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## **Is it worthwhile to conduct a randomised controlled trial of glaucoma screening in the United Kingdom?**

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## **ABSTRACT**

**Objectives** –To assess the feasibility of conducting a glaucoma screening randomised controlled trial.

**Methods-** Decision model based economic evaluation and value of information analysis. Model derived from a previous health technology assessment. Model updated in terms of structure and parameter estimates with data from surveys, interviews with the UK public and health care providers and routine sources.

**Results-** On average, across varying ages of initiating screening (age 40-60), varying glaucoma prevalence (1-5%), varying screening uptake (30-100%) and the performance of current case finding, screening was not cost-effective at a £30,000 threshold per QALY from the perspective of the UK National Health Service (NHS). The societal value of removing all uncertainty around glaucoma screening is £107 million at a threshold of £20,000 per Quality Adjusted Life Year (QALY). For informing policy decisions on glaucoma screening, reducing uncertainty surrounding the NHS and personal social care cost of sight impairment (£74 million) was of most value, followed by reducing uncertainty in test performance (£14 million) and uptake of either screening or current eye care (£8 million each).

**Conclusions-** A glaucoma screening trial in the UK is unlikely to be the best use of research resources. Further research to quantify the costs of sight impairment falling on the NHS and Personal Social services is a priority. Further development of glaucoma tests and research into strategies to promote uptake of screening or current eye care (e.g. through the use of a behavioural intervention) would be worthwhile.

## INTRODUCTION

Glaucoma, a chronic eye condition, is a leading cause of avoidable blindness in the UK and globally.<sup>1,2</sup> Open angle glaucoma is the commonest form.<sup>3</sup> Sight loss from glaucoma should be avoidable as early treatment of early glaucoma reduces the risk of sight loss,<sup>4</sup> yet in the UK around 3000 people are newly registered with sight impairment due to glaucoma per year.<sup>5</sup> Delayed detection and thus access to early treatment is the main risk factor for sight loss<sup>6,7</sup> and may be linked to areal or individual socio-economic deprivation.<sup>8-10</sup> Delayed access to treatment may occur at any stage of the referral pathway. There may be patient delay in terms of attendance for testing, process delay in terms of missed detection, or system delay leading to delayed referral for treatment.<sup>11-13</sup> The public health importance of glaucoma could indicate that a screening programme might be warranted. Before a screening policy is adopted evidence is required that the benefits of screening, namely reduced visual impairment, outweigh any harms, for example anxiety and cost.

A prior economic modelling evaluation, found that screening the UK population, selected on age alone, for glaucoma was unlikely to be cost-effective as the prevalence is too low in all age groups (screening at age 40 or 65 or 75) modelled.<sup>5,14</sup> A 'surveillance' programme targeted to higher risk groups (a sibling with glaucoma; ethnic minority groups; diabetics; or people with ocular risk factors such as raised intraocular pressure (IOP) and myopia) or those who do not normally access eye care might be worthwhile. The modelling evaluation, hereafter referred to as the glaucoma screening model, used the best data available but had acknowledged uncertainties in a number of areas e.g. how best to screen (tests and location), likely uptake of any screening programme and the effectiveness and coverage of current eye care services.

The most robust way to evaluate any proposed screening programme is a randomised controlled trial (RCT).<sup>15</sup> There are no RCTs evaluating glaucoma screening.<sup>16</sup> Any future trial is likely to be large scale and thus costly. In a recent trial platform study,<sup>17</sup> we undertook a multi-component mixed-methods approach to provide an evidence base to inform the optimal design for any future trial of glaucoma screening. We followed the Medical Research Council guidance for the development and

evaluation of complex interventions.<sup>18</sup> Our platform study consisted of two initial phases addressing specific issues– development of the screening test schedule and factors associated with motivation of the public to attend for screening. We took a systematic, theory-based approach to intervention development (identifying the evidence base, modelling process and developing outcomes) and explored the feasibility (for service providers), acceptability (for providers and users) and cost-effectiveness (for health and social services) of trial components. These individual components are published elsewhere.<sup>19-21</sup> In this paper we report the integration of their findings (revised screening test schedule, likely uptake of screening and uptake of usual care) into the glaucoma screening economic model to inform whether a glaucoma screening trial is feasible.

## **METHODS**

We used a Markov model to assess feasibility of a future glaucoma screening trial. We took the perspective that interventions compared within the model could be delivered (technical feasibility) and were acceptable (likely uptake by providers and the public) in the context of the UK National Health Service. Feasibility was judged in terms of likely value for money.

We revised the structure of the existing glaucoma screening model<sup>5, 14</sup> with the most likely cost-effective glaucoma testing schedules that might be brought to trial based on the prior Delphi survey<sup>19</sup> and views of UK National Health Service (NHS) providers.<sup>20</sup> We updated parameter estimates for screening attendance based on our theory based survey of the public to identify factors associated with intention (motivation) to attend a hypothetical eye health test. We also used data collected within the survey on attendance by the public for an eye test within the last three years to estimate uptake of the comparator pathway within the model of opportunistic case finding within current UK eye care.<sup>21</sup> Costs were reported in 2010 prices. We sought estimates of attendance at current eye care services for the risk groups (age over 50, black ethnicity, diabetes, myopia, family history of glaucoma and low socioeconomic status (SES) from the British Household Panel Survey data (BHPS)<sup>22</sup> to develop and fit the probability distributions around the mean uptake of current eye care for the general population and subgroups using the Excel© add-on Oracle© Crystal Ball. Revised utility data were

based on the EQ-5D-3 L<sup>23</sup> responses from 640 participants with ocular hypertension and glaucoma sampled from a secondary glaucoma service in the UK, Prior and colleagues submitted for publication 2013. All other parameters were as detailed in the original glaucoma-screening model.<sup>5, 14</sup> The model allowed movement between health states every year, estimated costs from a UK National Health Service (NHS) and a personal social services perspective and used the EQ-5D-3L quality of life weights to calculate Quality Adjusted Life Years (QALYS).

The base case analysis conducted from NHS perspective, considered a cohort of 40-year old males with prevalence from 1% to 5%. Gender-specific variables were not available for any of the model parameters except for mortality. We used male mortality rates in the base-case analysis, consistent with good modeling practice, as they are a conservative assumption for screening. Alternative likelihoods of attending screening (e.g. 30% to 100%) and estimated costs and QALYs over their estimated lifetime with screening occurring every ten years were included. All costs and QALYs were discounted at 3.5%. The results are presented as incremental cost effectiveness ratios (ICERs).

We conducted sensitivity analyses to identify plausible situations where screening might be considered worthwhile by varying screening start age and accuracy of glaucoma detection within current eye care services. We used alternative data for uptake of current eye care (based on the survey of the public<sup>17</sup> and BHPS data) for the whole population, for cohorts aged 50 and 60 as well as for higher risk subgroups of the adult population: those self-reported as having diabetes, sight problems in the family (excluding using spectacles) as a proxy for family history of glaucoma, and those at low household income (below £10,000 a year). Data were not available within the BHPS to investigate the impact of ethnicity or myopia on the uptake rates of current eye care by these groupings.

The effect of including Personal Social Services costs was explored in the sensitivity analysis by incorporating an annual cost of sight impairment varied between £1000 and £40,000. The upper value is in line with Personal Social Services expenditure per person with sight impairment for England for 2009-10.<sup>24</sup> Variations in cost of sight impairment were combined with variation in both prevalence rates and screening uptake to identify situations where screening might be worthwhile. We explored

the impact of increasing screening uptake because of a behavioural intervention and incorporating an additional cost for its provision. Without a behavioural intervention, glaucoma screening uptake was considered to be about 23% (based on our survey where 45% of the sample had strong intention scores (i.e. mean intention score of 7 on a 1-7 scale)<sup>21</sup> and the health behaviour literature that 50% of strong intenders will perform the intended behaviour.<sup>25</sup> We varied screening uptake from 30-100% to explore the impact of a behavioural intervention. Reflecting a simple behavioural intervention such as an invitation letter targeted to improve motivation by making it easier to attend a screening appointment to a fully tailored intervention, and thus more costly, to persuade those with low intentions to attend. The mean QALYs were expressed in UK pounds sterling by multiplying them by the willingness to pay for a QALY threshold (e.g. £30,000, see Figure 1).

We also explored whether improved uptake of current eye care (ie enhanced current eye care) would be better than enrolling in a screening programme by modifying the model structure in order to compare two current practice strategies. Two uptake rates of current eye care were compared using BHPS data: 6.5% (corresponding to the uptake rate of low income groups) and 17% (estimated uptake of eye care for people with diabetes).

All analyses incorporated probabilistic sensitivity analyses where the statistical imprecision is allowed for by sampling (e.g. 1000 times) from probability distributions attached to model mean parameter values. The uncertainty in the model parameter values has cost implications as the ‘correct’ strategy might not be chosen. In effect, if the analysis is run with alternative parameter values the choice of strategy might differ from the strategy finally adopted. The sum of the benefits forgone for not being able to make the right decision due to this uncertainty is the Expected Value of Perfect Information (EVPI), as perfect information would eliminate the possibility of making wrong decisions.<sup>26</sup> The EVPI can be compared with the cost of reducing uncertainty in the model by collecting further information. The Expected Value of Parameter Perfect Information (EVPPI) is a similar concept but corresponds to a particular parameter or group of parameters in the model. EVPPI was calculated to identify model parameters that contribute the most to the overall model decision uncertainty.<sup>26</sup> The

total EVPI and EVPPI were obtained by multiplying the EVPI and EVPPI estimated at an individual level by the number of individuals who would benefit from the intervention in a given period of time. We assumed 380,000 individuals with undiagnosed glaucoma in the UK, and an annual incidence of 11,000 new cases, <sup>5</sup> a time horizon of 10 years (representing the lifespan of the technology; in this case a specific screening strategy) and a discount rate of 3.5%.

## RESULTS

The revised model, now named the Glaucoma screening Platform Study [GPS] model, considers four possible screening strategies against a current practice comparator (no screening). The pathways modeled are specified in Box 1.

### *Box 1 Description of the pathways compared within the Economic Model*

*Glaucoma screening Platform Study (GPS)1* [Tonometry (measurement of intraocular pressure (IOP)) and optic nerve photography (ONP)]: The population to be screened are invited to a primary care setting to undergo tonometry and ONP by a technician or nurse who has received some training. Screen positives referred to hospital eye service.

*GPS11* [IOP and visual field (VF)]: As above but screening with tonometry and visual field test (perimetry). Screen positives referred to hospital eye service.

*GPS1d* [IOP + ONP]: Screening with tonometry and optic nerve photography and screen positives examined by a specialised optometrist (diagnosis). Diagnostic test positives referred to hospital eye service

*GPS11d* [IOP + VF]: Screening with tonometry and visual field test (perimetry) with further diagnostic refinement and screen positives examined by a specialised optometrist (diagnosis). Diagnostic test positives referred to hospital eye service.

*Current practice (UK NHS eye care)*: Opportunistic sight test at community optometrist with referral of suspect glaucoma to the hospital eye service.

IOP  $\geq$ 26mmHg = screen positive; IOP <26mmHg + second technology test positive = screen positive; IOP <26 mmHg+ second technology test negative = return to current eye care and re-screen cycle

The screening test schedule, based on the views of service providers in terms of practicality and equity, was screening an inception cohort age 40. The screening strategies allow for a technician as first screening contact. However, they differ in the tests performed. Glaucoma tests were either optic nerve photography (ONP) or screening mode perimetry (a measure of visual field [VF] sensitivity) with or without tonometry (a measure of intraocular pressure [IOP]). For those testing positive two pathways were explored, a diagnostic refinement step, using a specialised optometrist to examine screen positives as in the original model, or no referral refinement with screen test positives referred to a hospital based glaucoma service.<sup>20</sup>

Tables 1-2 show the updated data used in the GPS model. All other data in the model remained as for original model.<sup>5,14</sup>

**Table 1: Prevalence, incidence and progression of glaucoma**

Probability	Value	Source
Prevalence of glaucoma	1% to 5%	Assumption based on prevalence rates for general population and high prevalence sub-groups <sup>5,14</sup>
Progression to moderately severe glaucoma**	0.129	Progression data from GSM* 2007 <sup>5,14</sup>
Progression to severe glaucoma	0.048	Progression data from GSM 2007 <sup>5,14</sup>
Progression to visual impaired	0.042	Progression data from GSM 2007 <sup>5,14</sup>
Annual probability of having an eye test in current practice (not screening):		
General population (adults over 40 years old)	0.1728	Based on survey of the UK public <sup>21</sup>
General population (adults over 40 years old)	0.0741	Based on BHPS data and alternative assumptions <sup>22</sup>
Individuals with diabetes	0.1693	Based on BHPS data <sup>22</sup>
Individuals with eye problems	0.1192	Based on BHPS data <sup>22</sup>
Individuals within low income households	0.0653	Based on BHPS data <sup>22</sup>

\*GSM: Glaucoma Screening Model. BHPS: British Household Panel Survey



**Visual Field Based Glaucoma staging <sup>5</sup>	Mean Defect Score, decibels (dB)
Mild glaucoma	-0.01 to -6.00dB
Moderate glaucoma	-6.01 to -12.00 dB
Severe glaucoma	-12.01 to -20.00 dB
Visual impairment (partial sight/blind)	-20.01dB or worse

**Table 2: Data on screening tests and test performance**

Probability	Value	Source
<i>Current eye care</i>		
Optometry testing, sensitivity	0.32	GSM* 2007 <sup>5</sup>
Optometry testing, specificity	0.99	GSM 2007 <sup>5</sup>
Proportion of normal (no glaucoma) with IOP <26mmHg	0.96	GSM 2007 <sup>5</sup>
Proportion of glaucoma with IOP ≥26mmHg	0.35	GSM 2007 <sup>5</sup>
<i>Screening tests</i>		
Optic nerve photography, sensitivity	0.73	GSM 2007 <sup>5</sup>
Optic nerve photography, specificity	0.89	GSM 2007 <sup>5</sup>
Perimetry (Frequency Doubling Technology-C-20-1), sensitivity	0.79	GSM 2007 <sup>5</sup>
Perimetry (Frequency Doubling Technology -C-20-1) specificity	0.94	GSM 2007 <sup>5</sup>

GSM: Glaucoma Screening Model

**Base case analysis (inception cohort aged 40 estimated 1% glaucoma prevalence, screening every ten years and taking a NHS perspective)**

On average, screening the general population selected on age alone was not cost-effective at a £30,000 threshold (Table 3). It should be noted that as this is a population screening model we would expect a relatively small proportion of individuals to be identified with glaucoma and hence, on average for the population, only small gains in benefits.

**Table 3: Cost-effectiveness Base Case Analysis\* results**

Screening acceptance (%)	Strategy	Cost	QALYs**	ICER***
	Current Practice	£176	19.2530	
30%	GPS11d (IOP + VF)	£239	19.2537	88,908
	GPS1d (IOP + ONP)	£239	19.2536	(Dominated)
	GPS II (IOP + VF)	£266	19.2540	97,136
	GPS I (IOP + ONP)	£276	19.2539	(Dominated)
	Current Practice	£176	19.2530	
50%	GPS11d (IOP + VF)	£261	19.2539	74,408
	GPS1d (IOP + ONP)	£261	19.2538	(Dominated)
	GPS II (IOP + VF)	£304	19.2543	103,985
	GPS I (IOP + ONP)	£321	19.2541	(Dominated)
	Current Practice	£176	19.2530	
70%	GPS11d (IOP + VF)	£282	19.2541	68,718
	GPS1d (IOP + ONP)	£283	19.2540	(Dominated)
	GPS II (IOP + VF)	£342	19.2545	111,427
	GPS I (IOP + ONP)	£366	19.2544	(Dominated)

\*40 year-old inception cohort, 17% uptake of current practice, 1% glaucoma prevalence, lifetime time horizon. NHS costs. \*\*QALY- quality adjusted life years. \*\*\*ICER = Incremental Cost Effectiveness Ratio. ICERs are related to the, on average, cheapest non-dominated strategy.

### ***Sensitivity analysis***

*Screening start age and performance of current eye care-*For cohorts starting at 50 and 60 years old, ICERs were, regardless of the level of screening uptake, well above the typically accepted threshold value of £30,000. [link to online supplementary tables A1-2] Similar results were obtained when the sensitivity and specificity of case detection in current eye care were reduced to plausible minimum levels. [link to online supplementary tables B1-B2]

*Varying uptake of screening and current practice-* Using alternative assumptions about the estimated uptake of current eye care services, varying from low annual uptake 6.5% (estimated uptake of eye care for low income households) to 17% (estimated uptake of eye care for people with diabetes) based upon BHPS data, and varying the assumed uptake of screening from 50-100%, the cost-effectiveness of screening improved, although the ICER remained well above a £30,000 threshold. [link to online supplementary tables C1-2]

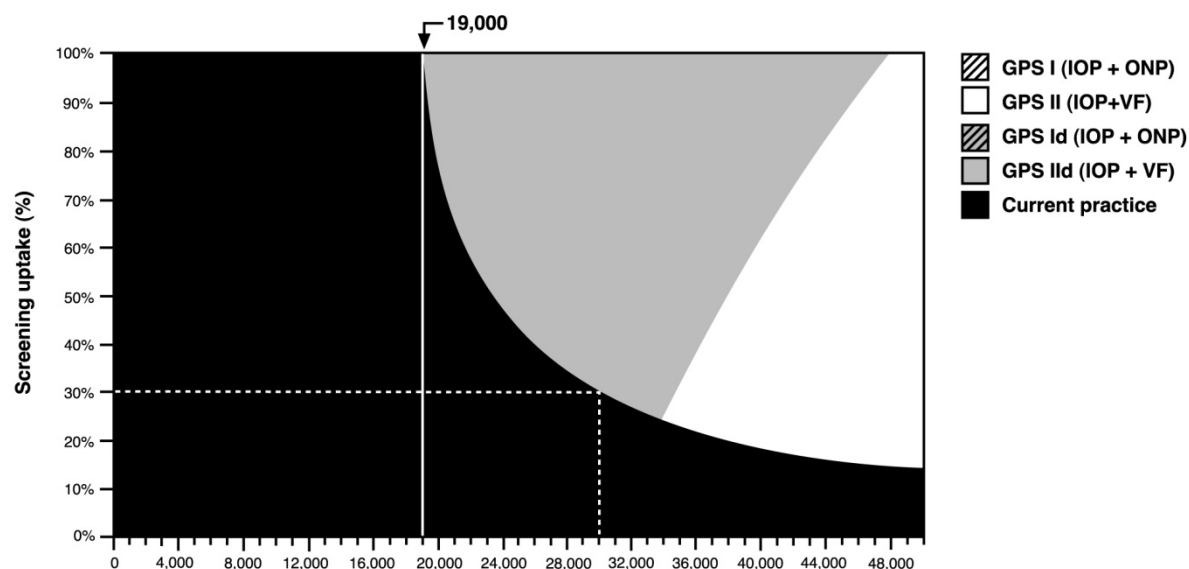
### ***Cost of sight impairment***

Figure 1 (a-c) shows the two-way sensitivity analyses results for the annual cost of sight impairment versus the percentage of screening uptake. That is, for each combination of cost of sight impairment and proportion of screening uptake, the figure shows the strategy with the highest net-benefit (e.g. willingness to pay times mean QALYs minus mean cost), assuming a £30,000 willingness to pay for a QALY.

For the illustrated cohort (inception cohort aged 50, assumed 1% glaucoma prevalence and 17% annual uptake of current practice<sup>21</sup>) none of the screening pathways would have a higher net-benefit compared with current practice, unless the annual cost of sight impairment is above £19,000. When the annual cost of sight impairment is above £30,000 screening is worthwhile if the uptake of screening is above 30%, (Figure 1a).

**Figure 1.** Strategies with the highest net-benefit (defined as £30,000 x mean QALYs minus mean costs) for alternative values of annual cost of sight impairment and percentage of screening uptake for a 50-year-old cohort. Willingness to pay is £30,000.

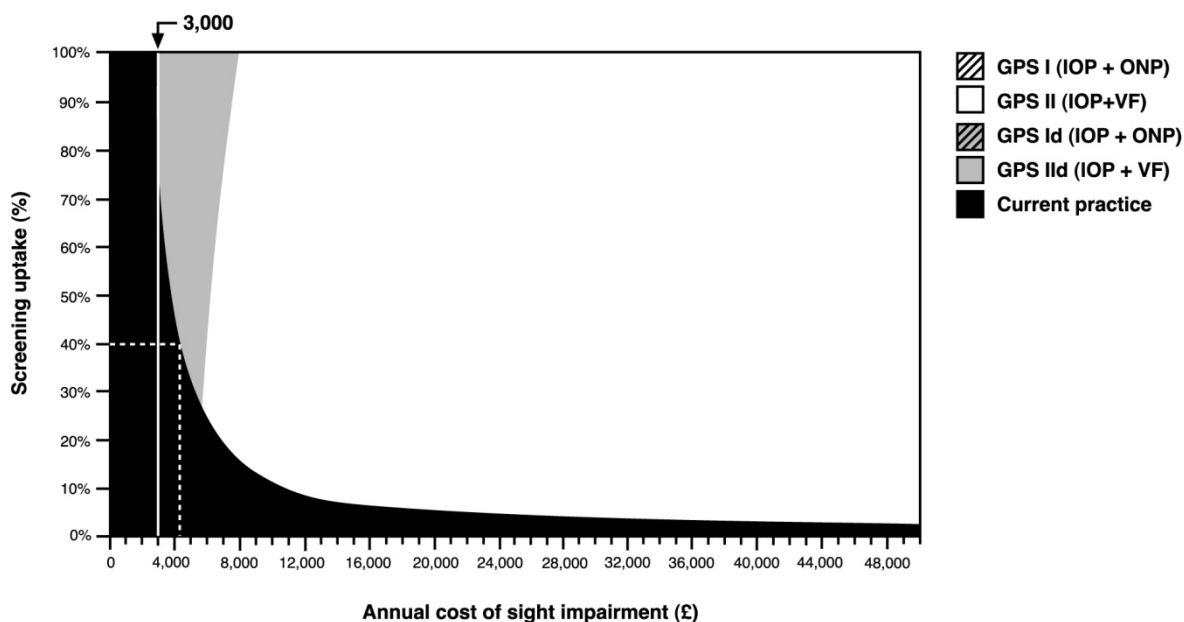
Figure 1.a) 1% Glaucoma prevalence and 17%<sup>21</sup> uptake current eye care practice.



For the range of values selected for the annual cost of sight impairment and uptake rate, only ‘current practice’, ‘GPS11d (IOP + VF)’ or ‘GPS11 (IOP + VF)’ are potentially cost-effective when society is willing to pay £30,000 per QALY. The dashed line is illustrative. The screening strategy ‘GPS11d (IOP + VF)’ has the highest net-benefit when the screening uptake is 30% and the annual cost of sight impairment is £30,000. The vertical continuous line at £19,000 cost of sight impairment illustrates that screening is not cost effective below this value, regardless of the screening uptake.

For a higher risk sub-group (assumed glaucoma prevalence of 5%) a targeted screening programme (surveillance) could be worthwhile if the annual cost of sight impairment is above £3000, (Figure 1b).

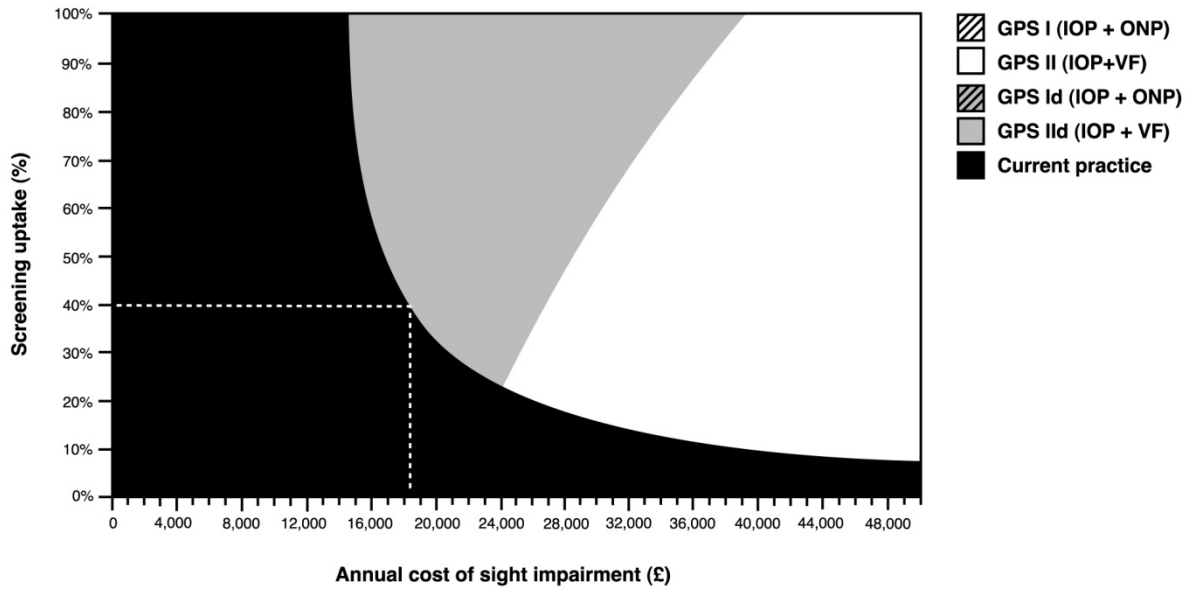
Figure 1.b) 5% glaucoma prevalence and 17%<sup>22</sup> uptake of current eye care.



Note: The dashed line is illustrative. The screening strategy ‘GPS11d (IOP + VF)’ has the highest net-benefit for screening attendance of 40% and annual cost of sight impairment just above £4,500. The vertical continuous line at £3,000 cost of sight impairment illustrates that screening by any pathway is not cost effective below this value, regardless of screening uptake.

Assuming a low uptake of current eye care (6.5% per year), as might be expected within a low income subgroup screening could be considered cost-effective if the annual cost of visual impairment is above £18,000 per year with screening uptake of 40% for a cohort with an assumed glaucoma prevalence of 1%, (Figure 1c).

Figure 1.c) 1% glaucoma prevalence rate and 6.5%<sup>22</sup> uptake of current eye care.



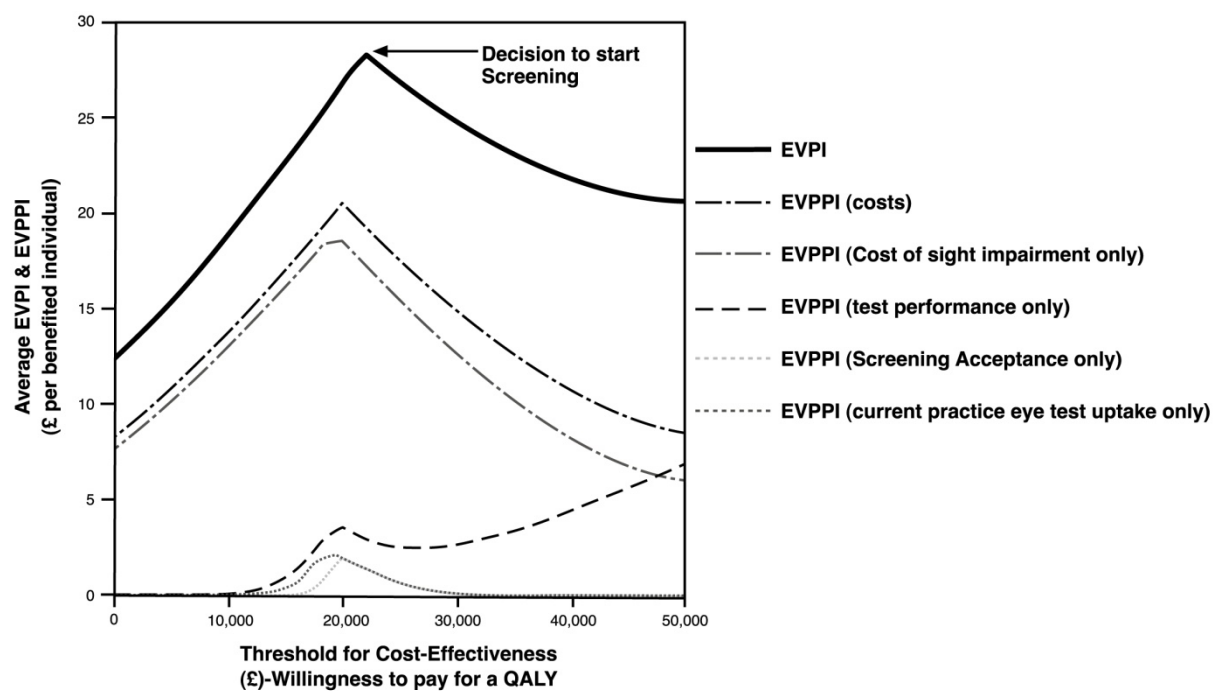
Note: The dashed line is illustrative. The screening strategy GPS IId (IOP + VF) having the highest net-benefit for screening attendance of 40% and annual cost of sight impairment above £18,000.

*Enhancing current eye care* - Increasing the uptake of current eye care for those in higher risk groups (>5% glaucoma prevalence), as opposed to a screening programme, is cost-effective when the annual cost of sight impairment is above £8000 and assuming no cost for a behavioural intervention to improve uptake. Increasing uptake rates would, however, be likely to incur costs. The cost per individual of increasing uptake would need to be <£20 with an annual cost of sight impairment per person of £20,000 for this strategy to approach cost-effectiveness. Details results are available from the authors.

The cost of sight impairment is uncertain. This uncertainty was built into the probabilistic sensitivity analysis by investigating the impact of the annual cost of visual impairment being equally likely to have any value between £1000 and £40,000 (i.e. assuming a uniform distribution) and investigating the value of removing all the imprecision around parameter estimates within the model i.e. the EVPI as well as the value of removing all uncertainty surrounding a particular (group of) parameter(s) i.e.

expected value of parameter perfect information (EVPPI). Figure 2 shows the average EVPI and EVPPI curves for a 50-year old cohort with a 5% prevalence rate of glaucoma (higher risk subgroup) and when uptake of current practice is 7.4% (described in Table 1). This situation was chosen as, based on the base case results, was the most likely scenario favouring screening. The value of removing the imprecision around the model parameter estimates is illustrated in Figure 2.

**Figure 2: Average Expected Value of Perfect Information (EVPI) and Expected Value of Parameter Perfect Information (EVPPI)\***



\*Scenario: model start age (and screening) 50 years old, prevalence rate 5%, screening every 10 years, whole population, current practice annual eye test uptake rate 7.4%, average annual cost of sight impairment £20,500. The upper and lower bounds limits for this distribution were informed by the literature,<sup>27,28</sup> assuming that NHS treatment as well as PSS cost were included. Incremental Cost Effectiveness Ratio for moving to screening (GPS1d (IOP + VF) = £21,720). The peak in EVPI corresponds to the uncertainty in the decision of changing from current practice (opportunistic case finding) to screening with a technician conducting tonometry and visual field test (perimetry) with screen positives examined by a specialised optometrist (GPS11d (IOP + VF)). EVPPI shown for selected parameters that contributed the most to decision uncertainty.

The peak in the EVPI curve corresponds to the willingness to pay for a QALY value where decision

uncertainty is at its highest (at around £20,000 WTP) and is the decision point on whether to screen or not. For a willingness to pay threshold of £20,000 for a QALY, the population EVPI is around £107 million, with the costs of sight impairment contributing the most to this decision uncertainty (EVPPI, £74 million), followed by the uncertainty due to test performance (e.g. £14 million), and screening acceptance or current practice eye uptake rate (e.g. £8 million each).

## **DISCUSSION**

We integrated new data on a feasible glaucoma-screening pathway, estimates of uptake of current eye care services, likely improvement of screening uptake by a behavioural intervention into an economic evaluation model of screening strategies for glaucoma, updating the original Glaucoma Screening Model.<sup>5</sup> Findings from the original evaluation suggested that glaucoma screening of a population selected on age is unlikely to be considered cost-effective at values for a QALY that society is typically willing to pay, but screening of high risk groups (prevalence of around 4%) might be. Glaucoma prevalence rises with age but in terms of life years to benefit from screening the optimal age for offering a screening programme is around age 50, however glaucoma prevalence for a 50-year-old cohort is around 1%.<sup>5</sup> In the revised GPS models we explored scenarios where screening might be worthwhile by varying screening uptake rate, performance and uptake of current practice. Across all the modelled scenarios the conclusion from the original evaluation is unchanged. Results were robust to all changes in the model parameter values except for the annual cost of sight impairment. When taking a wider perspective on the costs of sight impairment, findings from the two way sensitivity analysis, varying screening uptake and costs of sight impairment, suggest that assuming higher estimated costs of sight impairment screening the general population selected on age alone as opposed to surveillance of high risk groups might be worthwhile.

Data on the annual cost of sight impairment are very limited. The health costs of severe sight impairment due to glaucoma have been estimated as £800 per year (updated to 2010-2011 prices).<sup>27</sup>



These costs do not include the personal and social care costs associated with sight impairment. We accessed council data for England in an attempt to ascertain the annual personal and social cost of care for adults with sight impairment. For adults with physical disabilities, costs are estimated at £41,000 per year. These data did include estimates from people with sight loss but data were not reported separately.<sup>24</sup> The cost of sight impairment in the UK is reported by the Royal National Institute for the Blind as £12,457 per person per year.<sup>28</sup> However, these calculations include indirect costs (productivity losses), cost due to lower employment, premature mortality, as well as £8782 corresponding to burden of disease cost – the use of such figures entails some double counting as some of these effects are captured within the QALY estimates. Estimates by Mead and Hyde suggest that the cost of blindness for another chronic eye condition, age related macular degeneration, range around £8,000 (updated to 2010-2011 prices) for the first year of blindness but highlighted the limitations in the data to determine the true costs of failing eyesight.<sup>29</sup>

The purpose of updating the original glaucoma screening model was to determine if, given the newly defined screening pathways and target population, a future large-scale glaucoma screening RCT would be value for money in terms of informing policy decisions on glaucoma screening in the UK. The value of removing all uncertainty in the model was around £107 million indicating that further research on glaucoma screening might be worthwhile. The uncertainty around cost of sight impairment contributed most followed by the uncertainty around screening test performance, and the uptake of screening or current eye care services.

These findings suggest that before proceeding to a large scale RCT evaluating a glaucoma screening or surveillance programme, further research to understand and quantify the cost of sight impairment (NHS and Personal Social Services) is a priority. These data would be best collected within a well-designed cohort study, prospectively following individuals through the spectrum of visual impairment and as needs change and adaptation to sight loss occurs.

The effectiveness of any screening or surveillance programme requires that the target population attend. Our findings suggest that an evidence-informed behavioural intervention, such as a carefully worded invitation letter with a reminder or a more intensive intervention (eg tailored message, SMS reminder, buddy system) may improve attendance.<sup>17</sup>

### *Strengths and limitations*

This study used a transparent iterative approach building on a prior robust evidence synthesis and sought views of all stakeholders to inform decisions regarding glaucoma screening. We used robust qualitative and quantitative methods to provide an evidence-based recommendation for future research. It was not within the scope of this study to estimate the accuracy of screening tests or to evaluate the accuracy of current eye care services in the detection of glaucoma. We used the same estimates of performance of community optometric detection of glaucoma (current eye care) as used in the original model, based on a survey conducted by Tuck and colleagues in the late 1980s evaluating outcomes from 300,000 sight tests in community optometry. This was the largest published study on community eye care but may not now represent contemporary practice. To estimate screening test performance we used estimates from a prior evidence synthesis, but these were based on evidence from studies with heterogeneous populations and high risk of bias.

We had limited data on the uptake of current eye care services by higher risk groups, particularly by ethnic minority groups and those who might expect to have a higher uptake of current eye care, those with a family history of glaucoma. We did however use new primary data from our survey on eye testing within the last few years and used data from the British Household Panel Survey that is considered to be representative panel data on uptake of health services in the UK.

The value for information analysis can only capture those uncertainties incorporated into the economic model and is dependent on the model structure. The model did not consider the potential harms due to screening (e.g. anxiety for those with false positives) or the side effects of treatment (e.g. cataracts). While it is unlikely that these omissions would have a major impact on the model results, they are a limitation of the analysis. Finally, while the EVPI analysis constitutes a necessary condition

in determining whether further research is worthwhile it is not in itself sufficient to determine whether research should be conducted (although it can give a strong indication that further research is not worthwhile, if for example EVPI is less than the costs of conducting further research). A positive Expected Net-benefit of Sampling (ENBS) constitutes a necessary and sufficient condition to conduct further research. ENBS is the difference between the benefits of reducing uncertainty with a particular sample size study and the cost of obtaining that sample size. Unfortunately, ENBS can be obtained only under very restrictive assumptions and is often computationally prohibitive and there have been few examples where it has been used in practice to inform, for example, the sample size of a trial.<sup>30</sup> In such circumstances we believe the EVPI establishes a first step to inform the judgment that further research is potentially worthwhile.

## CONCLUSIONS

A glaucoma screening trial is currently unlikely to be the best use of research resources to inform policy decisions on screening policy in the UK. Further research to quantify the health and personal social services costs of sight impairment is recommended. Further development of glaucoma tests and an evaluation of a behavioural intervention to improve attendance for those who do not access current eye care services would be worthwhile. Our findings are UK specific, but the methods used and the modeling framework can be adapted and populated with country specific parameters.

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