**Health Economists Study Group**

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# Draft

## SCREENING OPTIONS FOR DIABETIC RETINOPATHY IN UK

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# Abstract

This paper seeks to determine the most Cost Effective option and optimal screening strategy for Diabetic Retinopathy in the United Kingdom.

The report achieves from a Markov modelling based approach using a combination of prospective data analysis, systematic literature review and subject experts.

The model was run on a diabetic cohort entering the system derived from a population of one million. Incidence and disease progression rates for diabetic retinopathy were then applied.

Three options were determined and fully costed, benefits were derived using the clinical literature the economic literature and from the cohort profiles of disease progression.
These were:

Indirect opthalmoscopy undertaken by high street optometrists.
Digital Camera (fixed) undertaken by high street optometrists.
Digital Camera mobile van.

In terms of cost effectiveness and cost utility the priority ordering of the options in terms of most cost effective to least cost effective is:

Digital Camera mobile van.
Indirect ophthalmoscopy
Digital Camera (fixed)

The conclusion as such are that

- Diabetic Retinopathy screening is a cost effective strategy for the UK.
- A key factor in implementing a successful screening strategy is the establishment of a diabetic register that has high population coverage.
- The most cost effective option for screening is using a digital system with a mobile van.
- Depending on the cost structure of digital cameras and who bears the cost of camera a mixture of vans and high street optometrist may be a viable screening solution but the evidence on this is not currently available.
- The results are sensitive to the cost of the digital camera.
- The result are sensitive to the sensitivities and specificity of the screening technologies.
- Whilst the slit lamp screening is often close in term of its cost effectiveness to the digital van there is a considerable loss in efficacy in term of sight year saved and blindness avoid in this option and hence the decision maker faces a trade off in term of cost effectiveness and efficacy.

# Objectives

To implement universal screening in the UK for Diabetic Retinopathy.

To determine the most Cost Effective option for screening for diabetic retinopathy.

# Background

Screening programmes are a common feature of the health service and in recent years programmes to detect diabetic eye disease using alternative screening tools have been tested by a range of health professionals.1-12 However there are few meaningful reports of cost-effectiveness.

## Method

Specification of the Options

The main options available for the screening of diabetic eye disease are as follows.

Ophthalmoscopy Direct or indirect
Photography using either slide or photography
Digital Camera

The options chosen for analysis were as follows
Indirect ophthalmoscopy
Digital Camera (fixed)
Digital Camera mobile van.

All the above were compared with the do nothing or null hypothesis that is no screening.

The reason for the choice of options was as follows.

The timeframe of the analysis undertaken did not allow for a randomised controlled trial to be conducted. Ophthalmoscopy is currently the most widely performed screening technique. Although photography was felt to be a powerful option, it was felt that the camera technology would be shortly superseded by the digital technology.

Not only is the choice of screening method important but the delivery setting for the technology.

A number of option are possible for the delivery of the screening method in brief these are to screen in a hospital setting, via an high street optometrist, to use GP screening or to set up a systematic mobile service such as that used in Liverpool (James 2000).

Screening is not best placed in a hospital setting. GP screening is becoming less frequent and often now undertaken only where a GP practice has a special interest not

only in diabetes but in diabetic retinopathy. Similarly the reported result for both sensitivity and specificity for GP screening are often poor (refs).

As such the three options chosen and there delivery setting were:

Indirect ophthalmoscopy
Digital Camera (fixed)
Digital Camera mobile van.

Indirect ophthalmoscopy yields both a cheap and accessible technology located in most high street optometrist hence it would have been inappropriate to suggest citing such a technology in a mobile van.

The method used was therefore one of Markov Modelling.

## Markov Modelling

Markov chain modelling allows a cyclic process to be modelled by taking a population cohort who pass through a series of health states, health technology interventions, and will experience a range of effects upon their health states. The model must have an end point, for the cohort, this is normally death. Modelling enables all assumptions and data used to be made explicit. Modelling can therefore incorporate any changes to these.

The model's data were furnished using a combination of prospective analysis, systematic literature review and expert review.

The model was based on a cohort of diabetics determined from a population of 1 million. The incidence rate for diabetes was then applied and the cohort progressed through the system in annual cycles. The cohort of diabetics was sub divided into type I, type II insulin requiring and type II non insulin requiring. The median age of developing in each sub group forms the start point, age 20 for type I and age 57 for both groups of type IIs. The number of cycles was determined from the average age of death derived from life expectancy in England 1995-96; this was 78. Thus the type I group pass through 59 cycles and the type II groups pass through 22 cycles; the cohorts are reduced in each cycle by death, the probability of which increases with age and is further increased by the additional risk of the diabetic health state. Appendix **1** presents a schematic diagram of the model in four parts.

Firstly, the cohort of diabetics is determined from the population according to the incidence of diabetes. The cohort is sub divided into type I, type II insulin requiring and type II non insulin requiring. The proportion registered and not registered is determined. Those not registered progress to the part of the model passing through health cycles with no screening (see below). Those on the register are offered screening and can decide whether or not to accept. Those who decline progress to the model passing through health cycles with no screening. Those who accept screening progress to the part of the model with health state cycles with screening.

The part of the model with health cycles with no screening pass through the following states, the probability of passing from one state to the next depends on the diabetic sub group. Initially the full cohort starts with no retinopathy, then progress according to the diabetic retinopathy sub group probability to early retinopathy, from there according to the diabetic retinopathy sub group probability to sight threatening retinopathy, from there according to the diabetic retinopathy sub group probability a proportion develop blindness. In each cycle there is a risk of death, the age specific probability of death is applied increased by an additional health state specific probability of death.

The part of the model with health cycles with annual screening pass through the same states as those with no screening. However, they experience annual screening, and if identified as having sight threatening retinopathy they are treated by laser which may abate, but not cure, their condition. This group moves into an abated sight threatening retinopathy group. No evidence was identified in the literature, or from asking ophalmologists, of how long the patient benefited from the treatment. The model currently assumes that the benefit lasts the individual's life, but such individuals are annually screened for monitoring purposes. They thus incur a cost, but no further health benefit. The same probabilities of health state progression and death as the no screening sub model are applied.

The screening part of the model divides the screened cohort into screen negative or screen positive. Those who screen negative comprise of those who do not have sight threatening retinopathy, true negatives, and those incorrectly identified as not having sight threatening retinopathy when in fact they do, false negatives. The latter group is not offered treatment, and all screen negatives return to their appropriate health state. Those who screen positive are referred to hospital. All those who screen positive but do not have sight threatening retinopathy, false positives, are correctly identified at hospital but incur a cost for consultation in addition to the cost of screening, which all who screen incur. Those with sight threatening retinopathy are provided laser treatment, the model assumes all accept, and the group is divided into those whose treatment is successful, these progress to the abated sight threatening retinopathy health state, those whose treatment is unsuccessful return to the sight threatening retinopathy health state.

Systematic Review

The systematic review was used to inform the model in a number of ways.

A structured proforma was use to abstract data on diabetic retinopathy screening from 1985 to July 2000. Data item included the cost of screening, taking both a patient and NHS and societal perspective, economic evaluations of screening, the sensitivity and specificity of screening. In addition to data on diabetic retinopathy the review was used to inform the debate on the epidemiology of diabetes and in particular the incidence and prevalence. The quality of life in diabetic eye disease treatment cost effectiveness of treatment and the lifetime cost of blindness or morbidity from visual impairment.

## Cost

Cost were quantified for each of the options specified based on the allocation of capital, staff and consumables.

In addition the treatment cost and the lifetime costs for supporting visual loss were calculated.

### Capital Cost

Cost for capital were allocated assuming that it is the NHS that bears the cost and not the independent operator i.e. the high street optometrist. All capital cost are expressed in the annual capital equivalents.

Mobile Screening

The cost for mobile screening were taken from a previous study conducted by one of the authors (James 2000) and extrapolated to apply to the diabetic cohort derived from a population of 1 million. A mobile van operate within a fixed cost boundary that one mobile van can handle 5000 screen event per annum

Digital Camera

The cost of the digital camera were determined from discussions with individual the NSF expert panel to determine the exact specification of hardware and software require to operate a digital system. The specification were then applied to direct cost obtained from the manufacturers of the digital systems. Overheads such as heating and lighting were apportioned accordingly.

Slit Lamp

A number of specifications and cost for ophthalmoscopy, slit lamp and lens were obtained. A mid range estimate was used in discussion with expert advice from the optometrist community.

Optometry Practice

Existing practice and research from Stockport health authority were used to establish the fixed cost boundary for the number of diabetic that could be screened at a high street optometrist. It was felt that the current figure based on an average case load was that one optometry practice could handle screening 360 diabetics per practice per annum. Overheads such as heating and lighting were apportioned accordingly.

Variable Cost

Staff costs were determine for both the digital and ophthalmoscopy options. Similarly the consumable costs. Ophthalmoscopy requires the addition of items such a eye drop where as the majority of the digital costs are in terms of computing software.

Patient Costs

Patient cost for attending for screening were determined from the literature where available. (REF)

Training

The cost of training was derived working closely with the NSF screening panel and the assumption made this panel on the numbers to be trained the length and duration of training and the specialist staff required to train.

It was assumed that the full cost of training would be born by the NHS, that is allocation of both the trainers time and travel cost and the time and travel cost of the trainees. As such it is the full opportunity or economic cost of training that is born by the programme. The cost were calculated assuming an initial three day training course. Involving a consultant ophthalmologist and a specialist technician. Hire of room and capital equipment, refreshment.

A maximum of 20 people could be trained at each session, the assumption was this would be 15 technicians, 4 optometrists and a diabetic nurse. Travel cost were assumed to be incurred for a round journey of 40 miles per person.

Each of the trainees would have to take an exit exam on a separate occasion. The full cost of the exit exam were calculated on the same basis as the three day training course.

It was a assumed that the training cost could be treated as human capital and run on a two year cycle.

Treatment Cost

The cost and effects of treatment were determine from the literature where available and using data from the Royal Liverpool University Hospital. (REF)

Fixed Screening Costs

A number of cost are fixed regardless of the screening system chosen. These include items such as a call recall system, administration costs and quality assurance that would be performed at a regional level.

Lifetime Cost

The lifetime cost of caring for visually disable adults were obtained from the literature review. All cost were converted into UK pounds and into their net present values (2000 prices).

Quality Adjusted Life Year Data

This was obtained from the literature using the Javitt paper (ref) (Drummond) for estimate of blindness and from the work on time trade off for visual morbidity states from Brown. (Brown 2000)

Sensitivity and Specificity

The sensitivity and specificity estimate were taken from the literature, for each method by type of screener where possible e.g. GP optometrist, to obtain pooled data enabling a meta analysis to be performed. Where possible the sensitivity and specificity data were calculate for all diabetic retinopathy non sight threatening and sight threatening. (refs)

Base Case

The base case assumptions for each of the options were as follows.

*Discount rate*

| | |
|---|---|
| Cost = | 6% (TDR) |
| Benefit = | 1.5% (TDR)<br>Undiscounted |

*Incidence*

1.2%

*Percentage on Diabetic Register:*

90%

*Compliance*

90%

*Effectiveness of Laser (Treatment)*

90%

*QALY Estimates*

| | |
|---|---|
| No Retinopathy | 0.89 |
| Early Retinopathy | 0.89 |
| STR Before Screening | 0.72 |
| STR abated by successful laser treatment | 0.72 |
| Blind | 0.4 |

*Sensitivity of the Screening Method*

| | |
|---|---|
| Optometrist | 80% |
| Digital | 87% |

*Specificity of the Screening Method*

| | |
|---|---|
| Optometrist | 94% |
| Digital | 91% |

*Cost of Digital Camera*

| | |
|---|---|
| Camera | £12,500 |
| Acquisition system | £14,000 |

*Proportion of diabetics in Sub Groups*

| | |
|---|---|
| Type I | 0.167 |
| Type II Insulin Requiring | 0.179 |
| Type II Non Insulin Requiring | 0.655 |

*Annual Transition Probabilities*

**To**

| **From** | **TYPE I** | No Retinopathy | Early Retinopathy | Sight Threatening Retinopathy | Blind |
|---|---|---|---|---|---|
| | No Retinopathy | 0.852 | 0.148 | 0 | 0 |
| | Early Retinopathy | 0 | 0.957 | 0.043 | 0 |
| | Sight Threatening Retinopathy | 0 | 0 | 0.91 | 0.09 |
| | Blind | | | | 1 |

**To**

| **From** | **TYPE II insulin requiring** | No Retinopathy | Early Retinopathy | Sight Threatening Retinopathy | Blind |
|---|---|---|---|---|---|
| | No Retinopathy | 0.883 | 0.117 | | 0 |
| | Early Retinopathy | | 0.930 | 0.070 | 0 |
| | Sight Threatening Retinopathy | 0 | 0 | 0.91 | 0.09 |
| | Blind | | | | 1 |

| | | To | | | |
|---|---|---|---|---|---|
| | **TYPE II non-insulin requiring** | No Retinopathy | Early Retinopathy | Sight Threatening Retinopathy | Blind |
| **F** | No Retinopathy | 0.835 | 0.165 | | 0 |
| **r** | Early Retinopathy | | 0.99 | 0.01 | 0 |
| **o** | Sight Threatening Retinopathy | 0 | 0 | 0.91 | 0.09 |
| **m** | Blind | | | | 1 |

*Additional Risk of Death with Diabetes*

| No Retinopathy | Early Retinopathy | Sight Threatening Retinopathy |
|---|---|---|
| 0.003 | 0.01 | 0.05 |

# Results

## Cost

The cost for the various options is presented below. All the results are based on the base case assumptions.

Certain cost are common to all three options. These include training and administration costs.

## Training

### Staff

Assuming 1 ophthalmologist, and 1 photographic technician

| Trainers: | | | | Rate | Hours | Days | per 3 day session |
|---|---|---|---|---|---|---|---|
| Type | Staff Grade | Per unit cost (£) | No. units | | | | Total cost (£) |
| Ophthalmologist | Consultant | £32.24 per hr (gross) | 8 hrs x1.5 | 32.44 | 8.00 | 1.50 | £389 |
| Photographic technician | Senior technician grade | £8.18 per hr (gross) | 8 hrs x 1.5 | 8.18 | 8.00 | 1.50 | £98 |
| | | | | | | | £487 |

Trainees for a per 3 day session
Assuming 15 technicians, 4 optometrists and 1 diabetic nurse

| Type | Staff Grade | Per unit cost (£) | No. units | | | | Total cost (£) |
|---|---|---|---|---|---|---|---|
| Graders | Technician | £7.45 per hr (gross) | 8 hrs x 5 | 7.45 | 8.00 | 3.00 | £179 |
| Photographer or grader | Technician | £7.45 per hr (gross) | 8 hrs x 5 | 7.45 | 8.00 | 3.00 | £179 |
| Slit lamp operators | Technician | £7.45 per hr (gross) | 8 hrs x 5 | 7.45 | 8.00 | 3.00 | £179 |
| Optometrists | | £21.45 per hr | 8 hrs x 5 | 21.45 | 8.00 | 3.00 | £515 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | (gross) | | | | | |
| Diabetic nurses | Grade D/E | £10.03 per hr (gross) | 8 hrs x 5 | 10.03 | 8.00 | 3.00 | £241 |
| | | | | | | | £4,982 |
| | | | STAFF COSTS = | | | | £5,469 |
| 40 miles @ 40pence per mile | | | Plus travel expenses = | | | | 1024 |
| | | | Plus accommodation costs = | | | | 0 |
| | | | | | | | £6,493 |
| Total Cost 3 day training course | | | | | | | £6,984 |

| Consumables and Capital | Per unit cost (£) | No. units | Total cost (£) | Type | Per unit cost (£) | | No. units | Total cost (£) |
|---|---|---|---|---|---|---|---|---|
| Room hire (academic venue) | 100.00 | 3.00 | £300 | Photographs | 1.00 | | 8.00 | 8 |
| Digital imaging equipment | 14084.00 | 2.00 | £77 | Refreshments (room hire) | £1.50 per person per day | 22x3 | | Total cost (£) |
| Slit lamp biomicroscopy with | 1150.00 | 2.00 | £6 | | 1.50 | 22.00 | 3.00 | 99 |
| Volk lense ophthalmoscopy | 67.00 | 2.00 | £0 | | | | | |
| TOTAL | | | £384 | | | | | 107 |

## Fixed Screening Costs

| | |
|---|---|
| **Quality Assurance** | |
| (Taking Linda's figure and diving by 12 to | |
| obtain a HA cost | |
| QA Director (0.2 WTE consultant) | £1,250 |
| QA manager and part time clerical assistant | £3,333 |
| Sessional commitment | £417 |
| QA screener and QA grader | |
| Office expense / overheads | £1,667 |
| **TOTAL - 1 System** | **£ 6,667** |
| **Call / Recall** | |
| (Taking Linda's figure to | |
| obtain a HA cost | |
| Computer Hardware | £10,000 |
| Call / Recall software | £5,000 |
| **TOTAL** | **£ 28,333** |

## Digital Camera

| ***Topcon Camera System*** | **COST** |
|---|---|
| Topcon fundus camera | £12,500 |
| Electric Table | £450 |
| Table top | £50 |
| Acquisition system | £14,000 |
| Capture | £165 |
| Colour Printer | £515 |
| ***TOTAL*** | ***£27,680*** |

***Network Connection***

| | |
|---|---|
| PC Net Server | £2,500 |
| Fast Ethernet Hub | £125 |
| ***TOTAL*** | ***£2,625*** |
| ***Total*** ***£30,305*** | |

## Mobile Screening

**Taking image Costs**
(from Liverpool unless elsewhere stated)

| | |
|---|---|
| 1.3 WTE photographer | £20,040 |
| 1 Auxiliary nurse | £10,617 |
| 0.5 WTE clerical | £6,359 |
| | |
| Medical drops and sundries | £2,710 |
| Stationary | £934 |
| Van | £7,571 |
| Petrol | £2,310 |
| Van maintenance | £300 |
| Camera Maintenance (From Linda) | £3,031 |
| Trolley | £3,000 |
| Additional admin for non attenders 80% uptake | £1,823 |
| | |
| **TOTAL** | **£58,695** |

**Grading**

| | |
|---|---|
| 0.125 WTE Clinical assistant | £3,918 |
| 0.135 WTE Nurse Grade F | £3,097 |
| 0.5 clerical | £6,359 |
| stationary | £934 |
| Overheads | £1,431 |
| | |
| **TOTAL** | **£15,739** |

## Slit Lamp

ANNUAL EQUIVALENT CAPITAL COST

| | Capital outlay | rate | No years |
|---|---|---|---|
| Topcon Slit Lamp | £2261 | 0.06 | 10 |
| Topcon Ocular Indirect Lens | £135 | | |
| Welch Allyn Ophthalmoscope Set | £210 | | |

| | | |
|---|---|---|
| Discount Factor | 7.360087 | Annual Equivalent Capital Cost |
| Topcon Slit Lamp | | 307.1975 |
| Topcon Ocular Indirect Lens | | 18.34217 |
| Welch Allyn Ophthalmoscope Set | | 28.53227 |

## Digital Optometrist Practice

Based on an optimal practice list of 360
Number who accept to be screened = 324
Percentage Time Equipment Used for DR Screening = 20%

| | |
|---|---|
| AECC Topcon Camera | 2.32 |
| AECC Network Connection | 0.22 |
| AECC Training | 1.58 |
| Recurring Costs | 9.35 |
| Unit Cost Per Ophthalmic Examination | 20 |
| **Total Annual Unit Cost** | **33.47** |

## Optometrist Slit Lamp

Based on a practice population of 360 (source Stockport Health Authority)
Number who accept screening = 324

Percentage Time Equipment Used for DR Screening = 20%

| | |
|---|---|
| Topcon Slit Lamp | 0.19 |
| Topcon Ocular Indirect Lens | 0.01 |
| Welch Allyn Ophthalmoscope Set | 0.02 |
| Unit Cost Per Ophthalmic Examination | 20 |
| Unit Training | 1.58 |
| Total Unit Opthalmic Cost | 21.79 |

## Treatment Cost

Referrals and assessment clinical Cost per patient = £55

Depending upon the severity of the eye a patient may have 1500 or 3000 burns
We assume t an average of 3 treatments per eye

I course of treatment cost approximately £1100 (RLUH)

| | |
|---|---|
| The final follow up appointment £77 | £77 |
| Total treatment cost of lasering | £1,232 |

# Lifetime Cost

**Direct Cost Annual Costs**

| | | Country | Author |
|---|---|---|---|
| Disease Cost for blindness and severe visual impairment | 863 | Sw | Fendrick |
| Medical Expenditures (severe impairment) | 1253 | US | Eastman |
| Medicaid payment | 4042 | US | Javit |
| Rehab | 3938 | US | Dasbach |

**Indirect Medical Expenditure Annual**

| | | Country | Author |
|---|---|---|---|
| Productivity loss | 4228 | SW | Fendrick |
| Welfare benefit averted | 7160 | UK | Foulds |
| Disability benefit legal blindness | 9372 | US | Eastman |
| Disability and SS benefits | 5107 | US | Javitt |
| Cost of maintaining blind person | 3805 | UK | Sakolainen |

# Quality Adjusted Life Year Data

*QALY Estimates*

| | |
|---|---|
| No Retinopathy | 0.89 |
| Early Retinopathy | 0.89 |
| STR Before Screening | 0.72 |
| STR abated by successful laser treatment | 0.72 |
| Blind | 0.4 |

## Sensitivity and Specificity

*Sensitivity of the Screening Method*

| | |
|---|---|
| Optometrist | 80% |
| Digital | 87% |

*Specificity of the Screening Method*

| | |
|---|---|
| Optometrist | 94% |
| Digital | 91% |

### Benefits

The base case results are presented below.

Benefits are present in terms of discounted Quality Adjusted Life Years (QALYs), undiscounted QALYs and in terms of sight years saved

# Cost Effectiveness \ Cost Utility

The results in terms of cost benefits and cost effectiveness are presented below.

**Table 1: Base Case - Costs and Benefits**

| | **Costs (Discounted)** | | **Benefits (Discounted)** | | | |
|---|---|---|---|---|---|---|
| | Total NHS | Total | Total Person Years of sight Saved | Disbenefit of Total Person Years Blind | Disbenefit of Total Person Years Blind for Those Screened | Total QALYS |
| **No Screening** | | £12,348,954 | | 7,558 | | 168,054 |
| **Digital - Van** | £4,219,855 | £7,153,617 | 17,515 | 2,221 | 390 | 170,427 |
| **Slit Lamp - Optometrists** | £4,498,912 | £7,650,722 | 17,171 | 2,367 | 536 | 170,380 |
| **Digital - Optometrists** | £6,219,090 | £9,152,853 | 17,515 | 2,221 | 390 | 170,427 |

All Figures Calculated for a Population of 1 Million

It can be seen from the table above that all option are less costly in total costs to society than the no screening option and generate additional benefits both in term of sight years saved (SYS) and Quality Adjusted Life Years (QALYs) Both digital option generate more benefits than the indirect ophthalmoscopy (slit lamp) option by optometrists. It can further be seen that the years of blindness in the population are significantly reduced by screening.

**Table 2: Base Case**

| | Cost Per Sight Year Saved | | Cost Per QALY | | Additional Years of Sight Gained per Person Year Blind for Those Screened |
|---|---|---|---|---|---|
| | NHS | Total | NHS | Total | |
| **No Screening** | | | | £73.48 | |
| **Digital - Van** | £240.93 | £408.44 | £24.76 | £41.97 | 44.9 |
| **Slit Lamp - Optometrists** | £262.00 | £445.55 | £26.41 | £44.90 | 32.0 |
| **Digital - Optometrists** | £355.08 | £522.59 | £36.49 | £53.71 | 44.9 |

All Figures Calculated for a Population of 1 Million

All Costs and Benefits Discounted

In term of cost effectiveness the most cost effective option both in terms of cost per sight year saved and cost per QALY is the digital van option. Followed by the slit lamp option. Although the slit lamp is more cost effect than the digital optometrist option is not as efficacious, as can be observed from the trade off in terms of the additional years of sight gained per person year blind.

**Sensitivity Analysis**

One Way Sensitivity Analysis

The following one way sensitivity analyses were performed. All other variables were kept constant. These variables were varied on the ground that they were most likely to effect screening results.

The combined results for each of the options are presented below.

**Discount rate**

Cost

Base
6% (TDR)

Options
6% all else 8% capital
8% all (TDR on capital)

5 and 10% All

Benefit

Base
Discounted 1.5
Undiscounted

Options
2%
6% (discount costs and benefits by the same factor)

**Incidence**

Base 1.2%

Options
1%
2%
3%

**Percentage on Diabetic Register:**

Base 90%

Options

50%
70%
100%

**Compliance**

Base 90%

Options

60%
80% Liverpool
100%

**Effectiveness of Laser (Treatment)**

Base 90%

Options
80% (As already successfully (proven?) technology therefore unlikely to be lower)

100%

**QALY Estimates**

Base

| | Estimate 1a |
|---|---|
| No Retinopathy | 0.89 |
| Early Retinopathy | 0.89 |
| STR Before Screening | 0.72 |
| STR abated by successful laser treatment | 0.72 |
| Blind | 0.4 |

Options

| | Estimate 1b |
|---|---|
| No Retinopathy | 0.89 |
| Early Retinopathy | 0.89 |
| STR Before Screening | 0.72 |
| STR abated by successful laser treatment | 0.72 |
| Blind Well Adjusted Drummond (Javitt 1996) | 0.48 |

| | Estimate 1c |
|---|---|
| No Retinopathy | 0.89 |
| Early Retinopathy | 0.89 |
| STR Before Screening | 0.72 |

| | |
|---|---|
| STR abated by successful laser treatment | 0.72 |
| Blind Poorly Adjusted Drummond (Javitt 1996) | 0.36 |

| | Estimate 2 |
|---|---|
| No Retinopathy | 0.81 |
| Early Retinopathy | 0.81 |
| STR Before Screening | 0.57 |
| STR abated by successful laser treatment | 0.81 |
| Blind | 0.39 |

***Sensitivity and Specificity of the Tests for STDR***

***Sensitivity***

| | |
|---|---|
| Base Optometrist | 80% |
| Options | |
| | 88%} |
| | 48%} Analysis of extremes (excluding 100%) |
| Base Digital Options | 87% |
| | 93%} |
| | 69%} Analysis of extremes (excluding 100%) |

***Specificity***

| | |
|---|---|
| Base Optometrist Options | 94% |
| | 99%} |
| | 89%} Analysis of extremes (excluding unobtainable or unreliable data) |

| | |
|---|---|
| Base Digital Options | 91% |
| | 97%} |
| | 70%} Analysis of extremes (excluding 100%) |

***Cost of Digital Camera***

| | |
|---|---|
| Base | |
| Camera | £12,500 |
| Acquisition system | £14,000 |
| Options | |
| Camera | £6,000 |
| | £10,000 |
| | Hold Acquisition system constant |
| | |
| Camera | £6,000 |
| | £10,000 |

The key results for the one way sensitivity analysis are presented in the tables below

Incidence – Table 3

The overall cost effectiveness is unaffected by a change in the incidence as cost and effects move in proportion. Both the benefit and cost however rise independently as incidence increases, with the greatest cost being incurred in the digital van. Although benefit are similar across groups the greatest disbenefit in terms of blindness is with the ophthalmoscopy.

Registered – Table 4

The greatest effect as registration increase is the increase in total person sight years saved in all three screening options. A further crucial factor is that across all three options when registration rise the total social cost falls however the cost to the NHS rises. Hence although the overall programme may represented a cost saving the results are not cost neutral to the NHS.

Compliance – Table 5

At very low level of compliance - 60% the order priority ordering in term of costs and effects in terms of Digital Van, Slit Lamp and Digital Optometry is changed with slit lamp becoming the most cost effective. Once compliance rises to 80% however this ordering again becomes Digital Van, Slit Lamp and Digital Optometry.

**Table 3: One Way Sensitivity Analysis - Incidence of Diabetes**

| | | Costs (Discounted) | | Benefits (Discounted) | | | |
|---|---|---|---|---|---|---|---|
| | % Incidence | Total NHS | Total | Total Person Years of Sight Saved | Disbenefit of Total Person Years Blind | Disbenefit of Total Person Years Blind for Those Screened | Total QALYS |
| **Digital - Van** | 3 | £11,000,000 | £18,000,000 | 44,000 | 5,600 | 970 | 430,000 |
| | 2 | £7,000,000 | £12,000,000 | 29,000 | 3,700 | 650 | 280,000 |
| | 1.2 | £4,200,000 | £7,200,000 | 18,000 | 2,200 | 390 | 170,000 |
| | 1 | £3,500,000 | £6,000,000 | 15,000 | 1,900 | 320 | 140,000 |
| **Slit Lamp - Optomotrists** | 3 | £11,000,000 | £19,000,000 | 43,000 | 5,900 | 1,300 | 430,000 |
| | 2 | £7,500,000 | £13,000,000 | 29,000 | 3,900 | 890 | 280,000 |
| | 1.2 | £4,500,000 | £7,700,000 | 17,000 | 2,400 | 540 | 170,000 |
| | 1 | £3,700,000 | £6,400,000 | 14,000 | 2,000 | 450 | 140,000 |
| **Digital - Optomotrists** | 3 | £16,000,000 | £23,000,000 | 44,000 | 5,600 | 970 | 430,000 |
| | 2 | £10,000,000 | £15,000,000 | 29,000 | 3,700 | 650 | 280,000 |
| | 1.2 | £6,200,000 | £9,200,000 | 18,000 | 2,200 | 390 | 170,000 |
| | 1 | £5,200,000 | £7,600,000 | 15,000 | 1,900 | 320 | 140,000 |
| **No Screening** | 3 | | £31,000,000 | | 19,000 | | 420,000 |
| | 2 | | £21,000,000 | | 13,000 | | 280,000 |
| | 1.2 | | £12,000,000 | | 7,600 | | 168,000 |
| | 1 | | £10,000,000 | | 6,300 | | 140,000 |

**The cost to the NHS per sight year saved remins the same at all incidence levels (because of assumptions) :**
**Digital Van £240; Slit Lamp Optomotrists £260; Digital Optomotrists £360.**

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

**Table 4: One Way Sensitivity Analysis - Percentage of Registered Diabetics**

| | Costs (Discounted) | | Benefits (Discounted) | | |
|---|---|---|---|---|---|
| | Total | Total NHS | Total Person Years of Sight Saved | Disbenefit of Total Person Years Blind | Disbenefit of Total Person Years Blind for Those Screened |
| 50% Registered | | | | | |
| **Digital - Van** | £9,500,000 | £2,300,000 | 9,700 | 5,500 | 220 |
| **Slit Lamp - Optomotrists** | £9,700,000 | £2,500,000 | 9,500 | 5,600 | 300 |
| **Digital - Optomotrists** | £11,000,000 | £3,500,000 | 9,700 | 5,500 | 220 |
| **No Screening** | £12,000,000 | | | 7,600 | |
| 70% Registered | | | | | |
| **Digital - Van** | £8,300,000 | £3,300,000 | 14,000 | 3,900 | 300 |
| **Slit Lamp - Optomotrists** | £8,700,000 | £3,500,000 | 13,000 | 4,000 | 420 |
| **Digital - Optomotrists** | £10,000,000 | £4,800,000 | 14,000 | 3,900 | 300 |
| **No Screening** | £12,000,000 | | | 7,600 | |
| 90% Registered | | | | | |
| **Digital - Van** | £7,200,000 | £4,200,000 | 18,000 | 2,200 | 390 |
| **Slit Lamp - Optomotrists** | £7,700,000 | £4,500,000 | 17,000 | 2,400 | 540 |
| **Digital - Optomotrists** | £9,000,000 | £6,200,000 | 18,000 | 2,200 | 390 |
| **No Screening** | £12,000,000 | | | 7,600 | |
| 100% Registered | | | | | |
| **Digital - Van** | £6,600,000 | £4,700,000 | 19,000 | 1,400 | 430 |
| **Slit Lamp - Optomotrists** | £7,100,000 | £5,000,000 | 19,000 | 1,600 | 600 |
| **Digital - Optomotrists** | £9,000,000 | £6,900,000 | 19,000 | 1,400 | 430 |
| **No Screening** | £12,000,000 | | | 7,600 | |

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

**Table 5: One Way Sensitivity Analysis - Compliance: Percentage of Diabetics Who Accept Testing**

| | Cost to NHS Per Sight Year Saved | Total Cost Per QALY | Costs (Discounted) Total NHS | Costs (Discounted) Total | Benefits (Discounted) Total Person Years of Sight Saved | Benefits (Discounted) Disbenefit of Total Person Years Blind | Benefits (Discounted) Disbenefit of Total Person Years Blind for Those Screened |
|---|---|---|---|---|---|---|---|
| 60% Compliance | | | | | | | |
| **Slit Lamp - Optomotrists** | 270 | 55 | £3,100,000 | £9,300,000 | 11,000 | 4,800 | 360 |
| **Digital - Van** | 300 | 57 | £3,600,000 | £9,600,000 | 12,000 | 4,700 | 260 |
| **Digital - Optomotrists** | 400 | 64 | £4,700,000 | £11,000,000 | 12,000 | 4,700 | 260 |
| **No Screening** | | 73 | | £12,000,000 | | 7,600 | |
| 80% Compliance | | | | | | | |
| **Digital - Van** | 260 | 47 | £4,000,000 | £8,000,000 | 16,000 | 3,000 | 350 |
| **Slit Lamp - Optomotrists** | 260 | 48 | £4,000,000 | £8,200,000 | 15,000 | 3,200 | 480 |
| **Digital - Optomotrists** | 370 | 57 | £5,700,000 | £10,000,000 | 16,000 | 3,000 | 350 |
| **No Screening** | | 73 | | £12,000,000 | | 7,600 | |
| 90% Compliance | | | | | | | |
| **Digital - Van** | 240 | 42 | £4,200,000 | £7,200,000 | 18,000 | 2,200 | 390 |
| **Slit Lamp - Optomotrists** | 260 | 45 | £4,500,000 | £7,700,000 | 17,000 | 2,400 | 540 |
| **Digital - Optomotrists** | 360 | 54 | £6,200,000 | £9,000,000 | 18,000 | 2,200 | 390 |
| **No Screening** | | 73 | | £12,000,000 | | 7,600 | |
| 100% Compliance | | | | | | | |
| **Digital - Van** | 230 | 37 | £4,400,000 | £6,300,000 | 19,000 | 1,400 | 430 |
| **Slit Lamp - Optomotrists** | 260 | 42 | £5,000,000 | £7,100,000 | 19,000 | 1,600 | 600 |
| **Digital - Optomotrists** | 350 | 50 | £6,700,000 | £9,000,000 | 19,000 | 1,400 | 430 |
| **No Screening** | | 73 | | £12,000,000 | | 7,600 | |

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

Camera Cost – Tables 6 & 7

If the combined cost of the camera cost and the acquisition system was to fall from the base case of £26,500 to £16,000 a fall of less than £10,000 the combined saving to the NHS are in excess of ½million in terms of the digital optometry option.

**Table 6: One Way Sensitivity Analysis - Costs of Digital Camera and Aquisition System**

| **Total Discounted NHS Cost (millions)** | | | | |
|---|---|---|---|---|
| Cost of Camera | 6k | 6k | 10k | 12.5k |
| Cost of Aquition System | 10k | 14K | 14K | 14K |
| **Digital - Van** | £4.2 | £4.2 | £4.2 | £4.2 |
| **Digital - Optomotrists** | £5.7 | £5.9 | £6.1 | £6.2 |

**Slit Lamp - Optomotrists is £4.5 million**

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

**Table 7: One Way Sensitivity Analysis - Costs of Digital Camera and Aquisition System**

| | **Cost to NHS Per Sight Year Saved** | | | |
|---|---|---|---|---|
| Cost of Camera | 6k | 6k | 10k | 12.5k |
| Cost of Aquition System | 10k | 14K | 14K | 14K |
| **Digital - Van** | £240 | £240 | £240 | £240 |
| **Digital - Optomotrists** | £330 | £340 | £350 | £360 |

**Slit Lamp - Optomotrists is £260 for all Options**

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

Sensitivity and Specificity – Table 8

As sensitivity and specificity rises cost effectiveness rises. Importantly at low level of sensitivity the cost to the NHS in each of the options are increased with the most notable change occurring in differences in the slit lamp. Essentially as can be seen from the table this is because as specificity falls the number of false positive going through the hospital system increases and although they incur no disbenefit they do generate and additional and unnecessary cost upon the hospital sector.

**Sensitivity & Specificity of Tests for STDR**

| | **Optomotry** | | **Digital** | |
|---|---|---|---|---|
| | Sensitivity | Specificity | Sensitivity | Specificity |
| Base | 0.80 | 0.94 | 0.87 | 0.91 |
| Upper | 0.88 | 0.99 | 0.93 | 0.97 |
| Lower | 0.48 | 0.89 | 0.69 | 0.70 |

**Table 8: One Way Sensitivity Analysis - Sensitivity and Specificity of Screening Options**

| | | Costs (Discounted) | | | Benefits & Ratios (Discounted) | | |
|---|---|---|---|---|---|---|---|
| | Cost to NHS Per Sight Year Saved | Hospital False Positives | Total NHS | Total | Disbenefit of Total Person Years Blind for Those Screened | Additional Years of Sight Gained per Person Year Blind for Those Screened | Total Person Years of Sight Saved |
| Base Case Estimates | | | | | | | |
| **Digital - Van** | £240 | £660,000 | £4,200,000 | £7,200,000 | 390 | 45 | 18,000 |
| **Slit Lamp - Optomotrists** | £260 | £440,000 | £4,500,000 | £7,700,000 | 540 | 32 | 17,000 |
| **Digital - Optomotrists** | £360 | £660,000 | £6,200,000 | £9,200,000 | 390 | 45 | 18,000 |
| Upper Estimates | | | | | | | |
| **Digital - Van** | £210 | £220,000 | £3,800,000 | £6,600,000 | 280 | 64 | 18,000 |
| **Slit Lamp - Optomotrists** | £240 | £70,000 | £4,200,000 | £7,100,000 | 370 | 47 | 18,000 |
| **Digital - Optomotrists** | £330 | £220,000 | £5,800,000 | £8,600,000 | 280 | 64 | 18,000 |
| Lower Estimates | | | | | | | |
| **Slit Lamp - Optomotrists** | £320 | £800,000 | £4,700,000 | £9,300,000 | 1,600 | 10 | 15,000 |
| **Digital - Van** | £340 | £2,200,000 | £5,700,000 | £9,200,000 | 810 | 20 | 17,000 |
| **Digital - Optomotrists** | £460 | £2,200,000 | £7,700,000 | £11,200,000 | 810 | 20 | 17,000 |

All Figures Rounded to 2 Significant Digits,
Costs Discounted at 6% and Benefits at 1.5%

Mulitway Sensitivity Analysis

In addition to the one way sensitivity analysis two multi variate sensitivity analysis were performed, scenario one examined the most favourable condition for screening and scenario two examined the least favourable conditions for screening.

**Scenario One Best Case**

The assumptions for scenario one were as follows:

| | |
|---|---|
| Registrations | 100% |
| Compliance | 100% |
| Treatment Effectiveness | 100% |

Camera cost = £6k Acquisition System = £10k

Slit Lamp

| | |
|---|---|
| Sensitivity | 88% |
| Specificity | 99% |

Digital

| | |
|---|---|
| Sensitivity | 93% |
| Specificity | 97% |

Discount rate for cost and benefits was held constant

The incidence was taken to be at 2%

**Table 9: Best Case - Costs and Benefits**

| | **Costs (Discounted)** | | **Benefits (Discounted)** | | | |
|---|---|---|---|---|---|---|
| | Total NHS | Total | Total Person Years of sight Saved | Disbenefit of Total Person Years Blind | Disbenefit of Total Person Years Blind for Those Screened | Total QALYS |
| **No Screening** | | £20,581,590 | | 12,596 | | 280,090 |
| **Digital - Van** | £7,027,520 | £7,370,263 | 37,386 | 226 | 226 | 285,157 |
| **Slit Lamp - Optometrists** | £8,320,293 | £8,933,079 | 36,968 | 405 | 405 | 285,100 |
| **Digital - Optometrists** | £10,418,482 | £10,761,225 | 37,386 | 226 | 226 | 285,157 |

All Figures Calculated for a Population of 1 Million

The cheapest and most efficacious option is again clearly the digital van. Although Slit lamp is again second in the priority list this is again at the expense of the benefits generated.

**'Table 10: Best Case**

| | **Cost Per Sight Year Saved** | | **Cost Per QALY** | | **Additional Years of Sight** |
|---|---|---|---|---|---|
| | | | | | **Gained per Person Year** |
| | NHS | Total | NHS | Total | **Blind for Those Screened** |
| **No Screening** | | | | £73.48 | |
| **Digital - Van** | £187.97 | £197.14 | £24.64 | £25.85 | 165.4 |
| **Slit Lamp - Optometrists** | £225.07 | £241.65 | £29.18 | £31.33 | 91.3 |
| **Digital - Optometrists** | £278.67 | £287.84 | £36.54 | £37.74 | 165.4 |

All Figures Calculated for a Population of 1 Million

All Costs and Benefits Discounted

The most cost effective option in terms of SYS and QALYs is the digital van. In this instance the difference is over £100 per unit of effect between the digital van and the digital optometry option.

**Scenario Two Worst Case**

The assumptions for scenario one were as follows:

| | |
|---|---|
| Registrations | 50% |
| Compliance | 60% |
| Treatment Effectiveness | 80% |

Camera cost was held constant

Slit Lamp

| | |
|---|---|
| Sensitivity | 48% |
| Specificity | 89% |

Digital

| | |
|---|---|
| Sensitivity | 69% |
| Specificity | 70% |

Discount rate for cost and benefits was held constant

The incidence was taken to be at 1%

**'Table 11: Worst Case - Costs and Benefits**

| | **Costs (Discounted)** | | **Benefits (Discounted)** | | | |
|---|---|---|---|---|---|---|
| | Total NHS | Total | Total Person Years of sight Saved | Disbenefit of Total Person Years Blind | Disbenefit of Total Person Years Blind for Those Screened | Total QALYS |
| **No Screening** | | £10,290,795 | | 6,298 | | 140,045 |
| **Slit Lamp - Optometrists** | £1,391,944 | £9,416,137 | 4,367 | 6,183 | 562 | 140,636 |
| | | | | | | |
| **Digital - Optometrists** | £2,658,150 | £10,339,193 | 4,934 | 5,943 | 321 | 140,713 |
| **Digital - Van** | £2,122,488 | £9,803,531 | 4,934 | 5,943 | 321 | 140,713 |

All Figures Calculated for a Population of 1 Million

It can be seen from the above table that in the worst case scenario the order of the option is reversed, with the slit lamp becoming the cheapest option. It should further however be noted that an important trade off is occurring as although slit lamp is the cheapest option it is also the least efficacious option in term of benefits generated.

**Table 12: Worst Case**

| | Cost Per Sight Year Saved | | Cost Per QALY | | Additional Years of Sight Gained per Person Year |
|---|---|---|---|---|---|
| | NHS | Total | NHS | Total | Blind for Those Screened |
| **No Screening** | | | | £73.48 | |
| **Slit Lamp - Optometrists** | £318.77 | £2,156.42 | £9.90 | £66.95 | 7.8 |
| **Digital - Van** | £430.20 | £1,987.06 | £15.08 | £69.67 | 15.3 |
| **Digital - Optometrists** | £538.78 | £2,095.64 | £18.89 | £73.48 | 15.3 |

All Figures Calculated for a Population of 1 Million

All Costs Discounted at 6% and Benefits Discounted at 1.5%

In the worst case scenario the order for cost effectiveness is also reversed with the slit lamp becoming the most cost effective option. However again the trade of is in terms of loss of benefits.

# Discussion

The implementation of a screening programme should be viewed for a societal perspective.

Screening is always better than a do nothing option both in terms of a cost and benefit perspective.

The data on sensitivity and specificity of screening methods is poorly reported and evidence is lacking, indicating a need for further research into the evaluation of screening technology.

Digital imaging is still in its infancy and further prospective studies are required to fully evaluate the technology.

Incidence is poorly reported in the literature. This work assume a base rate of 1.2% across the population. It is reported that this rate is increasing and is higher in certain ethnic groups, as such this raises the issue of targeting screening accordingly.

All cost are valued as if they are incurred by society or perhaps more important for both digital options by the NHS. This is an important issue regarding who bears the cost and the citing of technology, although in economic term it is the true cost that is important if the optometrist were to bear the cost of the digital camera privately and it was perhaps encompassed within the £20 sight test fee, given that the digital option is always the more efficacious it is the cost effectiveness ratio will improve in terms of the digital optometry option.

# Recommendations

- Diabetic Retinopathy screening is a cost effective strategy for the UK.
- A key factor in implementing a successful screening strategy is the establishment of a diabetic register that has high population coverage.
- The most cost effective option for screening is using a digital system with a mobile van.
- Depending on the cost structure of digital cameras and who bears the cost of camera a mixture of vans and high street optometrist may be a viable screening solution but the evidence on this is not currently available.
- Differential incidence will be observed depending on the demographic structure of the local population such as age and ethnicity, therefore national screening strategies may have to be supplemented by more local targeting.
- The least cost effective option is to go for a digital system using optometrists only.
- The results are sensitive to the cost of the digital camera. As there are only two major suppliers of such equipment a duopoly exist and as such there may be a role for the government in terms of market regulation.
- The result are sensitive to the sensitivities and specificity of the screening technologies. Further research is therefor required to establish accurate sensitivities and specificities.
- A low specificity will incur additional hospital cost in terms of false positives.
- Whilst the slit lamp screening is often close in term of its cost effectiveness to the digital van there is a considerable loss in efficacy in term of sight year saved and blindness avoid in this option and hence the decision maker faces a trade off in term of cost effectiveness and efficacy.

- **References**


1. Buxton MJ, Sculpher MJ, Ferguson BA, Humphreys JE, Altman JF, Spiegelhalter DJ, et al. Screening for treatable diabetic retinopathy: a comparison of different methods. *Diabetic Med* 1991;8:371-7.
2. Sculpher MJ, Buxton MJ, Ferguson BA, Humphreys JE, Altman JFB, Spiegelhalter DJ, et al. A relative cost-effectiveness analysis of different methods of screening for diabeticretinopathy. *Diabetic Med* 1991;8:644-50.
3. Fendrick AM; Javitt JC; Chiang YP Cost-effectiveness of the screening and treatment of diabetic retinopathy. What are the costs of underutilization? Int J Technol Assess Health Care 1992;8:694-707
4. Javitt JC, Canner JK, Sommer A. Cost-effectiveness of current approaches to the control of Retinopathy in type I diabetics. Ophthalmology 1989;96:255-264.
5. Lairson DR, Pugh JA, Kapadia AS, Lorimor RJ, Jacobson J, Velez R. Cost-effectiveness of alternative methods for diabetic retinopathy screening. Diabetes Care 1992;15:1369-77.
6. Dasbach EJ; Frybach DG; Newcomb PA; Klein R; Klein BEK. Cost-Effectiveness of Strategies for Detecting Diabetic Retinopathy. Medical Care 1991;29:20-39
7. Sculpher MJ; Buxton MJ; Ferguson BA; Spiegelhalter DJ; Kirby AJ. Screening For Diabetic Retinopathy: A Relative Cost-Effectiveness Analysis Of Alternative Modalities And Strategies. Health Econ 1992;1:39-51.
8. Scott JA, Harding SP, Broadbent DM, Vora J. Detecting sight threatening diabetic eye disease in an inner city setting in the UK - the Liverpool Diabetic Eye Study. Invest Ophthalmol Vis Sci 1996;37:S105
9. Finlay R, Griffiths J, Jackson G, Law D. Can general practitioners screen their own patients for diabetic retinopathy? *Health Trends* 1991;**23:**104-105.
10. Awh CC, Javitt JC, Chong LP, Gehrs KM, Gusman GI, Street DA, Cupples HP. Ophthalmoscopic diagnosis and referral of diabetic eye disease by Primary Care Physicians. ARVO abstract. *Invest Ophthalmol Vis Sci* 1993;**34**:713.
11. Forrest RD, Jackson CA, Yudkin JS. Screening for diabetic retinopathy. Comparison of a nurse and doctor with retinal photography. *Diabetes Research* 1987;**5:**39-42.
12. Kinyoun JL, Martin DC, Fujimoto WY, Leonetti DL. Ophthalmoscopy versus fundus photography for detecting and grading diabetic retinopathy. *Invest Ophthalmol Vis Sci* 1992;**33:**1888-1893.


Reference pooled data sen and spec.

Reference pooled


Burnett, S., Hurwitz, B., Davey, C., Ray, J., Chaturvedi, N., Salzmann, J. and Yudkin, J. (1998) The implementation of prompted retinal screening for diabetic eye disease by accredited optometrists in an inner-city district of North London: a quality of care study. Diabetes Medicine 15, S38-S43

Burns-Cox, C.J. and Dean-Hart, J.C. (1985) Screening of diabetics for retinopathy by ophthalmic opticians. British Medical Journal 290, 1052-1054.

Buxton, M.J., Sculpher, M.J., Ferguson, B.A., Humphreys, J.E., Altman, J.F., Spiegelhalter, D.J., Kirby, A.J., Jacob, J.S., Bacon, H. and Dudbridge, S.B. (1991) Screening for treatable diabetic retinopathy: a comparison of different methods. Diabet Med 8, 371-377.

Gardner, G.G., Keating, D., Williamson, T.H. and Elliot, A.T. (1996) Automatic detection of diabetic retinopathy using an artificial neural network : a screening tool. British Journal of Ophthalmology 80, 940-944.

.
Gibbins, R.L., Owens, D.R., Allen, J.C. and Eastman, L. (1998) Practical application of the European Field Guide in screening for diabetic retinopathy by using ophthalmoscopy and 35 mm retinal slides. Diabetologia 41, 59-64.

Griffith, S.P., Freeman, W.L., Shaw, C.J., Mitchell, W.H., Olden, C.R., Figgs, L.D., Kinyoun, J.L., Underwood, D.L. and Will, J.C. (1993) Screening for diabetic retinopathy in a clinical setting: a comparison of direct ophthalmoscopy by primary care physicians with fundus photography. Journal of Family Practice 37, 49-56.

Kerr, D., Cavan, D.A., Jennings, B., Dunnington, C., Gold, D. and Crick, M. (1998) Beyond retinal screening: digital imaging in the assessment and follow-up of patients with diabetic retinopathy . Diabetic Medicine 15, 878-882.
Abstract: Article Type

Moss, S., KLEIN, R., Kessler, S. and Richie, K. (1985) Comparison between ophthalmoscopy and fundus photography in determining severity of diabetic retinopathy. Ophthalmology 92, 62-67.

O'Hare, J.P., Hopper, A., Madhaven, C., Charny, M., Purewell, T.S., Harney, B. and Griffiths, J. (1996) Adding retinal photography to screening for diabetic retinopathy: a prospective study in primary care BMJ 312, 679-682.

Owens, D.R., Gibbins, R.L., Lewis, P.A., Wall, S., Allen, J.C. and Morton, R. (1998) Screening for diabetic retinopathy by general practitioners: ophthalmoscopy or retinal photography as 35 mm colour transparencies? Diabetic Medicine 15, 170-175.

Reenders, K., De Nobel, E., Van Den Hoogen, H. and Van Weel, C. (1992) Screening for Diabetic Retinopathy by General Practitioners. Scandinavian Journal of Primary Health Care 306-309.

Ryder, R.E., Close, C.F., Krentz, A.J., Gray, M.D., Souten, H., Taylor, K.G., Gibson, J.M. and Kritzinger, E.E. (1998) A fail safe screening programme for diabetic retinopathy. Journal of the Royal College of Physicians 32, 134-137.

Ryder, R.E., Kong, N., Bates, A.S., Sim, J., Welch, J. and Kritzinger, E.E. (1998) Instant electronic imaging systems are superior to Polaroid at detecting sight-threatening diabetic retinopathy [see comments]. Diabetic Medicine 15, 254-258.

Taylor, D.J., Fisher, J., Jacob, J. and Tooke, J.E. (1999) The use of digital cameras in a mobile retinal screening environment. Diabetes Medicine 16, 680-686.

Outcome and Liverpool

Brown, G.C., Sharma, S., Brown, M.M. and Kistler, J. (2000) Utility values and age-related macular degeneration. *Arch Ophthalmol* **118**, 47-51.

James, M., Turner, D., Broadbent, D., Vora, J. and Harding, S.P. (2000) Systematic screening or muddling through: cost-effectiveness analysis of detection of sight threatening diabetic eye disease. *British Medical Journal* **320**, 1627-1631.

Death Probabilities

DH Population Unit: Deaths in England, 1996-98 by all cause of death and gender for single years of age.

Javitt et al (1990) Opthalmol; 97: 483-495 table 1 p 485

Incidence progression

Klein R, Klein BEK, Moss SE, Davis MD, De Mets DL. (1989) The Wisconsin Epidemiological Study of Diabetic Retinopathy. IX. Four-year incidence and progression of diabetic retinopathy when age at diagnosis is 30 years or more. Arch Ophthalmic; 107:244-249

Klein R, Klein BEK, Moss SE, Davis MD, De Mets DL. (1989) The Wisconsin Epidemiologic Study of Diabetic Retinopathy. IX. Four-year incidence and progression of diabetic retinopathy when age at diagnosis is less than 30 years. Arch Ophthalmol; 107:237-243.

Javitt Refs

Javitt, J.C., Aiello, L.P., Bassi, L.J., Chiang, Y.P. and Ganner, J.K. (1991) Detecting and treating retinopathy in patients with type I diabetes mellitus: Savings associated with improved implementation of current guidelines. *Ophthalmology* **98**, 1565-1574.

Javitt, J.C., Aiello, L.P., Chiang, Y.P., Ferris, F., Canner, J.K. and Greenfield, S. (1994) Preventive eye care in people with diabetes is cost-saving to the federal government. Implications for health-care reform. *Diabetes Care* **17**, 909-917.

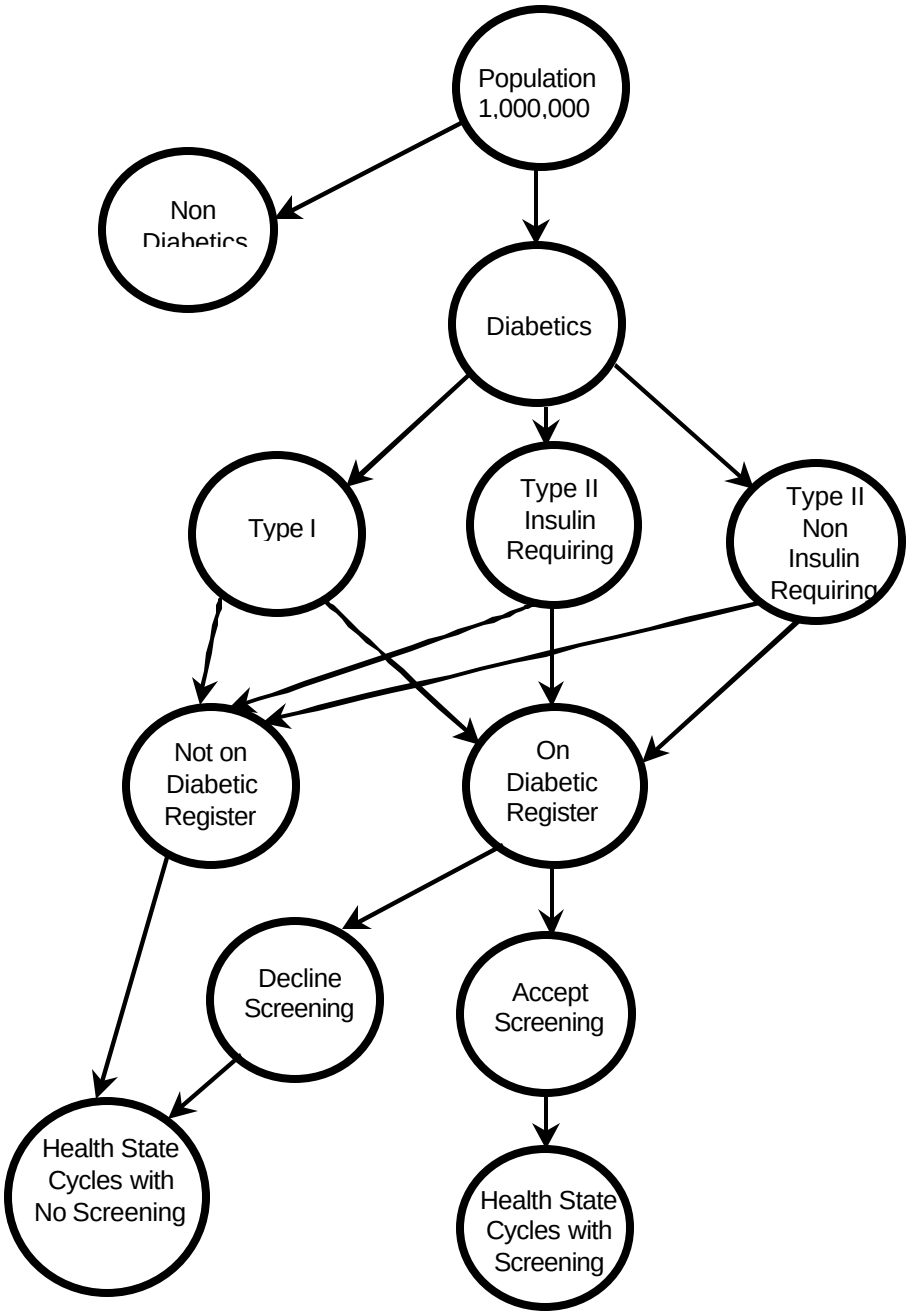
Javitt, J.C. (1994) What is vision worth? The Oregon medical approach. *Arch Ophthalmol* **112**, 311-311.

Javitt, J.C. and Aiello, L.P. (1996) Cost-effectiveness of detecting and treating diabetic retinopathy. *Annals of Internal Medicine* **124**, 164-169.

Javitt, J.C., Canner, J.K. and Sommer, A. (1989) Cost effectiveness of current approaches to the control of retinopathy in type I diabetics. *Ophthalmology* **96**, 255-264.

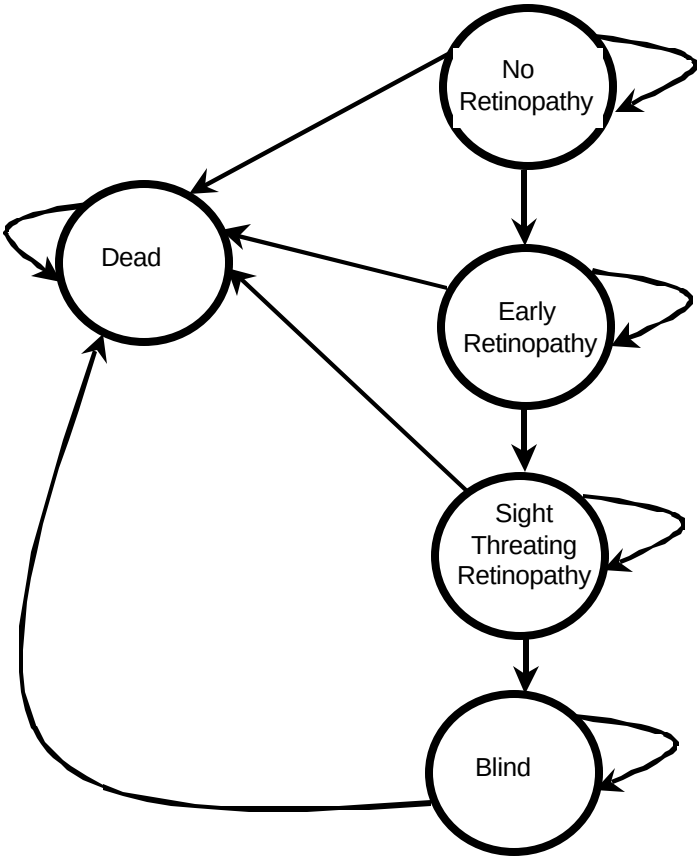
APPENDIX 1a

**Start of Markov Model - Determining Numbers of Diabetics Screened and Not Screer**



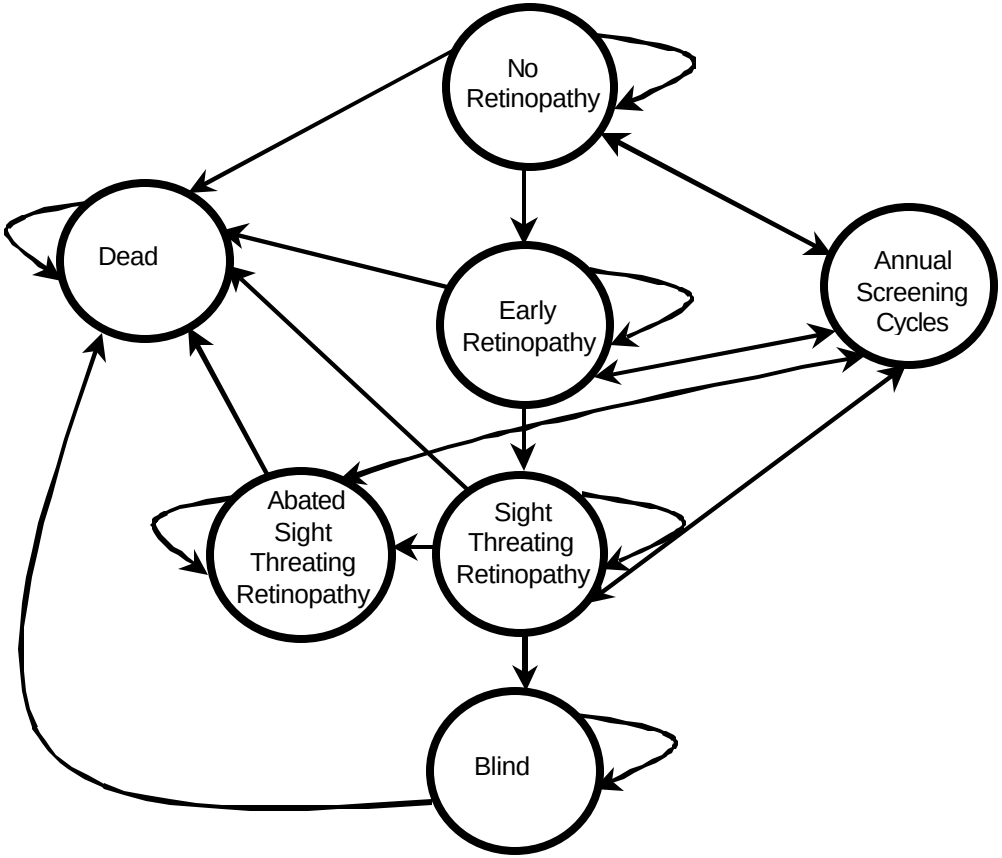
APPENDIX 1b

**Part of Markov Model - Health State Cycles with No Screening**



APPENDIX 1c

**Part of Markov Model - Health State Cycles with Screening**



APPENDIX 1d

**Part of Markov Model - Screening Cycles**