Big data, visual fields and glaucoma

David Crabb

Optometry and Visual Science  @crabblab
School of Health Sciences
Declaration of any conflicts of interest

• **None** for the presentation

• Recipient of honoraria and speakers fees for other work from Allergan; Santen; Centervue and Roche
Optometry at City, University of London
Measurement techniques
And what do people with AMD see?

Not clear, Out of focus, Fuzzy, Foggy, Hazy, Misty, Cloud
Bendy, Crooked, Wavy, Wobbly, Wiggled
Black parts, Space, Patchy, Grey area,
Words dropping from page
Flash, Sparkles, Spiral of light

No!
Big data, visual fields and glaucoma

David Crabb

Optometry and Visual Science  @crabblab
School of Health Sciences
Burden of monitoring glaucoma

- UK: One million hospital visits per year
Burden of monitoring glaucoma

• UK: One million hospital visits per year

IOP

Are practical recommendations practiced? A national multi-centre cross-sectional study on frequency of visual field testing in glaucoma

Simon S M Fung,¹ Claire Lemer,² Richard A Russell,³,⁴ Rizwan Malik,³ David P Crabb⁵

ABSTRACT

Aim To estimate current clinical practice for frequency of glaucoma in England, view of all patients with CAGQ attending hospital with VF tests.

British Journal of OPHTHALMOLOGY 2013 97: 843-847
**Burden of monitoring glaucoma**

- UK: One million hospital visits per year
Perimetry
Methods for detecting VF progression
Methods for detecting VF progression

Clinically useful software
Burden of monitoring glaucoma

- UK: One million hospital visits per year

Malik et al 2013

Perimetry
What do the experts say?

BMJ Open
A qualitative investigation into patients’ views on visual field testing for glaucoma monitoring

Fiona C Glen, Helen Baker, David P Crabb

www.bmjopen.com
Glen et al (2014)
What do the experts say?

Glen et al (2014)
**Burden** of monitoring glaucoma

- **UK**: One million hospital visits per year
enormous variability in progression rates...

...most treated patients in clinics are not at high risk of progressing to blindness..

Saunders et al IOVS 2014
- Ordinary linear regression of MD(dB) on time
- Estimate speed of loss (dB/year)
- Median speed of loss: - 0.1 dB/y but huge variability
- Only ~ 25% ‘progressing’ at a ‘significant’ rate
-0.5 to -1.0 dB/year ~ 16%
-1.0 to -1.5 dB/year ~ 5%

(95% confidence interval is smaller than +/- 1%)
• Worse than -1.5 dB/year ~ 3%

(95% confidence interval is smaller than +/- 2%)
Finding them in the haystack is difficult
How does speed of loss affect the patient?

Life expectancy and both eyes
Results
Results

Patients with at least one positive slope

51%
Results
Results

Patients ‘at risk’ of visual impairment in their lifetime

\(~5\%~\)
Results

Practical landmarks for visual field disability in glaucoma

Luke J Saunders,1 Richard A Russell,1,2 David P Crabb1

ABSTRACT

Background/Aims To assess whether mean deviation (MD) from automated perimetry is related to the visual field disability for legal fitness to drive (LFTD) in glaucoma. Methods 24-2 VFs of 2604 patients with bilateral glaucoma were retrospectively investigated. Immerialized MDs were calculated and used as a surrogate for LFTD according to current UK driving standards. The better eye MDs were used for the driving standard (DR) and a measure used in practice, to assess risk. The new MDs were compared to predict LFTD (using a ‘Probability of Failure’ (PoF) for various defect levels was calculated.

Testing is rarely performed. One measure can be derived from the International Driving License available on automated perimeters in the UK to assess the VF component of legal fitness to drive (LFTD) by the Driving Vehicle Licensing Agency (DVLA). Indeed, one of the criteria for assessing the consequences of glaucoma is the visual field defect (VF). Patients may lose their driving license and be unable to drive. VFs are measured using automated perimetry, typically the threshold visual field in the left and right eyes. In the DVLA interpretation, one eye need not be normal for a patient to drive. In practice, the driving standard (DR) is used for a ‘full width’ of the VF. However, there are no clear guidelines for the size of a ‘significant defect’.

Testing is rarely performed. One measure can be derived from the International Driving License available on automated perimeters in the UK to assess the VF component of legal fitness to drive (LFTD) by the Driving Vehicle Licensing Agency (DVLA). Indeed, one of the criteria for assessing the consequences of glaucoma is the visual field defect (VF). Patients may lose their driving license and be unable to drive. VFs are measured using automated perimetry, typically the threshold visual field in the left and right eyes. In the DVLA interpretation, one eye need not be normal for a patient to drive. In practice, the driving standard (DR) is used for a ‘full width’ of the VF. However, there are no clear guidelines for the size of a ‘significant defect’.

Aims: To assess whether MDs from automated perimetry are related to LFTD in glaucoma.

Methods: 24-2 VFs of 2604 patients with bilateral glaucoma were retrospectively investigated.

Results: The better eye MDs were used for the driving standard (DR) and a measure used in practice, to assess risk. The new MDs were compared to predict LFTD (using a ‘Probability of Failure’ (PoF) for various defect levels was calculated.

Conclusions: MDs from automated perimetry are related to LFTD in glaucoma.
**Results**

Patients at risk of visual impairment in their lifetime

\(\sim 5\%\)

All had at least one eye worse than -6dB at diagnosis
VF testing in diagnosed patients

Primary care

Case finding

Screening

MD -6 dB
VF testing in diagnosed patients

Primary care
Case finding
Screening

Are we getting better at detecting glaucoma before the disease becomes advanced?
Disease severity in newly diagnosed glaucoma patients with visual field loss: trends from more than a decade of data
Trishal Boodhna and David P. Crabb
Optometry and Visual Science, School of Health Sciences, City University London, London, UK

Citation information: Boodhna T & Crabb DP. Disease severity in newly diagnosed glaucoma patients with visual field loss: trends from more than a decade of data. Ophthalmic Physiol Opt 2015; 35: 225–230. doi: 10.1111/opo.12187

Keywords: glaucoma detection, glaucoma referral, trend analysis, visual field

Correspondence: David P. Crabb
E-mail address: david.crabb@city.ac.uk

Received: 5 September 2014; Accepted: 29 November 2014; Published Online: 29 December 2014

Abstract
Purpose: Large archives of visual fields are used to examine severity of visual field loss in a 13 year period in England
Methods: A total of 473 252 Humphrey glaucoma clinics in England were required to have a Humphrey mean deviation in at least one eye and had at least one visual field test between the start of 1999 and 2012.

70,955 VFs from 13,075 patients (2002 to 2012)
50,144 VFs from 11,279 patients (2000 to 2011)
320,334 VFs from 55,492 patients (1989 to 2012)
31,879 VFs from 9,086 patients (1999 to 2011)

~500K VFs!!
- Visual field loss at ‘diagnosis’ (first visit at clinic)
- Worse eye (detectable eye) - 25,251 patients! (13 years)
**Good:** Half of all newly diagnosed patients have early VF loss in both eyes.
Bad: Still more than 1 in 5 patients present with at least one severely damaged VF
big visual field data for audit

Are rates of vision loss in patients in English glaucoma clinics slowing down over time? Trends from a decade of data


Abstract

**Purpose**  To examine changes in rates of visual field (VF) progression in patients attending a sample of glaucoma clinics in England between 1999 and 2012.

**Introduction**

Rate of visual field (VF) series of examinations is useful in managing a patient. Rates of VF loss vary er

'Big' visual field data

- Calderdale and Huddersfield NHS 70,955 VF from 13,075 patients (2002 to 2012)
- Gloucestershire Hospitals NHS 50,144 VF from 11,279 patients (2000 to 2011)
- Moorfields Eye Hospital NHS 320,334 VF from 55,492 patients (1989 to 2012)
- Portsmouth Hospitals NHS 31,879 VF from 9,086 patients (1999 to 2011)

~500K VF!!
big visual field data for audit

Are rates of vision loss in patients in English glaucoma clinics slowing down over time? Trends from a decade of data


Abstract

Purpose To examine changes in rates of visual field (VF) progression in patients attending a sample of glaucoma clinics in England between 1999 and 2012.

Introduction

Rate of visual field series of examination useful in managing Rates of VF loss va
**big visual field data for audit**

Are rates of vision loss in patients in English glaucoma clinics slowing down over time? Trends from a decade of data

Boodhna, Saunders & Crabb (2015) *Eye*

---

**Abstract**

*Purpose*  To examine changes in rates of visual field (VF) progression in patients attending a sample of glaucoma clinics in England between 1999 and 2012.

---

**Introduction**

Rate of visual field (VF) series of examination useful in managing a rates of VF loss vary.
More frequent, more costly? Health economic modelling aspects of monitoring glaucoma patients in England

Trishal Boodhna and David P. Crabb*

Abstract

Background: Chronic open angle glaucoma (COAG) is a disease that progressively affects peripheral visual field (VF). Health service delivery for COAG is based on the large and lifelong periodic monitoring by hospital eye clinics. Patient examination, ongoing monitoring, and treatment are aimed at avoiding VF loss. However, the cost-effectiveness of this approach remains unclear.

The aim of the current economic evaluations is to determine whether more frequent monitoring of COAG is a cost-effective means of reducing vision loss and saving health care costs. We modelled the costs and outcomes of different monitoring frequencies, including quarterly and yearly visits, and compared them with a traditional monitoring strategy.

Methods: We used Monte Carlo simulations to assess the cost-effectiveness of different monitoring frequencies. We considered costs and outcomes over a lifetime and discounted them at a rate of 3%. The simulations were based on a previously published cost-utility model and included the costs of medications, consultations, and VF testing.

Results: The primary outcome was vision-related quality of life (VRQoL), which was measured using the EQ-5D-5L. The secondary outcome was the cost per QALY gained. The simulations showed that more frequent monitoring resulted in a higher VRQoL and lower costs. However, the incremental cost-effectiveness ratio was above the threshold of cost-effectiveness, indicating that more frequent monitoring was not cost-effective.

Conclusion: More frequent monitoring of COAG patients is not cost-effective in terms of cost-utility. Annual visits seem to be a sufficiently frequent monitoring interval for these patients.
NOD: Glaucoma feasibility audit – Visual fields

If you don’t measure it, you can’t improve it....
NOD: Glaucoma feasibility audit – Visual fields

1. Early
   - MD better than -6dB
   - Early (26%)
   - Moderate (31%)
   - Severe (34%)

2. Moderate
   - MD between -6dB & -12dB
   - Early (46%)
   - Moderate (29%)
   - Severe (25%)

3. Severe
   - MD worse than -12dB
   - Early (45%)
   - Moderate (50%)
   - Severe (25%)

4. [Visual Field Data]
   - Early (47.5%)
   - Moderate (29%)
   - Severe (25.5%)

5. [Visual Field Data]
   - Early (61%)
   - Moderate (27%)
   - Severe (22%)


Susan Bryan
Crabb Lab, research fellow
NOD: Glaucoma feasibility audit – Visual fields

![Graph showing density over time interval (months) for Centre 1 to Centre 5.]

![Graph showing density over rate of MD loss (dB/year) for Centre 1 to Centre 5.]

Glaucoma? Where you live?

- Use modern geodemographic tools to explore large scale VF data to examine factors that are associated with late presentation of glaucoma
Health inequalities

• Well known links between health and poverty
• Social class, occupation and where you live too...
Late diagnosis of breast cancer associated with socioeconomic status

“Catching the tumour late is a major explanation for the deaths.”

Rutherford et al (2013) Int J Cancer
“Catching glaucoma late is a major explanation for sight loss.”

Saunders et al (2014) IOVS
Hypothesis

- Average level of glaucoma disease severity at diagnosis is associated with socioeconomic status.
Large scale patient data

- **Calderdale and Huddersfield NHS Foundation Trust**
  - 70,955 VFs from 13,075 patients
  - (2002 to 2012)

- **Gloucestershire Hospitals NHS Foundation Trust**
  - 50,144 VFs from 11,279 patients
  - (2000 to 2011)

- **Moorfields Eye Hospital NHS Foundation Trust**
  - 320,334 VFs from 55,492 patients
  - (1989 to 2012)

- **Portsmouth Hospitals NHS Trust**
  - 31,879 VFs from 9,086 patients
  - (1999 to 2011)
Patient data

- Anonymised
- Postcode
- Age
- Humphrey SITA VFs
- MD in worse eye at first clinic visit

ID#: 046708
Age: 67
PC: E2 0JW
MD: -14 dB
Socioeconomic Status

• Index of Multiple Deprivation (IMD)
• Where people live
• Small areas based on postcodes
  - Income; employment; health deprivation; education; housing; crime; environment
• 1 (least deprived)
• 70 (most deprived)
Results
MD worse in patients from deprived areas

- Highly significant association after correcting for age
- Spearman's = -0.20
- High variability but a linear predictor for ‘averages’
• SW14 7AT
• IMD 2.4
• Wealthy
• Professionals
• large houses

• Predicted to present with glaucoma
  with an MD of -4dB (95% CI -3 to -5dB)
• E1 5HH
• IMD 66.2
• Hard pressed
• Multi-ethnic crowded flats

• Predicted to present with glaucoma with an MD of -10dB (95% CI -9 to -11dB)
..but nothing new!

- Link between late diagnosis of glaucoma & socioeconomic status **already well reported**
What next?

- “...Identify areas that would benefit from special initiatives or programmes....”
visualisation and mapping tool
visualisation and mapping tool
Visual field testing can be difficult

Can we test patients in a different way?

Supervise

Space

Results?
Visual field testing can be difficult

Can we test patients in a different way?

- Examine people during an ordinary visual activity?
- Collecting ‘big data’ whilst a person watches a movie?
What’s on TV? Detecting age-related neurodegenerative eye disease using eye movement scanpaths

David P. Crabb *, Nicholas D. Smith and Haogang Zhu

Department of Optometry and Visual Science, School of Health Sciences, City University London, London, UK

Dime cómo ves TV y te diré si tienes glaucoma

Una de las principales causas de ceguera en todo el mundo se puede detectar viendo cómo los ojos de las personas se mueven al ver televisión.
We make several saccades every second
– Gaze patterns give insight into visual perception
Background

- We make several saccades every second
  - Gaze patterns give insight into visual perception

- Huge developments in eye-tracking technology
  - Non invasive, accurate measurement
  - Masses of data can be collected
  - Lower cost
Previous research

- Glaucoma patients seem to make different eye movements in the ‘real world’

- VIEWING PHOTOS
  Smith et al. (2012). Seeing Perceiving

- FACE RECOGNITION

- READING
  Burton et al. (2014). Graefe’s Arch Ophthalmol

- VISUAL SEARCH
  Smith et al. (2013). BMC Ophthalmol

- DRIVING HAZARDS PERCEPTION
  Crabb et al. (2010). PLoS One
Hypothesis

- Glaucoma can be detected by examining patterns of eye movement recorded whilst a person naturally watches a movie

- *Proof-of-concept*: Using a case-control study
Experiment

• 3 unmodified video clips viewed on a monitor
  – Each 5-10 minutes long

• Eye movements recorded: SR Research EyeLink (500Hz)
Participants

• 32 normally sighted controls
  – Median age: 70 (IQR: 64 to 75) years

• 44 patients with clinical diagnosis of glaucoma
  – Median age: 69 (IQR: 63 to 77) years

• All participants had good VA and no other significant disease
A range of disease severity

- Severe: MD worse than -12dB
- Early: MD better than -6dB
Gene Expression Data Classification With Kernel Principal Component Analysis

Zhening Liu, Dechang Chen, and Halima Bennani

1Biostatistics Office, US Army Medical Research and Material Command, 110 North Market Street, Frederick, MD 21701, USA
2Department of Preventive Medicine and Biometry, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, MD 20814, USA
3Department of Mathematics, University of Tennessee, 321 Stokely Management Center, Knoxville, TN 37996, USA

Received 1 June 2004; revised 28 August 2004; accepted 3 September 2004

\[
X = \begin{bmatrix}
    x_{11} & x_{12} & \cdots & x_{1N} \\
x_{21} & x_{22} & \cdots & x_{2N} \\
    \vdots & \vdots & \ddots & \vdots \\
x_{M1} & x_{M2} & \cdots & x_{MN} 
\end{bmatrix}
\]
Analysis

- Kernel Principle Component Analysis (KPCA) used to extract features from the matrices
- Bayesian Classifier masked to the diagnosis
Results

![Graph showing sensitivity and 1-specificity](image)

Sensitivity vs. 1-Specificity

Lucy
Results

The graph shown is a Receiver Operating Characteristic (ROC) curve, which is commonly used to evaluate the performance of binary classification models. The x-axis represents 1-specificity, and the y-axis represents sensitivity. The point on the curve indicates the model's performance at a specific threshold. The area under the curve (AUC) provides a measure of the model's ability to distinguish between classes. In this case, the AUC is close to 1, indicating a high accurate model.
Conclusion

A group of patients can be well separated from normally sighted individuals using eye movements alone.

Limitations

- Small study
- Will it work as well on different eye trackers?
- The influence of the video content

What's on TV? Detecting age-related neurodegenerative eye disease using eye movement scanpaths

David P. Crabb *, Nicholas D. Smith and Haogang Zhu
Thank You

Crabb Lab is currently supported by unrestricted funding from Allergan, Novartis, Roche and also project grants from the Wellcome Trust, International Glaucoma Association and Fight for Sight charities.

d.crabb@city.ac.uk
www.staff.city.ac.uk/crabblab