for office settings).

High and low bounds for community facilities vary only by assumptions regarding followup rates and incidence rates assumed; costs per screening episode and test specificities and sensitivities did not vary. Because of this, the average per-case cost varies little between the bounds, but the total number of cases varies drastically. Thus, unlike the other settings, the model variant producing the most nun-bet- of cases diagnosed ("low" variant) actually produces much higher total costs than does the model variant producing the least number of cases ("high").

[c] For procedures involving ophthalmoscopy, OTA assumed that only very experienced ophthalmologists could attain the levels of sensitivity and specificity used for the low bound. Thus, despite the fact that opthalmologists' charges for ophthalmoscopy are higher than charges of other professionals, OTA assumed that other specialties could perform the procedure no less cheaply overall than could opthalmologists. The lowest cost per case found for ophthalmologists was thus assumed to be also the lowest attainable cost per case for any other profession.

SOURCE: Office of Technology Assessment, 1988.

Table 17--- High and Low Bounds[a] of Cost Per Confirmed Case of Open-Angle Glaucoma in Later Years of a Screening Program

Technology	Family Practice		Internist		Optometrist		Ophthalmologist		Community Facility[b]	
	Low	High	Low	High	Low	High	Low	High	"Low"	"High"
Tonometry	$4,900	$44,800	$5,500	$52,600	$4,500	$44,400	$5,900	$53,500	$10,200	$23,400
Ophthalmoscopy	(3,200)[c]	35,900	(3,200)[c]	43,700	(3,200)[c]	35,500	3,200	44,500	5,800	14,500
Tonometry/ophthalmoscopy in series	(7,600)[c]	61,100	(7,600)[c]	76,600	(7,600)[c]	58,100	7,600	80,900	7,400	23,100
Tonometry/ophthalmoscopy in parallel	(7,400)[c]	45,800	(7,400)[c]	54,500	(7,400)[c]	44,100	7,400	56,900	9,900	24,400
Perimetry	4,900	42,600	5,100	47,200	4,300	40,500	5,600	49,000	7,200	19,000

[a] High bound assumes lowest relevant reported sensitivities and specificities of the respective screening procedure, 40% followup rate for positive cases referred, incidence rate of 2 per thousand per year, and screening episode costs that include both visit and procedure-specific charges (for office settings). Low bound assumes highest relevant reported sensitivities and specificities of the respective screening procedure, 100% followup rate for positive cases referred, incidence rate of 4 per thousand per year, and screening episode costs that include only procedure-specific charges (for office settings).

[b] High and low bounds for community facilities vary only by assumptions regarding followup rates and incidence rates assumed; costs per screening episode and test specificities and sensitivities did not vary.

[c] For procedures involving ophthalmoscopy, OTA assumed that only very experienced ophthalmologists could attain the levels of sensitivity and specificity used for the low bound. Thus, despite the fact that ophthalmologists' charges for ophthalmoscopy are higher than charges of other professionals, OTA assumed that other specialties could perform the procedure no less cheaply overall than could opthalmologists. The lowest cost per case found for ophthalmologists was thus assumed to be also the lowest attainable cost per case for any other profession.

SOURCE: Office of Technology Assessment, 1988.

For procedures involving ophthalmoscopy, it was assumed that only a few ophthalmologists who were glaucoma specialists might actually attain the test accuracies implicit in the lowest-cost estimate. Thus, despite the higher charges of ophthalmologists, OTA assumed that the lowest-cost estimate for procedures involving ophthalmoscopy could be no lowe r for non - ophthalmologists than for ophthalmologists.

As the tables 14 and 16 demonstrate, **total annual health care costs of a screening program would be somewhere between $200 million and $1 billion.** Clearly, the benefit derived from such a program--the number of OAG cases identified--vary greatly within these bounds. A more accurate reflection of how efficiently the program might detect cases can be expressed in the average amount of money that must be spent to identify and confirm a case of OAG. As tables 15 and 17 show, **this amount lies somewhere between approximately $1,000 and $16,000 per case of OAG detected through the program in initial years and between approximately $3,000 and $81,000 per case in later years.** The actual cost, within these ranges, depends upon the variables listed above and upon the examiner and the screening procedure used. These costs do not include the costs associated with treatment.

The wide ranges of the above estimates--nearly 30-fold, in the last case--is indicative of the uncertainty surrounding the estimates. For example, in order to know more about the relative costs of screening as performed by different examiners in different sites, one must know not only their relative charges but their relative accuracies in identifying cases when using the different screening procedures. Since almost nothing about the relative accuracies of different examiners is known, OTA can conclude only that the true costs associated with each type of examiner probably lie within the extremes above. It is not known whether, on average, screening would be cheaper if done by optometrists, ophthalmologists, or other physicians. Nor is it known which procedure would, on average, be cheapest. At best, some hypotheses can be suggested - -for example, that if both tonometry and ophthalmoscopy are performed, there may be a substantial difference in cost in some settings depending on the referral criterion. The results of OTA's model suggest that referring for followup any person testing positive on either test results in more cases found and lower per-case costs than referring only those testing positive on both. The model results also suggest that mass screening in community facilities is not necessarily the least expensive method of screening; if office-based examiners can perform screening more accurately and/or have higher followup rates, the cost per OAG case detected in these settings would be lower.

Applying the Model to Screening for High Intraocular Pressure (IOP)

The model described above to estimate the costs and yield of a screening program for manifest OAG can also be applied to a program whose goal is detecting high IOP. The population with high IOP consists primarily of people with ocular hypertension (OH) --high IOP but no other signs of OAG--but includes a minority of people who, at the confirmatory visit, would be found to have manifest OAG.

Estimating the screening program cost per confirmed case of high IOP involves uncertainties similar to those for manifest OAG screening. Both the accuracies of the tests and the settings in which they would most often be performed (and, hence, the cost of the screening episode and the type of tonometer used) are largely unknown. The precise incidence and prevalence of high IOP in the U.S. elderly population is also still uncertain.

OTA estimated the likely upper and lower bounds of the costs of a screening program to detect elderly people with high IOP using the same basic model as for manifest OAG screening. Assumptions regarding population size, utilization of the program, and frequency with which screening would occur are the same as for the OAG screening model. Again, OTA calculated the average cost per confirmed case of high IOP (i.e., all persons with high IOP at the screening episode would be referred for a confirmatory, comprehensive visit; total costs are divided by

confirmed high IOP cases to yield the average cost of detecting a case of high IOP). Costs and medical benefits occurring after the confirmatory visit were not calculated due to the uncertainty regarding the likely benefits of treatment. Tonometry was the only screening technology considered. Table 18 presents other assumptions for the high and low bounds of the estimated cost per confirmed case of high IOP and the rationale for each assumption.

OTA estimates that **a program to screen elderly people for high IOP with tonometry would cost between $100 and $1,700 per confirmed case of high IOP in initial years, and between $300 and $14,600 in later years. Total costs of such a program would likely be between $100 million and $300 million initially and between $250 million and $500 million in later years of an ongoing program.[2] Because the cost of the confirmatory visit is so great compared to the screening visit, and because high IOP is fairly common (with a large number of positive tests), the proportion of people testing positive who actually show up for the confirmatory visit is especially crucial to costs and to the number of cases identified.**

This screening program would detect between 300,000 and 3 million people with high IOP per year in initial years and between 30,000 and 350,000 per year in later years. The cases of confirmed high IOP would consist primarily of people with OH but would include a minority of individuals who had manifest OAG.

2 Here, as with a program to detect only manifest OAG, high per-case costs do not lead to proportionately high total costs, because the highest per-case costs occur when there are relatively few cases detected.

Table 18--- Assumptions for Low- and High-Cost Bounds of a Model for Estimating Costs of Screening for High Intraocular Pressure

Component	Low-cost bound	High-cost bound	Rationale
Prevalence of high IOP (21 mm Hg or more)	24%	9%	Percent of elderly with IOPs equal to or over 20 and 22 mm Hg, respectively (based on Framingham, MA data)
Incidence of high IOP (21 mm Hg or more)	3%	1%	Assume that incidence is roughly 10 percent of prevalence
Cost of screening episode	$5.75	$40.34	Low figure is per-person cost of mass screening (based on Northern California data); high figure is Medicare average allowed charge for brief visit + tonometry by internist (based on HCFA data, updated for inflation)
Cost of followup visit	$75.85	$75.85	Medicare average allowed charge for comprehensive visit + perimetry by ophthalmologist (based on HCFA data, updated for inflation)
Rate of compliance with followup visit (if positive test)	100%	40%	High figure is absolute maximum; low figure is slightly lower than the experience of the National Society to Prevent Blindness programs
Sensitivity (tonometry, cutoff 21 mm Hg)	100%	71%	High figure is absolute maximum; low figure is based on accuracy of Schiotz compared with Goldmann tonometry
Specificity (tonometry, cutoff 21 mm Hg)	100%	97%	High figure is absolute maximum; low figure is based on accuracy of Schiotz compared with Goldmann tonometry

SOURCE: Office of Technology Assessment, 1988. Data for individual assumptions from: B. Bengtsson, "Comparison of Schiotz and Goldman Tonometry in a Population," Acta Ophthalmologica 50(4):445-457, 1972; H.A. Kahn and R. C Milton, "Alternative Definitions of Open-Angle Galucoma," Arch. Ophthalmol. 98:2172-2177, 1980; P. Jamgochian, "Northern California Society to Prevent Blindness, 1984 Glaucoma Program, Cost Benefit Analysis," unpublished paper, May 1986; National Society to Prevent Blindness, "Highlights of the 1985 NSPB Sponsored Glaucoma Screening Program," unpublished paper, 1986; M.J. Podgor, M.C. Leske, and F. Ederer, "Incidence Estimates for Lens Changes, Macular Changes, Open-Angle Glaucoma, and Diabetic Retinopathy," Am. J. Epidemiology 118(2):206-212, August 1983; unpublished data from the Health Care Financing Administration BMAD database (T. Kay, HCFA, Baltimore, MD, personal communication, 1988).